World Health Organization
REGIONAL OFFICE FOR Europe

Human Health in Areas with Industrial Contamination

EDITED BY

Pierpaolo Mudu
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ABSTRACT

In recent years, increasing attention has been focused on the health implications of large industrial establishments. Studying human health in areas with industrial contamination is complex. The aim of this book is to outline a framework for integrated assessment of the impacts of large industrial activities. The framework is supported by examples related to the adverse effects on environment and health of petrochemical industries, based on the results of a research project carried out in Sicily, southern Italy, by the WHO Regional Office for Europe. The Sicilian case studies provide examples of methods for estimating the adverse effects on health of petrochemical activities in highly contaminated areas and for developing strategies and tools for integrating health considerations in the formulation of policies and rehabilitation plans. This book is intended to contribute to the analysis of high-risk areas, by providing a review of the evidence, study design options, legislation, and results on the adverse impacts on health of industrial activities.

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CONTENTS

DESIGNING AND CONDUCTING SPECIFIC STUDIES

ABBREVIATIONS

Organizations, other entities and studies

APAT	Italian Agency for Environmental Protection and Technical Services
ARPA	Italian Regional Agency for the Protection of the Environment in a particular region
CIPA	Industrial Consortium for Environmental Protection
DASOE	Sicilian Epidemiological Observatory
EAS	Sicilian Aqueduct Company
Eni	Ente Nazionale Idrocarburi
EPER	European Pollutant Emission Register
EU	European Union
ICD	International Classification of Diseases
INES	Italian National Inventory of Emissions and their Sources
PRITASC	Spatial Perception of Risk, Health, Environment, and its Communication survey
SEBIOMAG	Human Biomonitoring Study in the Gela area
SIDRIA	Italian Studies on Respiratory Disorders in Children and the Environment

Technical terms

b/cd	barrels per calendar day
BMI	body mass index
CI	confidence interval
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DLgs	Italian Law
FEF_{25-75}	forced expiratory flow between 25% and 75% of vital capacity
FeNO	fractional exhaled nitric oxide
FEV1	forced expiratory volume in 1 second
GIS	geographical information system
HCB	hexachlorobenzene
HCH	hexachlorocyclohexane
IPPC	integrated pollution prevention and control
km	kilometre
LFL	low flammable limit
LQ	localization quotients
MSI	manufacturing specialization indexes
PM_{10}	particulate matter with an aerodynamic diameter smaller than 10 µm
$PM_{2.5}$	particulate matter with an aerodynamic diameter smaller than 2.5 µm
ppb	parts per billion
SMR	standardized mortality ratio
SIR	standardized incidence ratio
SPMRs	standardized proportional mortality ratios
SWOT	strengths, weaknesses, opportunities, threats

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FOREWORD

The environment is one of the important health determinants of concern to WHO. Among its pillars, Health 2020 (the comprehensive public health framework developed by the WHO Regional Office for Europe and its 53 Member States for the years to come) includes the promotion of supportive environments and resilient communities. Some important environmental health risks result from stressors of industrial origin, as documented in several instances in Europe. The public has become increasingly aware of these risks, and policy debates now include how to secure industrial development that does not adversely influence health and prejudice the quality of life.

Poorly designed or managed industrial activities can pollute air, water and soil. In such cases, there is concern about the health of workers and those living in the vicinity of these activities. Of particular concern are toxic agents that have direct health impacts on the populations exposed, especially such vulnerable groups as children.

Industrial development has changed radically over the years. In many countries, nowadays, norms and regulations attempt to ensure that adverse impacts are minimized, starting with the planning stage, choice of location and adoption of best available technologies. This, however, is not always the case, especially when old technologies continue to operate in populated areas or when norms and standards are weak or not complied with and significant emissions occur. In these cases, where health can be and often is adversely affected, proper planning is needed to ensure that reasonable economic development can be sustained without undue detrimental effects. This requires a combination of well-developed legislation, transparent industrial practices, active cooperation between the stakeholders involved and, crucially, a reliable assessment of the health impacts.

To address these issues, WHO has collaborated with the Regional Government of Sicily for more than ten years. The collaboration was originally motivated by the need to describe the health profile of residents in Sicily's three "high risk" areas, where large industrial facilities are located. This collaborative work has involved the consideration of how such information can help inform local environmental policies, which require a deeper understanding of the complex link between local environments and health and well-being.

The work that ensued is described in this book, which is the result of contributions from different disciplines and reflects the breadth of the approach needed if we are not only to understand, but also to govern, complex determinants of health. It is hoped that this book will be a valuable resource for all those concerned about the health implications of industrial sites, be they residents, workers, public administrators or other stakeholders.

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EXECUTIVE SUMMARY

In recent years, increasing attention has been paid to the health implications of large industrial establishments. Modern industrial development has resulted in many benefits – stemming from socioeconomic development – but it also resulted in environmental contamination and adverse impacts on health. These impacts are especially relevant when considering large facilities and operations involving toxic chemicals and petrochemicals, power generation, and heavy industry in general. Acute and chronic adverse effects on health in occupationally exposed groups and in the general population have been repeatedly documented, following industrial accidents. They have been documented for long-term and gradual environmental contamination and chronic occupational exposures. Establishing the relevant health effects and assessing the adverse impacts on health of large industrial facilities, however, is challenging, given the complexity of the interaction between multi-agent contamination and populations of residents and workers, through multiple pathways.

An example of this complex interaction occurs in three areas in Sicily (named after major towns and areas: Augusta–Priolo, Gela and Milazzo–Valle del Mela) where petrochemical activities started over half a century ago and where over 200 000 people live (including 7000 people employed in these activities). Over 20 years ago, Italian national legislation officially recognized the three areas as being at risk of environmental crisis, because of environmental pollution. This recognition entailed a mandate for the local governments of the three areas to develop and implement rehabilitation plans for these areas, which is underway.

Early in the new millennium, upon a request from Sicily's regional government, the WHO Regional Office for Europe engaged in projects to provide technical support for these efforts, through the consideration and analysis of the health dimension of the rehabilitation plans. The ensuing effort is described in this book.

The purpose of this book is fourfold: (a) to summarize the available evidence on the adverse health impacts of environmental contamination from petrochemical industrial facilities; (b) to describe the environment, health, living conditions and risk perception of the residents in the three areas of Sicily, based on epidemiological studies and surveys conducted ad hoc and on a compilation of existing information from the scientific literature; (c) to propose a methodology for the integrated assessment of the impacts on health of living in contaminated areas; and (d) to consider strategies and tools for integrating health considerations in the formulation of policies and plans for environmental rehabilitation. Such a methodology was needed to address the specific questions arising in the Sicilian context, but may be of interest in comparable cases, where decision-makers have to deal with the complex environmental health issues of large industrial facilities.

The project's investigations were based on data from current statistics, as well as information collected locally (for example, provided by local physicians); several area-specific analyses and studies were carried out.

The book is organized as follows. Chapter 1 describes the rationale for the book and the Sicilian case. Reviews of the scientific literature on the adverse effects of petrochemical plants on the environment and on residents' health are presented in Chapters 2 and 3. In Chapters 4 and 5, the presentation of health statistics, including congenital malformations, in the three Sicilian areas is preceded by general guidance on the interpretation of vital statistics on residents in polluted areas. Chapters 6 through 8 describe the impact of the industrial facilities in the three areas in terms of environmental pollution, air quality and social end-points. The three chapters that follow describe the epidemiological studies carried out ad hoc in Sicily – that is, residential and occupational cohort studies in Milazzo–Valle del Mela and Gela (Chapter 9), a biomonitoring study among residents in Gela area (Chapter 10) and a study of respiratory disease in schoolchildren in Milazzo–Valle del Mela (Chapter 11). Finally, the book analyses the living and working conditions of residents in the areas, as well as the residents' perception of risk (Chapters 12–18). The final chapter (Chapter 19) summarizes the lessons learned from the project.

Despite several knowledge gaps, routine environmental data indicate serious contamination of water, soil and air in the vicinity of the industrial plants. In the early stages of the project local priority contaminants (7 inorganic and 10 organic substances in the Augusta–Priolo area, and 9 inorganic and 8 organic substances in Gela) were identified a priori, on the basis of pre-existing literature. Two substances, linked to the industrial cycle (lead in the Augusta–Priolo area and 1,2-dichloroethane in Gela) were subsequently selected and investigated in detail. Lead concentrations in the Augusta–Priolo area, as high as 5393 mg/kg (more than a hundred times the national legal limits for bodies of surface water), were found in the first 50 cm of surface water sediments – that is the layer in which most of the aquatic organisms live. In the soil in Gela, concentrations of up to 1000 mg/kg of 1,2-dichloroethane were detected (the legal limit is 0.2 mg/kg in green and residential areas and 5.0 mg/kg in industrial areas).

Over the years, contaminants have been dispersed from their point sources through different matrices. In air, the available air quality monitoring systems measured marked excesses over the legal limits of some pollutants: sulfur dioxide, particulate matter with an aerodynamic diameter smaller than 10 μm, nitrogen dioxide and ozone. Contamination was also found to arise from accumulation of pollutants over time – for example, in deep levels of the marine sediment in the area of Augusta–Priolo, estimated to have started decades ago.

The analysis of health statistics focused on mortality data (and to a lesser extent on hospital discharge files), by comparing residents' mortality with the regional average and with the mortality of residents in adjacent towns, controlling for socioeconomic variables. For more than 20 years, significant excess mortality persisted among residents in the Gela area, compared with both the adjacent and the regional populations. During the period 1995–2002, the excesses over the neighbouring populations were more than 20 extra deaths in males and 15 in females every year. A comparison of risk estimates standardized only for age with those standardized also for socioeconomic status, however, indicated that a sizeable proportion of the excess mortality in Gela is attributable to socioeconomic factors, particularly in females. Overall mortality in the Augusta–Priolo and Milazzo–Valle del Mela areas did not differ significantly from that of the comparison populations.

As for specific causes of death, two consistent findings in all areas were the occurrence of a sizeable number of pleural cancers (attributable to previous exposure to locally produced asbestos) and an excess of mortality from acute respiratory diseases (confirmed by hospital discharge files). Both these findings suggest that public health action be taken, aimed at minimizing current exposure to risk factors while paying attention to socially mediated mechanisms. A number of other excess deaths from specific causes were observed; however, the interpretation of each of these excess deaths and their possible association with environmental exposures of industrial origin require additional investigations.

Mortality statistics were informative, but some specific areas of concern were investigated through more sensitive studies. A biomonitoring study in the Gela area showed an excess concentration of arsenic in urine and blood samples, possibly from ingesting contaminated food or water – rather than from residential proximity to the plant. The study in the Milazzo–Valle del Mela area, where an excess of acute respiratory disease had been reported, analysed the risk of respiratory disorders associated with air pollution in susceptible children: it found a correlation between air pollution (in terms of raised concentrations of sulfur dioxide and particulate matter with an aerodynamic diameter smaller than 2.5 μm) and spirometric measurements and bronchial inflammation.

Two earlier surveys on the occurrence of congenital malformations were also evaluated. Although criteria for identifying malformed children did not fully match those of internationally recognized malformation registries, results of both surveys indicated excesses in the Augusta–Priolo and Gela areas of some specific malformations, notably hypospadias.

Although the studies and the project as a whole focused on the effects of long-term pollution, the book also addresses the issue of vulnerability (and the response) of the population to industrial accidents, such as those that have occurred in these areas in the past.

The majority of studies carried out in Sicily on risk perception and health perception confirm the role of age, gender, education, working conditions, and the importance of children in how perception takes shape. A consistent finding is that the public perception does not always match risk estimates that originate in the scientific milieu, or those reported by authorities, industry and nongovernmental organizations.

The socioeconomic context is important for evaluating broader adverse impacts and is best understood by engaging local stakeholders. The changes in employment patterns are an example. Analysis of workforce migration patterns show that in Sicily, following the development of the petrochemical industry, the initial increase in employment was insufficient to absorb the workforce that was abandoning agricultural work and to restrain migration outflows in the long run.

The lessons learned in Sicily show the need for scientists to work jointly with local health authorities and local health workers, as well with local associations of citizens and other stakeholders. The presence and involvement of local counterparts proved crucial to launching and completing a number of studies, such as a biomonitoring study in the Gela area and a study on children's respiratory health in the Milazzo–Valle del Mela area. Throughout the whole investigation, multidisciplinary efforts (50 people collaborated on the present book) and interactions with local stakeholders were the driving force, and the authors suggest extrapolating the use of this approach in other contaminated areas.

BACKGROUND

1. HUMAN HEALTH IN AREAS WITH INDUSTRIAL CONTAMINATION

Pierpaolo Mudu, Benedetto Terracini and Marco Martuzzi

Rationale

Sites highly contaminated by a variety of hazardous agents exist in many places. In many cases, contaminants are released by active industrial sources – routinely or accidentally – or are present in accumulated toxic waste from past industrial activities. Often, multiple agents exist simultaneously, posing a mix of certain or suspected risks. Despite the abundance of such contaminated sites and the considerable extent of their potential adverse effect on health, a methodology for studying their impacts, which quantifies (in real cases) the effects estimated, is still lacking. Also, the literature on the topic of contamination is somewhat sparse, and the policy implications of the available studies are not derived systematically.

In stark contrast to this situation, the policy debate on rehabilitation of contaminated sites worldwide is rife with controversy, dampening its sense of urgency.[1] Among other things, the controversial nature of such rehabilitation is fuelled by uncertainties about the evidence, the feasibility of such efforts, cost–effectiveness and distributional justice – that is, the way to deal with unfair allocation of goods and resources in a society. Comparing and contrasting selected experiences and studies carried out in contaminated sites can be useful for a clearer understanding of the problem. Such comparisons can also be useful for developing more systematic methodologies and procedures, for a more consistent interpretation and, ultimately, for a better policy response.

The concentration of industrial activities – especially those of large-scale petrochemical, power generation, heavy industry and mining – involves environmental pressures, with potential adverse effects on the health of local communities through their occupational and residential roles (WHO, 2009). Normally, assessing the occurrence and extent of the associated health impacts is very difficult for several reasons; these include poor assessment of exposure, unreliable data on emissions and contamination, the presence of multiple substances and combinations of exposures, and the need to consider multiple health endpoints. Furthermore, specific confounding effects of lifestyle-related hazards, population mobility and the opposition of vested interests cannot be ignored.

Such difficulties may explain the relative lack of data on the possible health impacts of industrially contaminated sites. Such data is lacking even though many so-called hotspots – that is, large industrial facilities that contribute a considerable proportion of all noxious emissions – are well known and routinely monitored by national and local authorities for their environmental impacts.

Examples exist where a methodology was developed and applied to deal with the complexities and uncertainties always present in these assessments; however, the question of the overall health impact of these facilities remains essentially unanswered. Information and data are also needed on the extent to which these impacts pose additional health burdens on subpopulations already suffering from other pressures – for example, from a socially deteriorated environment. Also, if meaningful rehabilitation policies are to be identified and implemented, environmental justice – a crucial policy driver that implies that a certain part of the population, particularly the most deprived, is excessively exposed to environmental health hazards – needs careful and urgent clarification.

In particular, petrochemical and refinery activities are responsible for contaminating several sites. Box 1 discusses the importance of the magnitude of this activity.

1 Remediation and rehabilitation are often used interchangeably, but there are some distinctions which apply in certain contexts. Remediation refers to the clean-up of soil, sediment, groundwater or surface water contaminated by organic, inorganic or biological substances. This publication understands rehabilitation as intervention through remediation activities, but which can also include other socioeconomic strategies, that may or may not be connected with remediation, such as activities to provide income generation for local people.

Box 1. Worldwide petrochemical and refinery activities

At the beginning of the year 2000, there were about 730 refineries worldwide, with a treatment capacity of about 4 billion tonnes of crude oil (Giavarini, 2006). Petrochemical production from crude oil includes olefins (such as ethylene and propylene), aromatics (such as benzene and toluene) and many other derivatives (Matar & Hatch, 2001). Total ethylene consumption for 2006 was forecast to reach more than 110 million tonnes, while total propylene consumption reached about 69 million tonnes (CMAI, 2007). Also, benzene demand is forecast to grow at a rate of 4.1% a year between 2000 and 2020, resulting in total demand growth of 24.3 million tonnes (CMAI, 2005). The largest petrochemical industries are located in North America and Europe, but major growth is occurring in Asia.

Petroleum refining impacts are associated both with manufacturing operations and with the use of the finished products (EPA, 1995). The major classes of processes typically carried out by refineries include (EPA, 1995):

- desalting
- atmospheric distillation
- reforming and extractions
- waste recovery and treatment

The contamination process is related to:

- the unauthorized release of chemicals into surface water bodies, air, soil and (indirectly) the water-bearing stratums;
- the poor functioning of systems of control and abatement of emissions from industrial plants; and
- the production of toxic substances and/or waste disposal.

Petrochemical contamination involves a vast range of chemicals and adverse effects on health common to other industrial activities (Intrinsik Environmental Sciences Inc. & Stantec Consulting Ltd, 2010). It is necessary to generate hypotheses about contaminants of concern that may be associated with a particular source and use, such as a manufacturing operation, laboratory, mode of transport, disposal area or waste site (WHO, 2010). The known burden of disease worldwide due only to chemicals is considerable. Most recent estimates report 4.9 million deaths (8.3% of the total) and 86 million disability-adjusted life-years (DALYs) (5.7% of the total) attributable to environmental exposure and management of selected chemicals. These figures present only a number of chemicals for which data are available; therefore, they are more likely to underestimate the actual burden. Due to incomplete data and information, chemicals with known adverse effects on health, such as dioxins, cadmium, mercury and pesticides, have not been included (Prüss-Ustün et al., 2011).

The effects of industrial activities are complex, because pollutants have become ubiquitous in the environment. Pollutants are found in underground water, tap water, wastewater, soil, air and food, and polluting substances may transfer from one environmental matrix to another. In addition, oil refining also produces large quantities of oil sludge that consists of hydrophobic substances and substances resistant to biodegradation (Vasudevan & Rajaram, 2001). The scales of the effects of different industrial activities differ and involve fragile ecosystems, cultural aspects of indigenous groups, the health of communities and workers, the global climate, and military conflicts (O'Rourke & Connolly, 2003).

Contact with polluting substances can harm human organs – including respiratory, hematopoietic, hepatic and renal organs – through a variety of acute and chronic mechanisms. Many substances, for example, are either known or suspected carcinogens. However, estimating their adverse effects on health requires informative exposure assessment data – an invariably problematic step. Characterizing industry-related exposure of residents in polluted areas requires detailed information on the spatial and temporal trends of the distribution of various chemicals; it also requires patterns of people's mobility, as well as the ability to predict exposure in unmonitored settings (IPCS, 2005). Such detailed information, seldom available, is by and large case specific: for large industrial facilities, such as petrochemical sites, it is probably correct to assume that no two sites produce the same complex mixture of contaminants in the environment.

Also, the spatial and temporal dimensions used to investigate a phenomenon – that is, its scale – need to be considered, because the impacts of industrial contamination are seldom a single-scale issue; and the construction of each of the different scales of impact matters. Moreover, a person's development of a subjective perception of space and risk is anchored to their social relations (Auyero & Swistun, 2008); and their perception of environment (both in terms of such facilities as rubbish collection and such problems as air quality) at a neighbourhood scale influences their health (Bowling et al., 2006).

Large industrial concentrations and petrochemical areas are spaces of intense capital accumulation where the preferred remediation measures are environmental clean-ups (such as soil remediation, the installation of scrubbers on smokestacks, like catalytic converters in cars), rather than pre-emptive or proactive interventions (Harvey, 1996). In this context, health impacts are estimated or characterized mainly to inform remedial policies. When large areas are contaminated, "remediation measures should be spatially prioritized on the basis of the risk posed to human health and in compliance with technological and budget constraints" (Carlon et al., 2008:397). The issue is complicated by the need to consider, within the process of remediation, multiple health end-points and variable severity. For example, odour conveys part of the effect of refinery emissions and influences how residents perceive their health (Luginaah et al., 2000).

The main challenge is thus to develop a framework for bringing together a diversity of inputs to appraise the effects of industrial contamination on health. With regard to assessing and managing contaminated areas, a conceptual site model is needed – that is, a "description of a site representing what is known (or suspected) about the contaminant source areas, as well as the physical, chemical, and biological processes that affect contaminant transport from the sources through environmental media to potential environmental receptors" (Apitz et al., 2005a,b).

The readers that might benefit from this book include not only the skilled scientists whose work is related to health, social and environmental issues, but also include all people that have an active role in transforming contaminated areas.

The Sicilian case

Sicily provides good models of different environments for appraising the effects of industrial contamination on health: the island includes three high-risk areas (Augusta–Priolo, Gela and Milazzo–Valle del Mela)[2] with large industrial facilities with different characteristics and different implications for the environment and the health of its residents. In the three areas, these industrial facilities host large chemical plants, oil refineries, power plants and also minor manufacturing plants. Industrial activities started in the late 1950s and 1960s; subsequently, Italian national legislation officially declared the three areas to be "at high risk of environmental contamination".

As already noted, the Sicilian high-risk areas include Augusta–Priolo (more than 200 000 inhabitants), Gela (more than 100 000 inhabitants) and Milazzo–Valle del Mela (more than 50 000 inhabitants) (see Fig. 1). The municipality of Syracuse, part of the Augusta–Priolo area, is sometimes analysed separately, because of its size (about 120 000 inhabitants) and because it does not have major industrial establishments in its territory (with the exception of the former Eternit asbestos plant); however, many workers in the petrochemical plants are residents of the area, and the northern part of the city is adjacent to and downwind of the industrial area. The recognition of an area as being at high risk entails priority allocation of resources, for cleaning up contamination and for rehabilitation in general.

2 In Sicily, as a result of industrial activities, many municipalities have been designated as high-risk areas for rehabilitation (a regional responsibility):
- Augusta, Floridia, Melilli, Priolo Gargallo, Syracuse and Solarino (in Augusta–Priolo area),
- Gela, Butera, Niscemi (in Gela area),
- Condrò, Milazzo, Gualtieri Sicaminò, Pace del mela, San Filippo del Mela, Santa Lucia del Mela, San Pier Niceto (in Milazzo–Valle del Mela area);

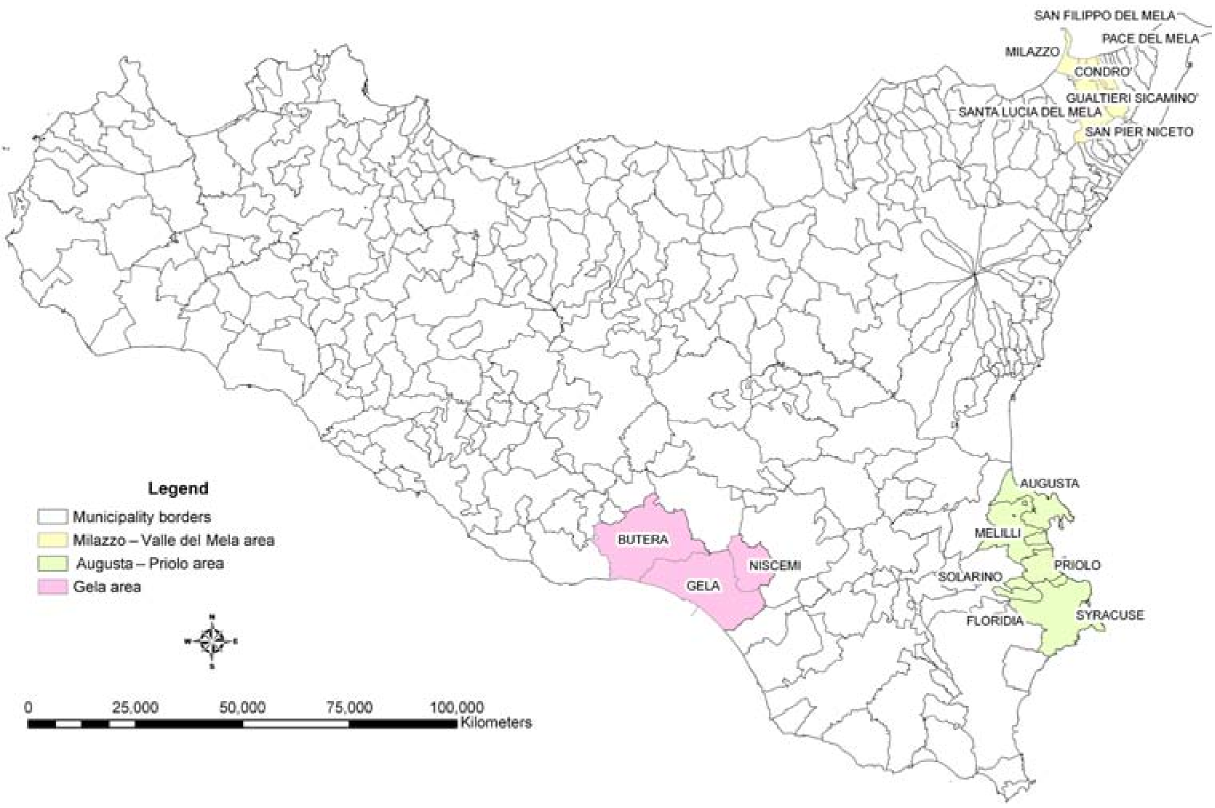
and/or as a national site of concern for remediative action (a national responsibility):
- Augusta, Melilli, Priolo Gargallo and Syracuse (in Augusta–Priolo area),
- Gela (in Gela area),

Milazzo, Pace del Mela, San Filippo del Mela (in Milazzo–Valle del Mela area).

The official designation for Valle del Mela is Comprensorio del Mela. The official name of the municipality of Priolo is Priolo Gargallo, but Priolo will be used in the text.

In 2002, the mayors of the Milazzo–Valle del Mela area requested the WHO Regional Office for Europe to work in the high-risk areas of Sicily. In 2005, the regional government in Sicily created a dedicated Office for Risk Areas and involved WHO in providing support for the rehabilitation plans of these areas. The work started in 2007 and was developed in line with paragraphs 11a and 11b of the Declaration of the Fourth Ministerial Conference on Environment and Health (WHO Regional Office for Europe, 2004).

Fig. 1. The location of the areas investigated



A variety of studies were used to produce or shape the scientific information that guided the policy action required for the high-risk areas. This approach was based on including human health among the key considerations in such policy processes, which is not always the case in the management of contaminated sites. Many questions immediately arose: What is the environmental and health profile of the areas? What is the industrialization pattern – that is, how has it developed temporally and spatially? What studies contribute the most information and value to the policy debate? How do facts and risk perceptions translate into a policy response? In the presence of long standing controversies and social conflicts, how can an effective communication strategy be identified? To address these challenging questions, the project was organized in various phases.

Phases of the project in Sicily

During a three-year period, the project developed through a number of phases, involving:

- creating a scientific committee and working groups and subgroups (on communication issues and on bioaccumulation of pollutants);
- identifying information gaps and building evidence;
- designing new studies for an integrated approach;
- mapping relevant stakeholders, both at the institutional and population level;
- developing a communication strategy; and
- disseminating results.

After creating a scientific committee (composed of national and international experts from the Italian National Institute of Health, the Special Office for Areas at High Environmental Risk, local technical structures and WHO staff) and working groups, the whole issue was framed; this occurred through a compilation and review of the existing information on the adverse effects on health of the presence of the petrochemical industry. Also, new studies were planned and designed, using different methodologies – both quantitative and qualitative.

The adverse effects on health of environmental contamination are a serious concern of local populations. Compounding their concern is the lack of trust in authorities, who are faulted for not providing effective information. This lack of trust also reinforces their feeling of living in a dangerous environment – both from the perspective of continuous harmful exposure and that of the constant threat of industrial accidents, such as leakage of gas or acid or of tank explosions. Hence, particular attention was given to investigating the limitations of available data from monitoring systems managed by local authorities.

Also, a map of all relevant stakeholders, both at the institutional and population level, was created. Communication was a key aspect of the work throughout the project. Substantial efforts were made to inform health authorities, municipalities, agencies and citizens about the research being implemented, to involve them and to disseminate the findings.

Methods

The analysis of the complex industrial system, of the environment affected by industrial activities and of the adverse impacts on health was organized in a series of investigations. These investigations cover environmental measures, descriptive epidemiology, analytical studies, population surveys and other areas.

Building the evidence: design of analytical studies

The scientific committee considered several new analytical studies and surveys to evaluate the design and methods of the project. Both discussion of the project and participation of the local populations were promoted, mainly through local consultation tables, following an approach inspired by Agenda21 (Sancassiani, 2005).

Details of the analytical studies and surveys carried out appear in Table 1. The choice of specific studies was based on health data or concerns – for example, the study on respiratory disorders in school-aged children in Milazzo–Valle del Mela was initiated after reports on increased occurrences of these disorders. Also, the choice of specific studies was based on environmental data – for example, the biomonitoring study in Gela was initiated after data suggested contamination in human tissues. Moreover, it was based on feasibility – for example, the residential cohorts in Milazzo–Valle del Mela took advantage of the availability of detailed residential data. Furthermore, through the involvement of many physicians, researchers, interviewers and junior epidemiologists, the project played an important role in training and capacity building.

In all three areas, the main activities were:

- updating epidemiological data on mortality and morbidity, including cohort and time trend analysis and detailed geographical analysis for selected causes;
- exhaustively reviewing the literature on the areas;
- performing a large review of the scientific literature on the adverse effects on health of petrochemicals;
- simulating accident patterns;
- collecting and analysing environmental and socioeconomic data;
- analysing current statistics on mortality and hospital discharge records, including analyses by calendar period and period of birth;
- performing geographical analysis of selected causes of mortality; and
- surveying the direct costs borne by the public health system for the population of the three areas.

Table 1. Analytical study and survey activities in Sicily

Item	Activity	Objectives	Area	Institution(s)	Main final policy implication(s)
1	Data collection	Exhaustively collect all scientific and grey literature Suggest the direction to be taken by the report for public discussion	All three study areas	WHO	Given the bulk of available information, no more studies (with few exceptions) would be needed. Suggest the areas that lack monitoring systems
2	Interviews with local witnesses	Provide a qualitative report on the ideas circulating in the area and the relationships among different stakeholders Perform strengths, weaknesses opportunities and threats (SWOT) analysis Suggestions for a document to be used for a consensus conference	Augusta–Priolo	University of Padua	Promote a dialogue among different and hostile stakeholders and actors
3	Focus groups on risk perception	Support the risk perception survey — for example, define questions and generate hypothesis Identify age and gender specificities related to risk communication Return information to the population and test analyses after the survey	Augusta–Priolo and Milazzo–Valle del Mela	University of Messina	Definition of criteria that relate to the need to have different communication patterns — according to age, gender and other relevant factors
4	Survey of risk perception and vulnerability	Identify the different circumstances of risk perception Map mobility and exposure Support communication strategies	Augusta–Priolo and Milazzo–Valle del Mela	University of Messina French National Center for Scientific Research University of Grenoble	Indicate communication activities Indicate emergency plans
5	Biomonitoring study questionnaires, blood and urine tests	Assess bioaccumulation of persistent toxic contaminants (heavy metals and polychlorinated biphenyls) in terms of daily intake, exposure and potential adverse effects on health	Gela	Italian National Research Council	Identify unacceptable circumstances of residents' exposures and priorities for rehabilitation
6	Exposure assessment of multidisciplinary working group	Propose a conceptual model of the impacts of industry on the area	Gela	Italian National Research Council and a multidisciplinary group that includes Italian National Institute of Health, University of Catania and University College London	Indicate the impacts of different pollutants
7	Interviews with local witnesses	Report on the perceptions of and proposals for land use and planning circulating in the area and the qualitative relationships among the different stakeholders	Gela	University of Messina University of Trieste	Indicate the actions required for rehabilitation and development of the area

Table 1 (continued)

Item	Activity	Objectives	Area	Institution(s)	Main final policy implication(s)
8	Cohort study of workers in the local petrochemical plant	Contribute to the epidemiological characterization of residents in the area	Gela	Italian National Institute of Health	Improve local public health structures for the health surveillance of workers Identify adequate interventions for preventing ill health
9	Cohort study of citizens living in Contrada Gabbia	Contribute to the epidemiological characterization of residents in the area Test the feasibility of this approach in an area of Sicily	Milazzo–Valle del Mela	Italian National Institute of Health	Assess the efficacy of previous environmental interventions and thus indicate further interventions
10	Cohort study of workers in an asbestos–cement plant	Assess the adverse effect on health of past occupational exposure to asbestos	Milazzo–Valle del Mela	Italian National Institute of Health	Perform health surveillance of asbestos workers and their families Identify adequate interventions for preventing ill health
11	Study of respiratory disorders in school-age children Air quality monitoring campaign	Estimate the prevalence of respiratory disorders among children in the area Assess the levels of air pollutants Identify the most susceptible children to provide them with health care	Milazzo–Valle del Mela	University of Florence	Intervene to reduce pollution when there are significant levels of air pollution Follow Children's Environment and Health Action Plan for Europe guidelines
12	Descriptive analysis of data on mortality and hospital discharge records	Create broad and particular epidemiological characterization (analysis of time trends and spatial distributions)	All three study areas	Sicilian Epidemiological Observatory	Strengthen coordination among public health actors and improve health surveillance Initiate specific health actions dedicated to particular groups in particular areas
13	Economic and demographic analyses	Learn about the impact of the petrochemical industry on population migration Learn about the impact of the petrochemical industry on total employment	All three study areas	University of Messina	Consider and discuss a model for sustainable development, based on health and an environment able to support high employment rates
14	Investigate the extra costs for the health system that result from excess pathologies	Check the costs due to excess pathologies and their potential to bias pharmaceutical expenditures	All three study areas	Sicilian Epidemiological Observatory Agency for Health Care Regional Services	Suggest how to balance pharmaceutical expenditures for particular pathologies
15	Provide air pollution time series	Meet the need for data in many locations and during several periods	All three study areas	Italian National Institute of Health	Improve the monitoring system

Table 1 (concluded)

Item	Activity	Objectives	Area	Institution(s)	Main final policy implication(s)
16	Meetings with stakeholders	Support and promote a dialogue among actors in conflict Collect suggestions and proposals	All three study areas	WHO and the focal point	Clearly indicate the expected development of the territory
17	Coordinate with the Italian Ministry of Environment and Territory	Create synergy for data collection	All three study areas	WHO	Provide access to data and information
18	Final report	Develop an integrated multi-method approach Provide broad and detailed characterization, in terms of both the health and environment of the areas investigated	All three study areas	WHO and scientific committee supervising the project	Produce an instrument capable of influencing rehabilitation plans that make health a benchmark
19	Disseminate results	Hold local and national conferences that present the study results Present study results in scientific publications and participate in international conferences	All three study areas	WHO and scientific committee supervising the project	Discuss the implications of the results

In the Augusta–Priolo area, the main activities were:

- reviewing the scientific literature, systematically and critically;
- reviewing the data from the Cancer Registry of the Province of Syracuse;
- reviewing and analysing available information, providing suggestions for a shared document, to create a consensus of relevant stakeholders;
- surveying the socioeconomic status and risk perception (700 questionnaires), convening focus groups, performing 40 in-depth interviews with local witnesses;[3] and
- holding seminars with the municipalities of the area, experts, representatives of industrial sectors, officers from central and local government, and civil society.

In the Milazzo–Valle del Mela area, the main activities were:

- studying respiratory disorders in school-age children and monitoring particulate matter, sulfur dioxide, nitrogen oxides, volatile organic compounds and other air quality indicators;
- studying cohorts of workers and citizens living in an urban centre close to the industrial area; and
- surveying socioeconomic status and risk perception (500 questionnaires).

In the Gela area, the main activities were:

- performing a biomonitoring study of residents contaminated by polychlorinated biphenyls, dioxins and heavy metals;
- constructing time series data for sulfur dioxide in a sample of adults (20–40 years of age);
- studying the mortality of a retrospective occupational cohort of chemical process plant workers;
- studying occupational cohort commuting patterns;
- interviewing local witnesses;
- reviewing a previous survey on the occurrence of congenital malformations;
- performing a socioeconomic analysis and risk perception survey through focus groups, questionnaires and interviews of local witnesses; and
- performing a life-cycle assessment of industrial activities.

Integrated approach

Each component of the project was conceived not as an isolated investigation, but was conceived as a network of methods and applications aimed at an integrated analysis of connected components (see Fig. 2). The collection and analysis of health data (node **p** in Fig. 2), environmental data (node **q** in Fig. 2) and data on economy and demography (node **z** in Fig. 2) had a central position. The socioeconomic and risk perception surveys (node **c** in Fig. 2) and the human biomonitoring study (node **f** in Fig. 2) were also part of the network. Moreover, parallel projects, such as one coordinated by the Italian National Health Institute on behalf of the Ministry of Environment and Territory on the evaluation of the economic damage related to the industrial activities in Gela and Augusta–Priolo, were also considered (see Chapter 6). The different studies were linked in three ways.

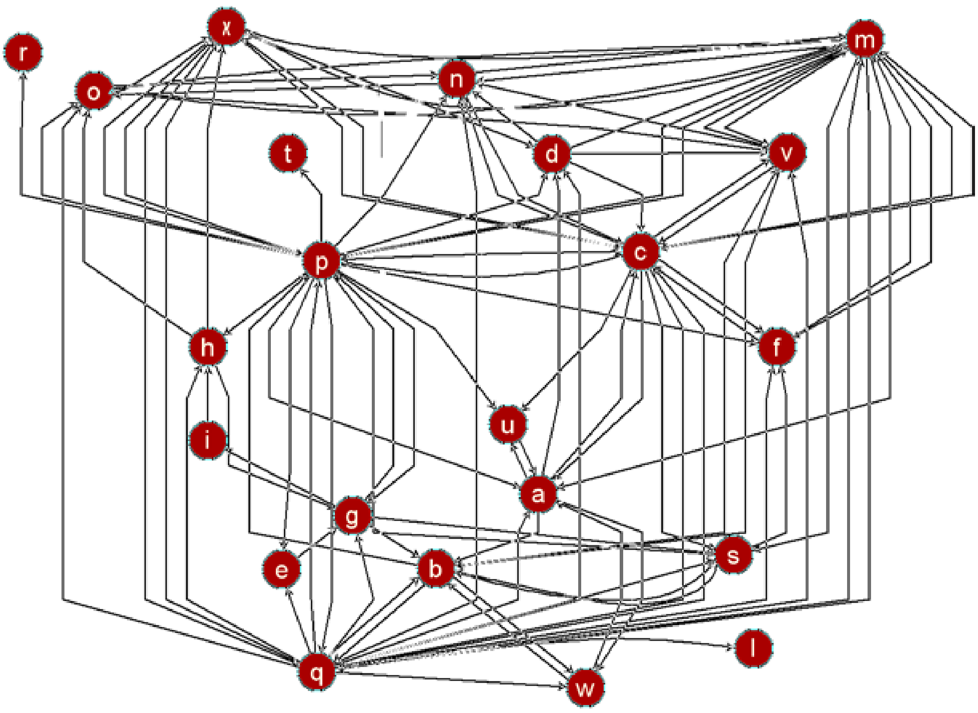
1. The same group of investigators worked in the same or different areas with different approaches.
2. Data produced by one study was the input for (or sustained) other studies.
3. Part of one study was intended to test results or hypotheses that stem from other studies, and results were compared or combined.

Furthermore, comparable studies used consistent methods – for example, the same methods were used in Chapter 10 of this book for a cohort study of workers in two different areas (San Filippo del Mela and Gela). Background data, such as mortality, were produced by the Sicilian Epidemiological Observatory. In the Milazzo–Valle del Mela area, questions used in the survey of respiratory disorders were also present in the survey of risk perception. The surveys of risk perception included the compilation of a diary aimed at estimating exposure patterns; these patterns were matched with a simulation of accidents

3 A witness is someone with knowledge (of a development) from observation or experience. Sociologists currently use the term local witness to define privileged and non-privileged witnesses. Chapter 16 clarifies the use of the term.

or with air pollution dispersion models. In addition, focus groups were used to test the questionnaires on risk perception; they also suggested approaches that could be taken to communicate risk and arguments that could also be compared with the points of view of local witnesses. Environmental data supported the studies on exposure – for example, those on polychlorinated biphenyls and heavy metals.

Fig. 2. Network of studies



Studies

(a) Study on respiratory disorders (2500 interviews)
(b) Cohort study of residents living in a neighbourhood surrounded by an industrial area
(c) Socioeconomic and risk perception survey (500 interviews)
(d) Focus groups in Milazzo
(e) Cohort of workers in the Milazzo–Valle del Mela area
(f) Study on exposure of citizens to polychlorinated biphenyls and heavy metals (400 in-depth interviews and 200 blood tests
(g) Cohort of workers in Gela
(h) Interviews with local witnesses in Gela
(i) Cohort of workers: commuting patterns
(l) Life-cycle assessment
(m) Socioeconomic and risk perception survey (700 interviews)
(n) Focus groups in Augusta
(o) Interviews with local witnesses in Augusta
(p) Collection and analysis of data on mortality and hospital discharge records
(q) Collection and analysis of environmental data
(r) Analysis of mortality by age cohort
(s) Geographical analysis of selected causes of mortality
(t) Survey on the direct costs of the public health system
(u) Drug consumption
(v) Simulation of accident patterns
(w) Intake fraction
(x) Collection and analysis of data on economy and demography

Working group

A number of working groups were set up, including a group that included experts on environmental epidemiology in Italy and risk assessment experts from the French National Center for Scientific Research (see Item 4 in Table 1). Among the institutions included in the groups that followed the development of the entire project were the following:

- Italian National Research Council
- French National Center for Scientific Research
- Italian National Institute of Health
- Sicilian Epidemiological Observatory
- University of Florence, Italy
- University of Grenoble, France
- University of Messina, Italy.

Many other institutions were involved in the project (see Table 2). The main networking activities included:

- meetings at various political levels (from national to municipal), which included families and schools involved in the analytical studies (as was the case in the Milazzo–Valle del Mela area), nongovernmental organizations and industry associations;
- appointment of a focal person at the local level – one per area – responsible for the organization of local activities and for liaising with local authorities;[4] and
- public meetings in all areas, to present progress and results to the population.

Table 2. Main institutions involved in the project and contacted

Name of institution	Name of institution
Agenda21 (Gela)	Local Health Service No. 5 of Messina
Agenda21 (Melilli)	Local Health Service No. 8 of Syracuse
Agenda21 (Milazzo–Valle del Mela)	Minister of the Environment
Association for Health Protection of Citizens (Milazzo–Valle del Mela)	Minister of Welfare
Association of Small and Medium Industries in the Province of Syracuse (APISIRACUSA)	Municipalities (mayors and council members in all three areas)
Augusta Municipal Committee	Navy (in Augusta)
Decontamination Sicily	Prefecture of Syracuse
Department of Health of the Sicilian Region	Provincial Commission for the Protection of the Environment (CPTA)
Department of Land and Environment of the Sicilian Region	Regional Province of Syracuse
Food Hygiene and Nutrition Services	Sicilian Epidemiological Observatory
Industrial Association	Sicilian Region
Industrial Consortium for Environmental Protection (CIPA)	Sicilian Survey on Congenital Malformations (ISMAC)
Italian Regional Agency for the Protection of the Environment (ARPA) in Sicily (Palermo Administrative Department)	Syracuse Regional Hospital Department of Medical Oncology
Italian Regional Agency for the Protection of the Environment (ARPA) in Sicily (Syracuse Administrative Department)	Syracuse Regional Hospital Department of Nephrology and Dialysis
Italian Society of General Medicine	Universities of Catania, Padua, Trieste and Venice
Legambiente	Women and Mothers Group of Augusta
Lentini Hospital Department of Surgery	

Communication strategy

Rehabilitation of the three areas studied is a complex process and involves economic resources, health systems, infrastructure and environmental resources for sea, coastal zones, landscapes and agriculture, among others. Since the project in Sicily focused on human health, most efforts were dedicated to informing and involving health authorities, as well as municipalities, stakeholders, agencies and citizens. The collaboration of stakeholders, institutions and citizens required specific activities intended to establish a network and partnership.

Communication was central to most activities. To ensure full comprehension of the social context, the project included surveys on perception of risk and health (see Chapters 15–17).

4 The three focal people selected are medical doctors: Pasquale Andaloro (Milazzo–Valle del Mela), Anselmo Madeddu (Augusta–Priolo) and Salvatore Migliore (Gela) (see Annex).

Structure of the book

The book is divided into five sections:

1. background information
2. review of the literature
3. using routine data
4. designing and conducting specific studies
5. addressing risk perception and local attitudes.

The studies in the project vary in their methods and philosophy, but the common thread of tackling health and its environmental determinants, in an integrated way, runs through them all. The concept of impact and investigation of contamination are addressed in Chapters 2, 6, 7, 13, and 14. Epidemiological issues are presented in Chapters 3–5. Some studies were carried out with epidemiological instruments: questionnaires and surveys (Chapter 11), biomonitoring and questionnaires (Chapter 10), and cohort investigations (Chapter 9). Modelling of different data, patterns of space-time activity (Chapter 12), accidents (Chapter 13) and production figures (Chapter 14) were used in other studies. Socioeconomic aspects were subsequently considered (Chapter 8), and risk perception was explored (Chapters 15–17).

After this introductory chapter, Chapter 2 discusses the lack of conceptualization of the definition of impact in the scientific literature on petrochemicals activities, among other things. Chapter 3 reviews the epidemiological literature on the adverse effects on health experienced by residents in the neighbourhood of petrochemical plants, finding consistent evidence of an association with several pathologies. The circumstances under which tension may exist between the two perspectives of the role of epidemiology – scientific or action oriented – are discussed in Chapter 4. Even in polluted areas, the main role of epidemiology and public health is to confirm causality and to focus on the need to prevent disease and promote health.

Chapter 5 describes and analyses the health status of the population of the three areas, as described in current health statistics (mortality data for the years 1995–2002 and hospital discharge data for the years 2001–2006), including the Cancer Registry of the Province of Syracuse and previous specific estimates of the occurrence of congenital malformations (in Gela and in the Province of Syracuse). Chapter 6 then describes a preliminary risk assessment of several chemical substances that have been detected in two Sicilian industrial areas. Next, Chapter 7, based on air pollution data, investigates the possible environmental impacts of emissions of sulfur dioxide, particulate matter with an aerodynamic diameter smaller than 10 μm (PM_{10}), nitrogen dioxide and ozone. After this, Chapter 8 presents an analysis of the industrialization process in the three high-risk areas (by occupational and demographic trends) and the ability of this process to achieve long-term socioeconomic benefits and create social capital.

Chapter 9 describes the cohort studies of two polluted Sicilian sites. The studies have produced scientific information that may contribute to improving the retrospective health impact assessment of these sites. In Chapter 10, exposure to several contaminants, such as heavy metals and chlorinated compounds, is investigated through human biomonitoring studies.

Chapter 11 describes studies of air pollution and asthma symptoms of all children attending primary schools in the Milazzo–Valle del Mela high-risk area. One cross-sectional survey and two panel studies on symptomatic and asthmatic children living in this area were performed, to study the association of spirometric measurements and bronchial inflammation with raised concentrations of air pollutants. The chapter explores the plausibility of interference between air pollutant concentrations and DNA methylation.

Chapter 12 discusses the role played by patterns of space-time activity in assessing the exposure of residents to industrial activities that generate dangerous substances. The chapter explores two main challenges: (a) those of space-time pattern methodologies; and (b) results of individual space-time-activity data extracted from the survey conducted in the Milazzo–Valle del Mela area.

Chapter 13 discusses the legislative framework for monitoring possible accidents, linked to the Seveso directives and introduces the issue of major accidents. Through a case study in Gela, Chapter 14 highlights three main points related to the 1996 European Commission directive on integrated pollution prevention and control (IPPC Directive): (a) access to and use of public data; (b) the possible inconsistency of public data on the environment; and (c) local area problems about air pollution and contamination surveillance in general.

Chapter 15 discusses the high vulnerability of different segments of the population to disrupted lives caused by industrial pollution. The chapter has four-parts: (a) a theoretical introduction on risk perception and risk communication; (b) the methods used and main findings of the research; (c) the mental-maps approach to characterizing people's spatial representation of risk; and (d) the results of the application of the mental-maps approach. Also, it notes how gender contributes to risk perception in general.

Chapter 16 identifies long-term contamination as a cause of environmental and psychological decline. It discusses redevelopment plans and describes the socioeconomic impact of the petrochemical industry, of which Gela is one of the Italian capitals. Chapter 17 discusses perspectives for sustainable local development and addresses the issue of risk perception in a population living close to a large industrial area, while Chapter 18 discusses the problems associated with a low degree of institutional trust and how this hampers rehabilitation, making risk a complex social issue.

This book also offers some instruments for further fieldwork – for example, the questionnaire on risk assessment included in the Annex.

REVIEW OF THE LITERATURE

2. CRITICAL OVERVIEW OF STUDIES ON THE ENVIRONMENTAL IMPACT OF PETROCHEMICALS

Debora Sabatini, Pierpaolo Mudu and Michele Faberi

Introduction

The present study seeks to review studies available on the environmental risks associated with the presence of petrochemical industries – including oil refineries – and to suggest options for the design of future studies. It is difficult to completely separate the activities of oil refineries from those of petrochemicals, in terms of analysis or clear-cut classifications, because these activities have been integrated according to two main principles (Giavarini, 2006:14):

> according to the first, the refinery must be adjacent to the petrochemical plant, but separate from it; according to the second (less frequent), the refining plants must be located inside the petrochemical complex, with shared utilities and integrated management. Modern refineries have adopted some processes previously typical of the petrochemical industry.

In this chapter, a *refinery* is defined as an industrial installation where oil is refined, with impurities or unwanted elements being removed by processing. In particular, an oil refinery converts petroleum crude oil into high-octane motor fuel (gasoline (petrol)), diesel oil, liquefied petroleum gas, jet aircraft fuel, kerosene, heating fuel, lubricating oils, asphalt and petroleum coke. Also, a *petrochemical* is defined as any of a large number of chemicals isolated or derived from petroleum or natural gas. Petrochemicals include several substances (such as benzene, ammonia, acetylene, and polystyrene) used to produce a wide variety of materials, including plastics, detergents, solvents, fertilizers, explosives, and synthetic rubbers and fibres.

The authors have attempted to identify all investigations published in international journals on environmental impacts (from 1995 through 2008) in which researchers examined the effects that result from petrochemical industry (including oil refinery) activities.[5] The impacts classified include water, soil and atmospheric pollution. During the years considered for the present book, some of the investigations of environmental impacts also reported on accidents and more integrated analysis, including those that pertain to population health.

Objectives

The present study focuses mainly on analyses of the impacts described in articles published in the international environmental science literature and on the implications of these analyses for both environmental impacts and conceptual aspects. It is worth noting that the journal *Oil and Chemical Pollution* (formerly known as *Oil and Petrochemical Pollution*) was published between 1986 and 1991. After 1991, no international journal focused on this important topic (with the exception of the magazines *Hydrocarbon Processing* and *World Oil*, edited by the oil industry and not peer reviewed).

The objectives of the present chapter are:

- to review the scientific literature on the impacts of petrochemicals on the environment;
- to critically assess the coverage of problems tackled and areas and populations analysed by different research;
- to identify the specific substances addressed;
- to consider the concept and definition of an impact; and
- to propose a research strategy for the future.

5 Although published in 2009, a few articles were included, as they were already online during 2008.

When researching the subject matter for the present book, two different concepts of *impact* were considered. The first, which is the more complete of the two, is an integrated assessment (an ecological risk analysis or assessment); it takes into account pollution (short-term and long-term effects) and population, including health and/or economy, such as consequences of industrial or commercial activities that affect other parties without being reflected in market prices (externalities) and cost–benefit analyses. The second can be thought of as a comparison between the *original* environmental situation and post-industrial conditions – that is, a before–after study; alternatively, it can be thought of as being limited to only the pollution aspect in an assessment based on actual results, rather than forecasts. In addition to considering the concept of impact, investigating how the *scientific community* examined petrochemical activities was also an interesting part of the research for this book.

Methods

The work presented here is a first step towards producing a database of articles on the impacts of petrochemicals on the environment. During 2009, a review of the articles published in the scientific literature between 1995 and 2008 was performed. The keywords used in that review were: oil, petrochemical, refinery and a combination of the keywords oil and contamination. A list of journals that publish mainly environmental topics was selected and examined.[6]

In the first step of the search strategy, a total of 147 articles responded to the keywords. All articles were read in full and, eventually, 76 articles were selected for inclusion in the present overview. The effects that originate in petrochemical plants, accidents and remediation solutions were the main criteria used to select articles. The articles considered do not include the following: the spill activity for which there are a set of effects investigated in some studies (Al-Lihaibi, 2003; Morales-Caselles et al., 2008), oil field effects (Kaplan et al., 1996; Mendes da Silva et al., 1997; Gogoi et al., 2003), pipeline projects (Leknes, 2001; Utzinger et al., 2005) and transport accidents (Pérez-Cadahía et al., 2007). Due to the bulk of articles and the complexity of the topic, the review work to be carried out to finalize an exhaustive review is enormous, but is it is important to consider it in the next review.

The 76 articles selected for inclusion in the present overview were classified according to a set of characteristics, which includes: geographical area (including, if available, other information, such as area dimension and resident population), type of study (specifying the method used), substances examined (list of substances analysed in the study), impacts (on water, soil, air, and single and/or multiple matrices), and results (see Table 3). Data were also matched with the Worldwide Refining Survey – 2007 (Koottungal, 2007).

Results and discussion

Table 3 summarizes the key characteristics of the 76 articles selected. This summary may be useful not only for environmental experts, but may also be useful for public health professionals who work in areas contaminated by petrochemical industries.

6 The list of journals selected includes: *Advances in Environmental Research; Atmospheric Environment; Bioresource Technology; Chemical Speciation and Bioavailability; Chemosphere; Energy Conversion and Management; Environmental Impact Assessment Review; Environment International; Environmental Pollution; Environmental Progress; Environmental Research; Environmental Science and Technology; Environmental Toxicology and Chemistry; Estuarine, Coastal and Shelf Science; FEMS Microbiology Ecology; Geochimica et Cosmochimica Acta; Human and Ecological Risk Assessment; International Journal of Environmental Health Research; International Journal of Environmental Research and Public Health; International Journal of Environmental Studies; Journal of Contaminant Hydrology; International Journal of Industrial Organization; Journal of Applied Geophysics; Journal of Environmental Chemistry; Journal of Environmental Management; Journal of Environmental Science and Health; Journal of Hazardous Materials; Journal of Public Health; Journal of the Air and Waste Management Association; Journal of Loss Prevention in the Process Industries; Marine Ecology; Marine Pollution Bulletin; Reliability Engineering and System Safety; Risk Analysis; Soil and Sediment Contamination; Science of the Total Environment; Water and Environment Journal; and Water Research.*

Table 3. List of articles analysed, classified according to a set of characteristics

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Abdul-Wahab et al. (2000)	Kuwait	Shuaiba Refinery (190 000 b/cd)	Mobile laboratory analysis for 12-month measurements; considered petroleum refinery, petrochemical plants and cement plants	Eighteen substances, including: methane, non-methane hydrocarbons, nitrogen oxides, carbon monoxide, carbon dioxide, sulfur dioxide, hydrogen sulfide, ammonia, ozone and total dust	Air	Ozone possesses a single peak, and it occurred during the midday hours on a daily basis. Also, the concentration patterns of relevant primary pollutants exhibited two maximums, during the morning and late afternoon hours. The peak concentration of ozone was measured during spring and fall. For primary pollutants, peak concentrations were measured during summer and winter. The data show the presence of high concentrations of primary pollutants, in comparison with the limits set by the United States Environmental Protection Agency.
Akhter & Al-Jowder (1997)	Bahrain (all coastal areas around Bahrain)	NA	Nineteen sampling stations; considered industries and traffic	Heavy metals	Sediments	The concentration of heavy metals in the areas near industries was generally higher than in other regions of the island.
Baek et al. (2008)	Republic of Korea	The refinery's name was not mentioned; petrochemical complex in rural area and semi-industrial area; steel complex in residential area.	Air sampling analysis at 19 sites for 6 months	Polychlorinated biphenyls and other contaminants	Air	A specific petrochemical process was a likely important source of polychlorinated naphthalenes.
Bakker et al. (2000)	Zelzate, Belgium	Zelzate refinery (356 629 b/cd)	Sample analysis in the area of an oil refinery	Polycyclic aromatic hydrocarbons	Soil, leaves and grass	The samples from the site adjacent to the refinery contained very high total polycyclic aromatic hydrocarbon concentrations: namely 300, 8 and 2 µg/g dry weight for soil, Plantago major leaves and grass, respectively. It is suggested that particle-bound deposition is relatively more important for deposition to soil than to plants, due to blow-off and wash-off of compounds from leaves. It appears that it is not possible to predict precise polycyclic aromatic hydrocarbon concentrations for one plant species from known concentrations of other species.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Bixian et al. (2001)	Pearl River and estuary, China	Guangzhou Petrochemical Oil Refinery (154 000 b/cd)	Eleven sampling stations in an area with coke from steel, plastics, dye and petrochemical industries	Polycyclic aromatic hydrocarbons	River and estuary sediments	The sediments from the sampling stations at Guangzhou Channel had the highest concentrations of polycyclic aromatic hydrocarbons, owing to contributions from the large amount of urban and/or industrial discharges from the city of Guangzhou. The pyrogenic (combustion) source, characterized by an abundance of parent polycyclic aromatic hydrocarbons, was predominant in the heavily contaminated station near the ageing industrial area, and the petrogenic (petroleum-derived) polycyclic aromatic hydrocarbons were more abundant in the stations adjacent to the petrochemical plant and shipping harbour.
Bleckmann et al. (1995)	NA	Unspecified petroleum refinery	Eleven wastewater samples for analysis collected (from a petroleum refinery) during a 35-day period and testing on freshwater organisms	Toxicity tests	Water and freshwater organisms	Aquatic toxicity tests did not show a sufficient level of correlation to substitute freshwater organisms for the permitted marine test species in the toxicity reduction evaluation. None of the chemical analyses of the refinery effluent water pointed to obvious toxicants. Ammonia and phenol were present consistently, but did not show particularly wide variations in concentrations.
Bosco, Varrica & Dongarrà (2005)	Gela, Italy	Gela Refinery (105 000 b/cd)	Forty-one samples of pine needles in the area of a petroleum refinery	Heavy metals and phenols	Air	The petrochemical plant appeared to be associated with raised levels of arsenic, molybdenum, nickel, sulfur, selenium, vanadium and zinc. The study of airborne particulate matter should be extended to its chemical speciation and its impact on nearby agriculture.
Bozlaker, Muezzinoglu & Odabasi (2008)	Izmir, Turkey	Izmir Refinery (226 440 b/cd)	Concurrent ambient air and dry deposition samples collected during two sampling programmes carried out between 2 and 17 August 2004 and between 20 March and 5 April 2005; 28 samples (14 samples in summer and 14 samples in winter) collected in the industrial area with petroleum refinery, petrochemical industry and iron–steel industries; average sampling duration: 24 hours	Polycyclic aromatic hydrocarbons	Air pollution; air–soil deposition	The spatial distribution of polycyclic aromatic hydrocarbon concentrations indicated that the urban Aliağa (Turkey) steel plants, the petroleum refinery, and the petrochemical plant were the major sources of polycyclic aromatic hydrocarbons in the area.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Cetin et al. (2007)	Izmir, Turkey	Izmir Refinery (226 440 b/cd)	Petrochemical industry, a petroleum refinery and steel plants operate in the area; ambient air samples collected concurrently from urban and industrial sites during two sampling programmes between 28 March and 8 April 2005 and between 13 and 20 June 2005; soil samples also collected around sampling sites; chemical mass balance modelling used	Polychlorinated biphenyls, PM_{10} and other trace elements	Air and soil	Significant polychlorinated biphenyl sources included the steel industry, fuel oil combustion, and the nearby vinyl chloride process in the petrochemical plant.
Cetin, Odabasi & Seyfioglu (2003)	Izmir, Turkey (Izmir population: 2 700 000 inhabitants)	Izmir Refinery (226 440 b/cd)	Petroleum complex and a petroleum refinery in the area considered; ambient air samples collected between September 2000 and September 2001 at three sites around the petrochemical complex and the oil refinery	Volatile organic compounds	Air	Values for volatile organic compound concentrations measured around a petroleum industrial site were generally higher than values measured at urban and suburban sites in Izmir and at other sites around the world. Evaluations based on wind direction indicated that emissions from the refinery and petrochemical complex affected the ambient volatile organic compound concentrations measured. These concentrations generally increased with temperature and wind speed. The highest concentrations were measured in summer, followed by autumn, probably due to the increased evaporation of volatile organic compounds, as a result of higher temperatures.
Chang, Chang & Yuan (2003)	Taipei, Taiwan, China	Taoyuan Refinery (200 000 b/cd)	Areas considered: Minshi municipal sewage treatment plant and Chinese Petroleum Corporation's refinery in Taoyuan; sludge samples collected from municipal and petrochemical active sludge; biodegradation rate assessed	Polycyclic aromatic hydrocarbons	Soil	Degradation is assisted by autochthonous microorganisms – that is, microorganisms that produce their own energy.
Chen, Fang, Shu (2005)	Kaohsiung, Taiwan, China	Kaohsiung Refinery (270 000 b/cd)	Samples with canisters from 25 sites, twice per season during one year, inside the petrochemical plant	Volatile organic compounds	Air	The dominant volatile organic compounds were alkanes, alkenes, dienes and aromatics. These accounted for 99% of the total volatile organic compounds. By means of contour plots, the emission sources for alkanes, aromatics and alkenes plus dienes were successfully located.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Cheng, Hsu & Chou (2008)	Taiwan, China	NA (5 industrial districts: petrochemical and science-based districts)	Sample analysis and volatile organic compound cost analysis of treatment systems	Volatile organic compounds (such as acetone, acrylonitrile, methylene chloride and chloroform)	Air	A sealed cover with venting and an incinerator with 93% regenerative heat recovery system are recommended for treating high-concentration volatile organic compound emissions.
Colombani et al. (2009)	Italy	Unspecified location in Northern Italy; area: 1 km^2 around petrochemical plant	Sample of groundwater and a flow model; overall simulation time: 4.5 years (from 1 October 1999 to 1 February 2004)	Benzene, toluene, ethylbenzene and xylenes compounds and others	Water	At the site studied, natural attenuation as the sole remediation strategy was not sufficient to prevent the contaminants from reaching potential receptors, and active remediation was required (pump and treat). Depending on the efficacy of removal of non-aqueous phase liquids (liquids that do not dissolve readily in water) from the source zone, the importance of natural attenuation (and biodegradation) in the overall mass removal may increase.
Conaway et al. (2005)	San Francisco Bay, California, United States	Five refineries (combined capacity: about 95 million litres of crude oil per day)	A suite of gasoline (n = 20) and diesel (n = 19) samples; refineries, distribution stations, and service stations in the San Francisco Bay Area	Mercury	Air	Mercury is not measurably enriched in gasoline or diesel fuel refining, and there was little evidence of contamination in motor fuels from high mercury crude oil in California refineries.
Conley, Thomas & Wilson (2005)	Harris County, Texas, United States	Lyondell Refinery (282 600 b/cd); Valero Energy Corp. (90 000 b/cd)	Air samples were collected daily during an 8-hour period from December 2002 to March 2003 at 5 locations in Harris County, Texas, home of a petrochemical complex	Volatile organic compounds	Urban air	The atmosphere near Harris County's industrial complex had higher concentrations of volatile organic compounds than the atmosphere in areas farther away.
Custer et al. (2001)	Casper, Wyoming, United States	Closed petroleum refinery	Tree swallow and house wren eggs and chicks were collected near a refinery site on the North Platte River and at a reference site 10 km upstream	Polycyclic aromatic hydrocarbons, aliphatic hydrocarbons, and other pollutants	Air	Total polycyclic aromatic hydrocarbon concentrations in swallow and wren chicks were higher at the refinery site than at the reference site.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
De Lima, Sato & Porsani (1995)	Bahia, Brazil	Camaçari Petrochemical Center (269 003 b/cd)	A geophysical procedure that combines conventional Schlumberger sounding with a scheme for sampling the resistivity stratification in depth was used in the petrochemical complex to image groundwater contamination	Hydrocarbons	Soil and groundwater	Increases in the salinity of the groundwater, both laterally and in depth, were inferred to be associated with the downward percolation of waters used in the various industrial processes.
Emoyan, Akporhonor & Akpoborie (2008)	Warri City–River Ijana, Nigeria	Warri Refinery and Petrochemical Company Limited (125 000 b/cd)	At three sampling stations, samples were collected once a month in March/April and July/August 2003	Metals, suspended and dissolved solids, biochemical and chemical oxygen demand, and phenol	Water	Oil and grease, pH, dissolved oxygen, phenol, cadmium, chromium, copper, iron, nickel, lead, and zinc concentrations in the study area were above the WHO allowable threshold, while temperature, conductivity, suspended and dissolved solids, biochemical and chemical oxygen demand levels approached WHO allowable limits for aquatic environments. The river could be said to be polluted as a result of the measured pollutants concentrations in the refinery effluent and the leachates from the refinery sludge lagoon.
Fahy et al. (2008)	Carrington, Manchester, United Kingdom	Petrochemical plant	Bacteria analysis	Benzene	Soil and groundwater	Remediation through microbial degradation.
Farhadian et al. (2008)	NA	NA	Review of studies of methods for removing monoaromatic hydrocarbons, used for polluted waters located near oil refineries and industries	Benzene, toluene, ethylbenzene and xylenes	Water	Aerobic biofilm processes can achieve treatment efficiencies up to 99% and above in removing benzene, toluene, ethylbenzene and xylenes from the liquid phase.
Gómez, Contento & Carsen (2001)	Buenos Aires, Argentina	Buenos Aires Refinery (110 000 b/cd)	Analyses of aromatic hydrocarbon compounds were carried out for eight and three samples of raw and treated effluents, respectively, and toxicity tests were performed. An industrial complex, including an oil refinery, was considered	Polycyclic aromatic hydrocarbons and general toxic elements	Water (untreated effluents and treated effluent)	The results of this study revealed the need, in conjunction with traditional chemical specific analyses, for criteria to identify unacceptable toxicity in effluents by employing appropriate toxicity tests.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Guerzoni et al. (2007)	Venice, Italy	Porto Marghera Refinery (80 000 b/cd)	Forty-two new atmospheric deposition samples were collected monthly at 6 sites during the period March to December 2004. Two hundred water samples were collected monthly by the water authority during 2001–2002, from 15 stations in the lagoon. Samples of sediments and clams were collected concurrently during this study in the north, central and south lagoon	Persistent organic pollutants (dioxins and furans, polychlorinated biphenyls and hexachlorobenzene)	Water (lagoon), atmospheric depositions and lagoon sediments	Persistent organic pollutant values of water and atmospheric deposition fluxes were one to two orders of magnitude higher than background values, and the whole central part of the lagoon contained more than five times pre-industrial levels. Persistent organic pollutants showed the same trends already highlighted in sediments collected in the lagoon. It was shown that the consumption of Tapes philippinarum from illegal fishing, still practised in the most contaminated area, represents a threat to the health of a small percentage of local regular consumers.
Guo et al. (2007)	Songhuajiang River, China	Jilin refineries (166 000 b/cd)	In the flood season (August 2005), 10 sediment samples were collected from the river. During the ice-bound season (December 2005), 17 sediment samples were collected from the river, and 7 exposed sediment samples near the river bank were also collected	Polycyclic aromatic hydrocarbons	River sediments	Polycyclic aromatic hydrocarbons heavily polluted the river, which was located near a heavily industrialized area.
Hall & Burton (2005)	Delaware, United States	Delaware Refinery (190 000 b/cd);	The Triad approach to environmental assessment that integrates chemical characterizations, sediment toxicity assessments, and assessments of resident biological communities to determine pollution-induced degradation	Polynuclear aromatic hydrocarbons and heavy metals	Water (aquatic biota)	A retrospective evaluation of the effect of the Refinery's effluent on the Delaware River ecosystem.
Hayat et al. (2002)	India	Mathura Oil Refinery (156 000 b/cd)	Samples of groundwater and treated wastewater were collected just before each irrigation, to test changes in the microbial dynamics of the soil	Heavy metals	Soil bacteria	The findings of the investigation revealed that no change in the status of the microflora of the soil was evident.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Hers et al. (2000)	Delta, BC, Canada	Former Chatterton (Vancouver, BC) petrochemical plant site	Soil sampling and model simulation	Benzene, toluene and xylene	Soil	The results of monitoring and model simulations indicate that biodegradation through aerobic respiration was an important attenuation process at the Chatterton research site. Measured first- and zero-order benzene, toluene and xylene degradation rates were relatively high and similar to those reported in other studies.
Hong & Luthy (2007)	California, United States	Just mentions five oil–gas plant sites in California	Lampblack-impacted soil samples were obtained from five different oil–gas plant sites in California	Polycyclic aromatic hydrocarbons	Soil	The presence of an oil tar phase on lampblack had a significant impact on the sorption behavior of polycyclic aromatic hydrocarbons. This study illustrates the importance of understanding interactions among polycyclic aromatic hydrocarbons, oil tar, and lampblack for explaining the differences in availability of polycyclic aromatic hydrocarbons among site soils and, consequently, for refining site-specific risk assessment and establishing soil cleanup levels.
Horn, Rocha & Vargas (2004)	Caì River basin area of Rio Grande do Sul, Brazil	Two refineries in the area (198 000 b/cd)	Five samplings were performed at three points along the stream, in each season of 1999 and in the summer of 2000. Various analyses were performed	Mutagenic and/or cytotoxic activity	Water sediments	The stream is undergoing ecotoxicological degradation, the first area showing the environmental impact of the petrochemical complex.
Iqbal, Portier & Gisclair (2007)	Louisiana (coast), United States	Eighteen refineries (2 911 600 b/cd, in total)	In three consecutive years, 3 420 georeferenced sediment samples were collected at 1 140 points in areas of high spill probability spaced about 3 km apart	Polycyclic aromatic hydrocarbons, aliphatic hydrocarbons, and common petroleum biomarkers	Soil and water sediments	The study indicated that 4% of the sites exceeded the effect-range low value (concentration of a chemical in sediment below which toxic effects are rarely observed) of national sediment quality guidelines based on ecotoxicological effects, while only one site exceeded the effect-range median value (concentration of a chemical above which effects are frequently or always observed). The petrogenic and pyrogenic input of polycyclic aromatic hydrocarbons, as well as the biogenic origin of n-alkanes, was evident in coastal Louisiana sediments. The study recommended regular monitoring of hotspot areas for ecotoxicological profiling and potential biomarker compounds.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Im et al. (2002)	Changwon and Masan, Republic of Korea (780 000 people reside in the area)	NA (petrochemical industry and other industrial areas)	Soil samples from 23 locations in November 1994	Polychlorinated dibenzo-*p*-dioxins and dibenzofurans	Soil	Nearly all tetrachlorinated through octachlorinated polychlorinated dibenzo-p-dioxins – the most toxic chlorodibenzo-*p*-dioxins – and dibenzofurans were detected in all soil samples.
Israel et al. (2008)	Port Harcourt, Nigeria	Eleme Petrochemical Plant (120 000 b/cd)	Water and sediment samples were collected once a month between July 2005 and March 2006	Biological oxygen demand; dissolved oxygen; chemical oxygen demand; total dissolved solids; total suspended solids; total hydrocarbons; and chloride, phosphate, sulfate, and nitrate ions	Effluents (process wastewater, clarified water and discharge water)	This study showed that effluents from this petrochemical plant generally contain low concentrations of pollutants in the water and sediment, except the concentration of total dissolved solids. The long-term impact of the petrochemical effluent on the surrounding environment is not known.
Kalabokas et al. (2001)	Greece	Corinth Oil Refinery (110 000 b/cd)	Field measurements of atmospheric hydrocarbons were performed at several sites around the refinery in weekly campaigns during four different months in 1997 (February, May, September and October)	Saturated alkane (hexane, heptane, octane) and aromatic (benzene, toluene, ethylbenzene, xylene and trimethylbenzene) hydrocarbons	Air	The average ambient air concentrations of saturated and aromatic hydrocarbons around the refinery were relatively low, on the order of few micrograms per kilogram. The total aromatic hydrocarbons were higher than the total saturated hydrocarbons. The most abundant aromatic and saturated hydrocarbons were hexane and toluene, respectively.
Kassinis (1998)	NA	NA (case model of a petroleum refinery)	A pollution estimation model (relying on an input–output type matrix formulation and pollution coefficients obtained from engineering studies) was applied to estimate the air emissions of a petroleum refinery under two different operating scenarios	Air emissions	Air	The model allows analysts (both industry and non-industry experts alike) to review the pollution-generation dynamics of a complex industry in a comprehensive manner. In an environment of information scarcity, the resulting estimates can be used to better inform the impact assessment process and, by extension, the development of effective environmental policies.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Khaitan et al. (2006)	United States	Case study I: closed refinery in Missouri; case study II: closed refinery in Midwest	Review of published literature on remediation of petroleum-contaminated sites; recovery of: 1 900 000 gallons of free products (case study I); 1 700 000 gallons of petroleum products (case study II)	Remediation of non-aqueous phase liquids, including polycyclic aromatic hydrocarbons and benzene, toluene, ethylbenzene and xylenes	Soil	A review of the literature revealed significant progress in the technologies available for the remediation of non-aqueous phase liquid contaminated sites. The pump-and-treat method is often used to manage the plume and contain it. Application of a combination of techniques, such as a physical process with bioremediation and phytoremediation, may offer a better remediative solution. The efficiency of these processes is affected by site conditions.
Khan & Abbasi (1999)	NA	NA	TORAP is a computer-automated tool for rapid risk assessment in petroleum refineries and petrochemical industries. The use of TORAP is demonstrated through a rapid and quantitative risk assessment of a storage unit at a typical petroleum refinery	Accident scenarios are described.	NA	According to the authors, TORAP enables a user to quickly focus on the accidents likely to occur and enables the user to forecast the nature and effects of such accidents.
Knight, Kadlec & Ohlendorf (1999)	NA	NA	Review of treatment wetland performance for petroleum industry, including chemical oxygen demand and biochemical oxygen demand	Trace organic compounds, metals, total suspended solids, nitrogen and phosphorus.	Water (effluents)	Pollutant removal is highly dependent on hydraulic loading and influent concentration and, to a lesser extent, on internal plant communities, water depth, and hydraulic efficiency. In most cases, data from petroleum industry wetland studies indicate that treatment wetlands are equally or more effective in removing pollutants from petroleum industry wastewaters than they are from other types of wastewater. Until industry-specific data are more complete, this finding can be used along with published rate constants from other wastewater categories to provide conservative estimates for sizing petroleum industry treatment wetlands.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Konstandinidou et al. (2006)	Greece	Greek refineries (423 000 b/cd in four refineries)	Greek output of crude oil products: about 18x106 tonnes per year; 5000 workers; statistical analysis of incidents in the Greek petrochemical industry (extraction sites, refineries, and production and storage sites)	NA	NA	Accident analysis revealed the magnitude of the contribution of human factors in causing reported accidents. Despite the increased hazard awareness and a pro-safety mentality that were registered, deficiencies still exist, leading to human-related incidents and accidents. In cases where the main registered cause was mechanical failure, a deeper investigation could have led to an organization-related failure, since the existence of proper procedures, correct designs and/or adequate maintenance could have prevented the failure. For the more important incidents, the analysis showed that in certain cases the incident could have been prevented with a better safety-management system in place at the installation.
Koppol et al. (2004)	NA	NA	Mathematical programming to analyse the feasibility of the zero liquid discharge option in different industries, including refineries	NA	Water (modelling study of single or multiple contaminant systems)	Large reductions in liquid discharge and operating cost are possible by means of reuse and regeneration of wastewater.
Kubin & Lippo (1996)	Finland	Neste Oil's Naantali Refinery (51 800 b/cd) and Porvoo Refinery (200 000 b/cd)	In 1985–1986 and 1990–1991, 4 883 moss samples were collected. The analysis focused on the atmospheric deposition of heavy metals in Finland	Heavy metals (cadmium, chromium, copper, lead, nickel and vanadium)	Atmospheric deposition	Elevated levels of vanadium were found around the oil refineries.
Kulkarni, Chellam & Fraser (2007)	Houston, Texas, United States	Two refineries in the area feature: (a) 282 000 b/cd; (b) 90 000 b/cd.	Levels of particulate matter with an aerodynamic diameter smaller than 2.5 µm ($PM_{2.5}$) at four monitoring stations (three sites located near the Houston ship channel)	$PM_{2.5}$ and metals (sodium, magnesium, aluminium, silicon, potassium, titanium, vanadium, manganese, iron, cobalt, nickel, copper, arsenic, zinc, selenium, rubidium, strontium, cadmium, caesium, lead, thorium and uranium)	Air	The results show a significant (33–106-fold) increase in the contribution of fluidized-bed catalytic cracking units to $PM_{2.5}$, compared with background levels associated with routine operations. The impacts of emissions from the fluidized-bed catalytic cracking units were tracked up to about 50 km downwind.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Kuo, Lo & Chan (1996)	Kaohsiung, Taiwan, China	Kaohsiung Refinery (270 000 b/cd)	Wastewater samples were retrieved from five locations along the Ho-Chin River, in Kaohsiung, and also near petrochemical plants. Samples were also taken from tap water and underground water in residential areas near the Ho-Chin River	Volatile organic compounds	Water	High concentrations of 1,2-dichloroethane and benzene were detected near a petrochemical plant's wastewater outlet.
Lee & Fang (1997)	South-west coast of Taiwan, China	Kaohsiung Refinery (270 000 b/cd)	Areas monitored in this study include eight estuaries and three ocean outfall fields. Two to six stations are allocated in each area. Samples were taken between April and October 1995 to collect surface sediments	Congeners of chlorobenzenes and hexachlorobutadiene	Sediments	Sediments from the Tso-yin outfall field, which receives the wastewater from a very large petrochemical complex, had concentrations of 1,3,5- trichlorobenzene, pentachlorobenzene, hexachlorobenzene and hexachlorobutadiene two to three times higher than those from the Chon-chou outfall field (which discharges the domestic wastewaters collected from Kaohsiung City) and Da-lin-pu outfall fields (which discharges the wastewaters collected from the petrochemical complexes in the southern Kaohsiung area).
Lee Vail (2000)	Wisconsin, United States	Wisconsin refinery (33 250 b/cd)	Wastewater characterization study and treatability study	All wastewater pollutants	Wastewater	Based on the study and lessons learned from the design and installation of a new treatment facility at the refinery, wastewater treatment was considerably improved. Effective wastewater treatment plant design and operation have led to a reduction of 85% in biochemical oxygen demand, compared with historical levels. Also, design and in-plant waste minimization efforts led to a 92% reduction in ammonia, compared with historical levels.
Lin et al. (2004)	Kaohsiung, Taiwan, China	Kaohsiung Refinery (270 000 b/cd)	Air samples were collected from 28 April to 4 May 2001 at 26 sites in and around the petrochemical complex	Volatile organic compounds	Air	Among the volatile organic compound species detected were high concentrations of aromatic hydrocarbons, such as benzene and toluene. For total concentration of volatile organic compounds, the highest among the 26 sites was 102.5 μg/m^3 near a waste burning stack. High concentrations of volatile organic compounds were also detected at the wastewater management area and the east gate of the plant. The values were 10–18 times higher than those detected in Kaohsiung City.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Lin et al. (2007)	Second Songhua River, China	Jilin Oil Refinery (166 000 b/cd)	A large amount of mercury was discharged from petrochemical industries in Jilin City from the 1960s to the 1980s. Surface sediment samples were collected in August 2005 in an area of concern of 73 000 m^2	Mercury	Soil sediments	The concentration of mercury in the sediments decreased at an exponential rate with distance downstream, from 1.27 mg/kg at Jilin City to 0.01 mg/kg at Haerbin City. The previously accumulated and buried mercury in sediments may not significantly affect water quality, but may pose a potential ecological risk to aquatic and amphibian animals. For these sediments, natural attenuation seems to be an economic remedial possibility.
Morelli et al. (2001)	La Plata, Argentina	Refinery in La Plata (189 000 b/cd)	Sludge–soil systems were prepared at four different sludge concentrations (1.25, 2.50, 5.00, and 10.00% w/w – that is, grams sludge per 100 grams dry soil). Soil without the additional sludge was used as a control system. The Ames test for mutagenic activity was used	Polycyclic aromatic hydrocarbons	Soil	After a year of treatment, only the system of highest initial concentration (10% w/w) showed direct mutagenicity; all the systems, however, showed indirect mutagenicity, with no significant difference among them. While chemical analysis suggests that, at lower sludge application rates, the genotoxic polycyclic aromatic hydrocarbons were degraded, a persistent mutagenic residue was detected one year after sludge application. Although the Ames test is only an indicator of potential carcinogenicity, it is essential to know the chemical and genotoxic characteristics of the sludge, as well as to carry out studies that reveal the residual mutagenicity of the system. Treatment should be carried out in enclosed systems that include: suitable waterproofing, to prevent pollution from water tables and surrounding areas; drainage systems that allow the percolated water to be treated; suitable protection for workmen; and strict plans for the treatment process.
Nadal et al. (2006)	Tarragona, Spain	Tarragona Refinery (160 000 b/cd)	A geographical information system (GIS)-integrated integral risk index was developed. It takes into account the hazard index and the concentrations of all pollutants in soil from 24 samples collected in four different areas. A GIS characterization, based on this integral risk index, was carried out in the industrial area of Tarragona	Polychlorinated dibenzo-*p*-dioxins and dibenzofurans, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and seven heavy metals	Soil	Although some specific zones of the chemical and residential areas of Tarragona could present a relative higher risk than others, the current environmental pollution does not pose, in principle, a significant risk to the population living in the vicinity of the chemical and/or petrochemical area.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Nadal et al. (2008)	Tarragona, Spain	Tarragona Refinery (160 000 b/cd)	Construction of a hazard index, using a probabilistic approach based on: toxicity to human beings, bioaccumulation potential, and persistence	Polychlorinated dibenzo-*p*-dioxins and dibenzofurans, polychlorinated biphenyls, polychlorinated naphthalenes, polycyclic aromatic hydrocarbons, and heavy metals	Soil and vegetation samples	Between 2002 and 2005, an important decrease in risk was observed in the chemical and urban and/or residential areas, whereas the risk in the petrochemical zone increased.
Nadal et al. (2009)	Tarragona, Spain	Tarragona Refinery (160 000 b/cd)	Of the samples collected, 24 were from soil, 15 from vegetation and 8 from ambient air	Polychlorinated dibenzo-*p*-dioxins and dibenzofurans, polychlorinated biphenyls, polychlorinated naphthalenes, polycyclic aromatic hydrocarbons, and heavy metals	Soil, vegetation and air	The multimatrix surveillance tool was shown to be a suitable for monitoring the state of pollution of areas presumed to be contaminated. The use of multiple environmental matrices with differential characteristics, in contrast to monitoring only one, allows total knowledge of the environmental levels and processes affecting the area.
Nafissa, Bouzerna & Chettibi (2005)	Skikda Bay, Algeria	Skikda Refinery (300 000 b/cd)	Sampling in six locations, applying gravimetric and chromatographic methods	Hydrocarbons, carbon dioxide, calcium, and magnesium ions, chlorides and phosphates, and alkalinity	Water	The chemical analyses performed showed a large amount of contaminated seawater, compared with uncontaminated water.
Nivolianitou, Konstandinido & Michalis (2006)	Europe	Petrochemical plants	From the European major accident reporting system, 85 accidents in the petrochemical sector were analysed	NA	NA	Although the knowledge needed to prevent major accidents and minimize their consequences is often available, there is a lack of a proper safety culture to enable effective use of this knowledge and a lack of a structured communication system to diffuse this knowledge.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Olajire et al. (2005)	Warri and Ughelli, Niger Delta, Nigeria (218 000 and 54 000 inhabitants, respectively, in 1991)	Warri Refinery (125 000 b/cd)	Sample analysis: chemical analysis and toxicity bioassays	Polycyclic aromatic hydrocarbons	Soil sediments	Reclamation by Shell Petroleum Development of Nigeria
Pandya et al. (2006)	India (location not shown)	Unspecified oil refinery	Sampling was carried out using an organic vapour sampler at 12 sites	Volatile organic compounds and total hydrocarbons	Air	Both the ambient and workplace air environment were contaminated with many chemicals emitted from different processes in the refinery. In most cases, the concentrations were quite low. Although the quantity of data generated was substantial, they were inadequate to assess human exposure and to establish long-term trends. The data were most useful in comparing the volatile organic compound concentrations in the ambient and workplace air of a refinery.
Pecoraino et al. (2008)	Sicily, Italy (14 basins)	NA	Volatile organic compounds in groundwater from 14 hydrological basins in Sicily (25 710 km²) were sampled at 324 selected points. All groundwater sampled was collected twice, from October to December 2004 and from February to May 2005	Thirteen volatile organic compounds	Groundwater	Thirteen volatile organic compounds were determined in 324 untreated groundwater samples collected in Sicily. Of these, 162 were free of volatile organic compounds, while only three were over the limit. Two of these are located near petrochemical industries (Augusta–Priolo Plain). Concentrations of chloroform that exceeded legal limits were found in wells situated close to petrochemical industries (Augusta Plain).
Pfau, McBeek & Van Den Bussche (2001)	Caddo County, Oklahoma, United States	Oklahoma Refining Company oil refinery	About 30 adult cotton rats from three contaminated sites and three uncontaminated reference sites were examined, for a total of 177 rats. Genetic diversity of an immune-response gene within the major histocompatibility complex in cotton rats inhabiting an oil refinery complex was analysed	Organic compounds, caustic wastes, heavy metals and cotton rats	Cotton rats	This study indicated either that the level of contaminant-induced selection was insignificant at this major histocompatibility complex locus or that gene flow from surrounding areas obliterated the effects of selection.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Propst et al. (1999)	Caddo County, Oklahoma, United States	Abandoned Oklahoma oil refinery that operated from 1920 to 1984	In this 3-m by 3-m mesocosm (an experimental water enclosure designed to provide a limited body of water with close to natural conditions) study, using three experimental exposure trials, cotton rats were housed in three contaminated mesocosms (Tank Battery, API Separator, and Land Farm) for either 4 weeks (acute exposure) or 8 weeks (chronic exposure). An 8-week exposure trial was conducted in both the winter of 1991 and the summer of 1992; a 4-week exposure trial was conducted during the summer of 1993	Organic hydrocarbons, heavy metals and cotton rats	Soil	Cotton rats collected from the API Separator mesocosm had lower absolute brain weights and reduced macrophage phagocyte activity than animals from the reference mesocosm; this mesocosm had the highest diversity of contaminants detected and the greatest soil toxicity compared with other mesocosms in this study. Two of the contaminants detected at this location were toluene and mercury. Decreased brain weight was also seen in animals from the Tank Battery mesocosm, along with decreased peritoneal macrophage metabolic activity. Lead contamination at the Land Farm mesocosm site may have been responsible for the increased haemolytic plaque formation. Heavy metal contamination may have also been responsible for the increased metabolic activity of peritoneal macrophages. The mesocosm approach used on these three locations contaminated with petrochemicals did not reveal severe immunotoxicity risks to the resident populations of small mammals. This study supports the use of resident animals in place of the use of mesocosms to assess immunotoxicity risks.
Relić et al. (2005)	Danube River, Serbia	Pančevo Oil Refinery (98 000 b/cd)	Fourteen alluvial sediments from five boreholes (taken from 4.00- to 7.50-m depth) were sampled in October 2001. The study aimed to define the fractions of the trace metals and to explore the metals bioavailability	Nickel, zinc, lead, copper, with iron and manganese oxides	Water sediments	Trace metals originated from the geochemical background when their substrates were manganese oxides, while trace metals originated from an anthropogenic source of pollution when their substrates were iron oxides.
Roseth et al. (1996)	Slagentangen, Norway	Esso Oil Refinery (116 000 b/cd)	Aquatic toxicity tests were conducted using a fish, a flagellate and a diatom	Chemicals: Nalco 537-DA, Nalco 625, Ivamin and technical monoethanolamine	Water	The ecotoxicological risk associated with the normal use of process chemicals may be acceptable if adequate biological treatment of the effluent is carried out.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Sanchiz, Garcia-Carrascosa & Pastor (2000)	Mediterranean coast of Spain	Castellon de la Plana Refinery (110 000 b/cd)	The concentrations of heavy metals in the sediment and in five species of soft-bottom marine macrophytes were collected in 17 sampling stations along the Mediterranean coast of Spain	Mercury, cadmium, lead and zinc	Soil sediments	The levels of metals were generally low and similar to those found by other authors in uncontaminated zones. Some locations showed higher metal contents, reflecting contamination – for example, in Almassora (under the influence of a petrochemical complex), there were high levels of mercury and lead. Two seagrass species, Posidonia oceanica and Cymodocea nodosa, seem to be good biomonitors of heavy-metal pollution, due to their capacity to accummulate abnormal levels that are not reflected in the sediment.
Schroder et al. (1999)	Cyril, Caddo County, Oklahoma, United States	Abandoned Oklahoma refinery, that operated from 1920 to 1984	Land farming is used extensively by the petroleum industry to dispose of waste. Many inorganic substances that include fluorides and metals do not biodegrade and tend to accumulate when land farmed. Cotton rats, soil, and vegetation were collected from the land farm and from a matched reference site adjacent to the facility	Fluorides	Soil and cotton rat bones	Fluorides in soil and in the bones of cotton rats collected from the land farm site were highly elevated, compared with the matched reference site. Also, the majority of cotton rats captured on the land farm site had dental lesions characteristic of fluorosis. The practice of land farming may pose a threat to the health of terrestrial organisms. The degree of risk is related to the inorganic fluoride content of the waste and the potential exposure pathways. Moreover, not all petrochemical waste may be safely land farmed when the overall health of the ecosystem is considered. Waste that contains excessive levels of inorganic contaminants may not be suitable for disposal in soil.
Schroder et al. (2000)	United States	NA	Cotton rats and soils from 12 petrochemical-contaminated and matched reference sites were analysed over a three-year period	Metals and fluorides	Soil and cotton rat bones	The disposal of petrochemical wastes can result in the contamination of soil with cadmium, chromium, copper, nickel, lead, strontium, titanium, vanadium, zinc and fluorides. Contamination with fluorine can be prominent on land farms, compared with other waste disposal sites. Elevated levels of chromium, lead, strontium and fluorides were found in the bones of cotton rats from several contaminated petrochemical sites, and lead and fluorides were the most frequently bioaccumulated contaminants, with different seasonal trends.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Schuhmacher, Nadal & Domingo (2004)	Tarragona County, Catalonia, Spain	Oil refinery (160 000 b/cd)	In the winter of 2002, 24 soil and 12 wild chard samples were collected in various zones of Tarragona County	Polychlorinated dibenzo-*p*-dioxins and dibenzofurans, polychlorinated naphthalenes, and polychlorinated biphenyls	Soil	The current levels of polychlorinated dibenzo-*p*-dioxins and dibenzofurans, polychlorinated biphenyls, and polychlorinated naphthalenes in soil and vegetation are similar or even lower than those reported in previous surveys carried out in other industrialized regions. According to the concentrations of the pollutants analysed, the potential adverse effect on the health of the population living in the vicinity of the industrial complex should not be of special concern.
Sherry, Scott & Dutka (1997)	Ontario, Canada	NA (three Ontario, Canada refineries)	Aquatic toxicity tests of refinery effluents were carried out on microbes, plants, invertebrates and fish. Acute toxicity was assessed by the Microtox™ test. Short-term toxic effects were measured with: bioassays of growth and survival of a larvae; survival and reproduction of a water flea; growth of an alga; growth of an aquatic plant; germination of a non-aquatic plant; survival, growth, and maturation of a nematode; and genotoxicity in the SOS chromotest	General toxicity	Freshwater ecosystems	The effluent treatment systems used at Ontario refineries have largely eliminated acute toxicity to the organisms in the test battery. Although reduced survival and sublethal effects were detected in some of the effluents, the effects were minor.
Škrbić & Miljević (2002)	Novi Sad, Serbia; 171 000 hectares; 350 000 inhabitants	Novi Sad oil refinery (116 826 b/cd)	Following the destruction of crude oil and its products in storage tanks during the Kosovo[d] conflict, soil pollution was investigated. More than 100 000 tonnes of crude oil and its products were destroyed, of which about 90% of these were burned off, 10% leached and 130 tonnes recovered	Polycyclic aromatic hydrocarbons , polychlorinated biphenyls and others.	Sand and soil	The measured concentration of polycyclic aromatic hydrocarbons in soil samples indicated that they migrated to a depth of 60 cm at the places where crude oil spilled and burned. The concentration of heavy and inorganic metals showed their migration to a depth 1 m or even to greater depths. Concentrations of polycyclic aromatic hydrocarbons ranged from 0.75 to 86.19 µg/g dry soil. The contaminated soil can be expected to act as a permanent pollution source, while the mobile constituents are likely to cause groundwater pollution and be a risk in drinking-water.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Soldi et al. (1996)	Pavia, Italy (10 000 inhabitants in the area)	Pavia refinery (200 000 b/cd)	Vanadium and lead concentrations were evaluated in the area near the plant – in atmospheric particulate matter, meteoric water, soils and groundwater	Vanadium and lead	Air, water and soil	The lead and vanadium concentrations found in atmospheric particulate matter had the same concentration ranges measured at the collection points nearest the plant. By varying the soil composition and permeability, the vanadium distribution may assume a completely different trend. The fallout emitted by the refinery made no significant vanadium contribution.
Song et al. (2007)	Beijing, China	Beijing refinery (170 000 b/cd)	Ambient concentrations of volatile organic compounds and contributions from gasoline, petrochemicals and liquefied petroleum gas sources were continuously measured with a time resolution of 30 minutes in August 2005 in Beijing. Three important chemical plants, Yanshan Petrochemical Corporation Limited, Beijing Chemical Plants and Eastern Chemical Works are located at about 31.26 and 34.00 km, respectively, from the sampling site	Volatile organic compounds	Air	Gasoline-related emissions, petrochemicals and liquefied petroleum gas contributed 52%, 20%, and 11%, respectively, to the total ambient volatile organic compounds.
Sonibare et al. (2007)	Nigeria	Four operating oil refineries (505 000 b/cd) and 14 newly licensed refineries	Sample analysis	Volatile organic compounds	Air	The four operating petroleum refineries contribute about 147 212 tonnes a year to Nigeria's airshed. The addition of the 14 approved refineries can raise the potential by about 240%.
Suedel et al. (2006)	Colorado City, Texas, United States	Former Col-Tex refinery site	Ecological risk assessment	Chromium and lead	Soil	Results demonstrated that information about lead and chromium bioavailability and speciation can raise soil cleanup concentrations while being protective of ecological receptors.
Tarek, Aboul-Kassim & Simoneit (1995)	Alexandria, Egypt	Two refineries in Alexandria area (total of 178 000 b/cd)	Particulate fallout sampling for 45–67 days; considered petrochemicals and general industries	Aliphatic and aromatic hydrocarbons	Air (atmospheric fallout)	The results show that all samples contained aliphatic hydrocarbons. The main source of these compounds was petrochemical contamination. Polycyclic aromatic hydrocarbons were also distributed in all samples.

Table 3 (continued)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Vasudevan & Rajaram (2001)	Chennay, Tamil Nadu, India	Chennay city (listed in the Survey as Madras city) refinery (130 660 b/cd)	Soil was collected from open fields near the petroleum refinery site for laboratory experiments on bioremediation)	Petroleum hydrocarbons	Soil	The use of a bulking agent played an important role in the bioremediation of oil-contaminated soil. In general, tillage of soil might enhance the contact between oil and bacterial populations, thereby enhancing the bioremediation process.
Wake (2005)	European Union (EU)	NA	The study reviewed the effect of European oil refineries (about 80 refineries), up to the year 2000	All chemicals and/or metals of oil refinery effluents	Marine organisms and the aquatic environment	It is possible to detect two effects that oil refinery effluents have on the environment: (a) a toxic effect close to the outfall, which is seen by the absence of all or most species; and (b) an enrichment effect that can be distinguished as a peak in the abundance of biomass. These effects are not limited to just oil refinery effluents; this makes it difficult to distinguish the effects of the oil refinery effluent from those of other sources of pollution.
Wang et al. (2007)	Taiwan, China	Unspecified petrochemical industry in southern Taiwan, China	Polycyclic aromatic hydrocarbon sampling system comparable to United States Environmental Protection Agency Modified (sampling) Method 5	Polycyclic aromatic hydrocarbons	Air pollution	The use of the liquid injection incinerator for incinerating the petrochemical industrial wastewater was found to produce high concentrations of heavy metals and polycyclic aromatic hydrocarbons with high carcinogenic potency. This finding suggested that the better incineration efficiencies – for example, the destruction of benzene rings – and air pollution control device removal efficiencies for disposing of petrochemical industrial wastewater are necessary in the future.
Yang et al. (2004)	Taiwan, China	Three Taiwan, China, refineries (Taoyuan, Kaohsiung and Talin) (770 000 b/cd)	The relationship between pregnancy outcome – 7 095 births in the study area – and residential proximity to a source of petroleum emissions was investigated	NA	Air pollution	Petroleum air pollution may have an effect on an adverse pregnancy outcome (preterm delivery).

Table 3 (concluded)

Author(s)	Geographical information	Data from Worldwide Refining Survey – 2007[a,b] (output in b/cd)[c]	Type of study	Substances, properties or organisms analysed	Environmental field(s) or organisms effected	Results
Yawetz, Benedek-Segal & Woodin (1997)	Ashdod, Israel	Oil refinery (90 000 b/cd)	Comparative study of cytochrome P4501A induction in liver microsomes from three species of freshwater turtles	Polycyclic aromatic hydrocarbons, polychlorinated biphenyls and chlorinated dibenzofurans, and chlorinated dibenzodioxins	Freshwater turtles	The sensitivity of cytochrome P4501A induction in turtles must be established further before being used as a biomarker of exposure in turtles.
Zhu et al. (2007)	Jilin Province, China	Refineries in Jilin (140 000 b/cd)	A microcosm was used to mimic the polluted water system and to study the transport and fate of nitrobenzene in the river water. An explosion was considered, and a Markov model was applied to predict the fate of nitrobenzene in the environment after an explosion	Benzene, aniline and nitrobenzene	Water (river)	The simulated results matched very well with the results obtained from the microcosm experiment. Most of the nitrobenzene (around 82%) evaporated into the air, and 18% was degraded by microorganisms in the sediment.

NA: not available.
[a] Koottungal (2007) (except for Conaway et al., 2005).
[b] 1 metric tonne of oil = 7.3 barrels; 1 barrel/day = 50 tonnes/year.
[c] b/cd: barrels per calendar day.
[d] Kosovo in accordance with the UN Security Council Resolution 1244 (1999)

A fundamental aspect of the work was to assess the coverage of the problems tackled by the various articles. The articles selected were also examined to see if they did or did not take an integrated approach to investigating the environment and if, for example, the social and health aspects of the local population were analysed.

In general, for the impacts presented in the articles, usually only one substance is discussed. Table 4 shows the most commonly investigated substances analysed by the various authors – and also the number of articles (frequency) that contain them. At the top of the table are polycyclic aromatic hydrocarbons or, more generally, volatile organic compounds. Some authors analysed the effect of volatile organic compounds on one environmental field (for example, Kuo, Lo & Chan, 1996; Conley, Thomas & Wilson, 2005), and others analysed their effect on more than one field: air and water, soil and water, or other combinations (for example, Bozlaker, Muezzinoglu & Odabasi, 2008). It is worth noting that several of these substances are known to be mutagenic and/or carcinogenic.

Table 4. Chemical substances most frequently investigated

Environmental matrix	Substance	Frequency [a]	Per cent
Air, soil, water, sediments or a combination of them	Volatile organic compounds (examined in general or as only polycyclic aromatic hydrocarbons or monoaromatics)	40	52
	Heavy metals (including vanadium)	18	23
	Polychlorinated biphenyls (sometimes associated with other contaminants, such as dioxins and furans)	9	12
	$PM_{2.5}$	1	1
	Various substances (and general toxicity)	7	9
Soil and cotton rat bones	Fluoride	2	3
	Total	**77**	**100**

[a] A few articles were counted more than once, and eight articles were not considered.

Nivolianitou, Konstandinidou & Michalis (2006) and Konstandinidou et al. (2006) reported that the most common substances involved in petrochemical accidents are heavy and light hydrocarbons. Such findings coincide with the chemicals that are more commonly investigated (Table 4), with polycyclic aromatic hydrocarbons being investigated more frequently than other pollutants. It is worth noting that polychlorinated biphenyls, which are harmful persistent organic pollutants, were found in only 7 of the 76 articles.

Schroder et al. (1999) affirmed that contaminants other than petroleum hydrocarbons, such as fluoride, should also be analysed, because it "accumulates in the soil from land farming or petroleum waste" and "may pose [a] risk to terrestrial vertebrates". Only two articles elaborate the effects of fluorides.

Also, Tables 3 and 4 do not include all authors' investigations, and chemicals other than the most common ones are considered in rare cases – for example, by Zhu et al. (2007), where benzene, aniline and nitrobenzene are examined. Some other articles study emissions in general (Kassinis, 1998; Lee Vail, 2000; Yang et al., 2004). The investigations reviewed cover a partial spectrum of the potential impacts associated with petrochemical and refinery activities. For example the United States Environmental Protection Agency compiled a list of various impacts associated with petrochemical and refinery activities (see Box 2). In a few cases, the counts presented in Table 4 were not applicable: different types of analysis were carried out – for example, analysis of Greek petrochemical industry accidents (Konstandinidou et al., 2006), analysis of major accidents in the petrochemical sector (Nivolianitou, Konstandinidou & Michalis, 2006), mathematical programming (Koppol et al., 2004) and models that allow analysts to review the pollution-generation dynamics quickly and comprehensively (Kassinis, 1998; Khan & Abbasi, 1999).

Box 2. Impacts associated with petrochemical and refinery activities

The following list of substances and impacts gives a picture of the complexity of investigations, remediation actions and policies to be considered in relation to petrochemical activities.

Air (the associated impacts would be most significant near and downwind of a given facility):

- volatile hydrocarbons from crude oil (benzene is a carcinogen and is a significant component of refinery air emissions);
- carbon monoxide;
- sulfur oxides from crude oil and process heaters;
- nitrogen oxides and particulate matter from process heaters;
- hydrogen sulfide from sulfur recovery operations;
- ammonia;
- particulate matter;
- metals;
- spent acids; and
- other toxic organic compounds.

Water (potential for contamination from leaks and spills):

- process wastewater from desalting, distillation, cracking, and reforming operations;
- a percentage of total toxic emissions is released as wastewater; and
- large quantities of cooling water.

Solids (potential for contamination from leaks and spills):

- desalter sludge;
- spent catalysts;
- other process sludges; and
- storage tank bottoms.

Global warming (these activities are a significant contributor):

- refining is an energy-intensive operation; and
- most of the energy is consumed as process heat generated from refining by-products.

Other:

- hydrocarbon spills from leaking storage tanks and pipes; and
- hydrocarbon spills during receiving and shipping.

Source: EPA (1995).

The type of funding that supported the articles analysed is important to understanding their aims and details. Normally, funding is provided by a government body, a university department, or a private company that aims to develop the research and allow the development of the articles.

In investigating this aspect of the research, the authors of the present chapter found that the source of funding is declared in 68% of the articles reviewed (see Table 5). The source of funding of each article was examined to better understand the works carried out – and their so-called guiding force. The results of this examination showed that about a third of the articles do not mention any financial support and another third were funded by universities or by a private company. In such cases, the facts on which the articles focused appear to be oriented strongly towards the specific and unidirectional needs of the institution or private company that provided the funding.

However, when analysing the works supported by ministries, national research councils or national environmental protection agencies, which cover more than a third of the total number of articles, the results were as follows. In these cases, the approach was never global (referring to the scale of analysis) and integral (referring to the integration of methods), which would have been more useful for setting effective future actions. In one case, the analysis was connected to a court-ordered study.

Table 5. Source of funds declared by article authors

Source	Number of articles	Per cent
No funds or unknown source	27	32
Universities or academic centres	15	18
Private company	11	13
Ministries (8 articles) or similar entities (8 articles), national research councils (9 articles), national environmental protection agencies (5 articles) and the European Commission (2 articles)	32	38
Total	**85** [a]	**100**

[a] Seven articles were funded by two different entities, so they are counted twice.

The literature cited by the articles reviewed does not overlap, and different local scientific sources are quoted, without referring to similar situations elsewhere – that is, without a global perspective. Also, the reference works cited and quoted in the articles reviewed are strongly heterogeneous. A vast amount of literature is cited, and none of it is quoted frequently or considered to be a reference point. Web references are found only for works from the year 2005 and on and are often for very recent articles (2007 and 2008). Moreover, large institutions, such as national environmental protection agencies, are quoted most frequently (with EU institutions mentioned less frequently): national bodies, such as environmental protection agencies, are cited in 33 articles (counting also the ones not included, but mentioned in the earlier section on "Methods" in the present chapter). This bias in favour of large institutions can be interpreted as the absence of a systematic literature review carried out to report on a particular risk investigated. In this context, most of the articles are oriented towards local debates and consider just their own national situation. This local and nation-centred approach is found in citing texts written and published in the language of the country of origin. Facing a set of local analyses and discussions makes it difficult to rank the impacts and make comparisons.

Of the articles considered in the present review, only 10% considered health impacts, with most of them just making a few general reflections, based on the literature available (for example, Kuo, Lo & Chan, 1996). Only 8% (6 articles) investigated the adverse effects on environment and health in detail (for example, Yang et al., 2004), and rarely is literature on the adverse effects on health considered – although in recent years, several studies have been published on the increased risk associated with petrochemical plants (for example, Gascon Merlos, 2009; Intrinsik Environmental Sciences Inc. & Stantec Consulting Ltd, 2010) (see also Chapter 3).

Some of the limitations of the present work should be considered when reading its findings. The literature on the adverse effects of the petrochemical industry is extensive, and only a small number of articles from a few journals have been selected. The main limitation of the present work is that it may have missed some relevant studies, because they are available only in the so-called grey literature – that is, information that cannot be found easily through conventional channels, such as technical reports from government agencies or scientific research groups, working papers from research groups or committees, white papers, dissertations and preprints (for example, Kennedy et al., 2002; Pedersen et al., 2003; Witter et al., 2008) – or because they were produced by the oil industry (see www.concawe.org). Also, another limitation is reviewing articles published in English only.

Altogether, the impacts on the environment usually presented are very limited – for example, as already mentioned, often only one (harmful) substance is analysed. Also, the evolution and transformation of the environment brought on by the petrochemical complexes is seldom described. Moreover, the de facto definition of impacts covers a narrow range of effects and few substances, and no mention of the debate on sustainability is reported. The general approach to dealing with the challenge of pollution from petrochemical complexes is to intervene only after the event, which implies no irreversible problems are linked to adverse effects on health, species extinction or habitat destruction. The emphasis on the after-the-event approach means that environmental issues are essentially regarded as incidents, the result of errors and mistakes that should be dealt with on a case-by-case (and often place-by-place) basis (Harvey, 1996). The preference, then, is for environmental clean-ups of particular sites and so-called end-of-pipe solutions – for example, soil remediation, the installation of scrubbers on smokestacks, and catalytic converters in cars – rather than for pre-emptive or proactive interventions (Harvey, 1996). What emerged from the present review is that the majority of the articles just cover the environmental effects, while usually omitting the social and health effects. Most often, only specific effects on one or (at most) two environmental matrices (such as air, soil and sediments; or water and sediments) are examined.

The petrochemical industry's impact on water is particularly important: on one hand, the petrochemical and agricultural sectors often share a limited water resource; on the other hand, water use is vital to the general public. Consider, for example, the contamination of the Songhua River by the petrochemical plant in Jilin operated by China National Petroleum Corporation. An explosion took place at Jilin Petrochemicals, but company officials denied for several days that the river had been polluted. The river supplies drinking-water to the north-eastern Chinese city of Harbin, which experienced a four-day cut-off of water supply (Zhu et al., 2007). Remediation methods available for water contaminated by oil can be physical, chemical or biological (Farhadian et al., 2008). In general, although remediation policies are very relevant, particularly in the case of bioremediation, costs are usually not specified in the articles reviewed. Useful lists of literature on petroleum-contaminated sites were published – for example, on remediation (Khaitan et al., 2006).

Also, the texts of the articles reviewed seldom discuss the location of the industries in the territory. Maps are presented in 57% of all the articles considered, and of these articles 55% present maps with a scale. The types of maps presented are mostly schematic maps of the areas studied, with only a few examples of maps that show physical or topographical features. Risk maps are presented only in three cases (Chen, Fang & Shu, 2005; Nadal et al., 2006; Bozlaker, Muezzinoglu & Odabasi, 2008), and it is well known that the distribution of environmental risks is uneven (Wheeler, 2004). Moreover, in one case, the location of the study is not indicated (Colombani et al., 2009).

The diversity of the published works is another aspect worth stressing. With regard to concern about global pollution or local populations, no author follows a general theme. Each article focuses on a particular aspect of a problem or of pollution – for example, describing the application of a particular model (Koppol et al., 2004; Zhu et al., 2007) used for a specific environment, making that model useful only locally and probably only by the one university department that used it originally.

Although analyses of the social and health situation and of the emissions in the various environmental matrices are important, the literature reviewed contained none. Such analyses, however, are important for carrying out general and practical considerations – for the future also (Aronson et al., 2010). Moreover, both evident and remarkable is the absence, in the majority of the articles analysed, of any mention of the local population. More than 70% of the cases lack a description of the territory and/or population. This means, for example, that density of inhabitants, demographical characteristics, number of workers and health conditions in the locale of petrochemical facilities are not mentioned. More precisely, the mention of a population living near the plants and affected by pollution occurred in 16 articles (21%), while 56 articles (74%) made no mention of this; and in 4 articles, consideration of local populations was not relevant and/or applicable. Because petrochemical activities affect the environment and its population – for example, asthma attacks (Loyo-Berríos et al., 2007) – this aspect of the subject should be considered with care. Considering the emergency measures taken during the evolution of accidents in the petrochemical sector in Europe, evacuation of nearby communities occurred in 10% of cases, sheltering of the population in 6%, and decontamination of the surroundings in 6% (Nivolianitou, Konstandinidou & Michalis, 2006).

Another important consideration concerns the consumption of local resources by the industries analysed. Looking at how many authors consider the consumption of water (from surface water bodies or from underground water), other environmental resources or energy, the situation is as follows: very few articles consider the importance of local resources. For example, Iqbal, Portier & Gisclair (2007) considered biological resources to be very important for the local economy and life, while Hall & Burton (2005) emphasized the importance of local rivers and their waters. However, no study on the quantitative use of local resources is analysed or mentioned in any article reviewed.

The geographical coverage of the articles also needs to be considered. Considering all the largest refineries in the world – that is, the 20 largest, ranging from 400 000 to 940 000 b/cd of crude oil, as listed in Nakamura (2007) – not all of them have been investigated or studied. In particular, no peer reviewed articles cover the Falcon refinery, in Venezuela, which is the largest one in the world; nor do they cover the large Republic of Korea (Ulsan, Yosu and Onsan), Singapore (Jurong), Texas (Baytown and Texas City), Indiana (Whiting), Kuwait (Mina Al-Ahmadi) refineries, and other large refineries. This lack of studies does not exclude the possible negative effects on the environment or accidents caused by these refineries – for example, the large fire that occurred in Venezuela in July 2006.

To summarize the results, it is worth noting that very few researchers and authors consider the same concept of impact and that the articles reviewed offer narrow views of the study of impact. Also, recognition of how environmental change can adversely affect health and survival is extremely limited (McMichael, 2002). Moreover, the articles lack indications of pollution prevention measures or environmentally conscious chemical processes (Allen & Rosselot, 1997).

It is also worth noting that, in the last 20 years, the scientific and political debates have examined the impact of human activities through a series of different practices, the most important being the environmental impact assessment and the strategic environmental assessment. According to the European Commission, an "Impact assessment is a set of logical steps which structure the preparation of policy proposals" (EC, 2005a:4). The preparation of policy proposals appears to be a neglected part of impact assessment, where the main focus is a description of cause–effect relationships. These relationships are usually considered from an ex-post position and are based on an analysis of the association between the release of a contaminant and its particular level of concentration in air, water or soil. This way of proceeding does not seem to address any political perspective or any integrated vision. For a long time, a reductionist approach to environmental problems has prevailed, and scientists did not try to understand and predict how their specialty fitted into more integrated analytical approaches (Odum, 1982). Also, this way of operating without a holistic perspective is often considered as an apolitical and neutral activity, but this view is simplistic and uncritical (Catney et al., 2008).

Conclusions

This section summarizes a number of considerations and conclusions and makes some suggestions. To begin, most of the articles reviewed for this book, all on petrochemicals activities, do not clarify the concept of impact they adopt to assess the presence and the effects of process plant activities on their surrounding environment. Also, they do not provide a definition of impact, which would be useful if placed at the beginning of the works, and only sometimes do the articles express the specific impact of particular substances or refining activities.

The analysis of the articles reviewed led to the idea that a concept for impact is unconsciously adopted. This concept is generally based on the quantification of substances detected in a given environmental matrices, but not present in the environment before the process plant was operative. In summary, an implicit (not explicitly described) concept of impact is employed as the measure of quantifiable differences in a given set of compounds between two space-time states of environmental matrices. This is an important and workable concept that allows scientists and technicians to improve petrochemical processes, optimize production and possibly improve communication with the local population. These concepts, however, do not help the strategic decision-making or integral assessments essential to social and environmental development.

Improving processes, optimizing production and improving relationships with the population or the political settings are far from the goals of the articles. But moving a step forward in the environmental impact assessment of process plants that are highly demanding of resources and land requires consideration and adoption of a different perspective. In particular, this step forward could arise from considering the damage caused to bodies exposed to petrochemical and/or refinery pollution. In other words, a quantification of potential problems in the observed environmental matrices, if given quantities of pollutants are found in it, should be described in advance. For example, when evaluating the criteria and parameters suitable for quantifying impact, human, animal or living plant health should be considered, as should the toxic concentration levels of the pollutants sought.

None of the articles contain the opinions or perspectives of the populations affected by these industries. This leads to a complete lack of social responsibility for pollution events or the processes investigated and to a lack of concern for industrial ecology (Tansey, 2006). This approach also implies very limited suggestions for operating measures, recommendations and proposals, which are missing in the vast majority of articles (90%) reviewed. In 70% of the articles, a description of the territory and/or population is missing, and also local resources are not analysed. In general, only very specific substances are assessed.

Moreover, although it seems that the articles analysed state which chemical compounds are investigated, they fail to state why. Brief consideration given to why the investigation is carried out might improve the impact evaluation and possible policy-making suggestions.

Some recent works discuss prioritizing reductions in air emissions from oil refineries (Gower et al., 2008). In prioritizing them, rankings of air contaminants commonly emitted from Canadian oil refineries were based on predicted case incidence or the application of a common health impact metric, DALYs, to the incidence predicted (Gower et al., 2008).

By examining the source of funding of each article, the type of analysis generally presented in it can be better understood. First, 27 articles (35%) do not mention any financial support. Second, various articles are funded by universities and/or academic centres, or by a company. In such cases, the focus and orientation of the article is very specific and unidirectional and is probably guided by the needs of the institution or private company. Less clear is the situation where a ministry (education, health or environment, depending on the case) or national research council or similar entity has financially supported the research. In such cases, a more global approach, useful for setting future operational guidance would be expected.

In the majority of the articles selected, no suggestion of a possible method for multifactorial investigation was found. Different possibilities exist. As suggested by Nadal et al. (2009), the use of multiple environmental matrices (soil, vegetation and air), in contrast to monitoring only one, allows a total knowledge of the environmental levels and processes that affect a contaminated zone. This should be considered by reversing the environment-centred approach – that is, starting from the health conditions of the population and only then taking emissions, water, pollution and other factors into account. Another possible approach would be to consider health and environment together, from the beginning of the analysis. Such suggestions would help address the environmental burden attributed to the petrochemical industry.

Another consideration is how to tackle the very heterogeneous situations that emerge. As it turns out, every situation is specific to the particular environment and the analysis of each situation is also specific to that environment and differs from all the others. Some global and/or uniform research should be performed in each country where pollution from petrochemical plants and refineries is of public concern and causes health and/or environmental damage. Without such research, it is difficult to compare and analyse the various situations described in the articles, each having a specific aim and covering different targets. An answer to how to tackle the very heterogeneous situations could be provided by international organization programmes, such as those of the United Nations (its most relevant programme is the International Programme on Chemical Safety), environmental protection agencies or the European Commission; they could provide financial support for parallel work to be performed where the local situation has revealed the need for further study, without forgetting the necessity for more integrated examinations and comparisons. The financial support should, at least partially, be linked to the results obtained.

Some options and suggestions for the future are as follows.

- It is essential to prioritize measures of certain substances that appear particularly noxious and are present in many instances of contamination caused by petrochemical and petroleum refinery activities. It is also essential to build on the work of the European Risk Ranking Method of the European Commission and the Chemicals Hazard Evaluation for Management Strategies of the United States Environmental Protection Agency.
- There is the need to build a framework for integrated assessment of the effects of large industrial activities that is not only based on environmental impacts (often also very fragmented). This also involves training experts able to carry out integrated assessments – that is, the necessity of training a small number of investigators in a multidisciplinary framework.
- The concept of impact has to be developed to embrace different perspectives. The needs of the population living in the industrial area comprise one of the most important perspectives, since these needs entail both environmental and socioeconomic considerations – for example, on health and the use of resources.
- A good practice in presenting the results of the impact of the petrochemical industry would be to consider and describe the population exposed to possible contamination and to quantify the use of local resources – for example, water consumption.
- Policy implications of the analysis presented should be verified – for example, in terms of the best available technologies adopted, monitoring networks operating on site and risk perception – which means that an analysis of priority measures and potential interventions should be carried out and outlined.
- A database of completed studies also needs to be developed. An indication of data availability (such as data on industry production and emissions) and of web sites should be given – for example, in the EU, according to the IPPC Directive, it is mandatory for each country to provide publicly available data in the European Pollutant Release and Transfer Register on industrial emissions collected.

Finally, future articles and works need some general indications – in particular, on possible reproducible research protocols on what has to be examined, why it has to be examined and how to examine it. The implications of the public availability of data are linked to an increased possibility of public participation in decision-making, according to the Aarhus Convention (UNECE, 1998). Also, the constraints of a research protocol may, in some contexts, conflict with feasibility issues, thus suggesting the utilization of less-stringent criteria for including some substances and for collecting a large range of information. Moreover, investigators should always remember to consider all aspects of contamination and natural and human-induced environmental changes at different scales and, whenever possible, consider environmental policy appraisal. This is the only way to contribute to setting priorities in environmental remediation and rehabilitation programmes, as well as thinking about more sustainable and integrated development.

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USING ROUTINE DATA

3. REVIEW OF THE EPIDEMIOLOGICAL EVIDENCE ON THE ADVERSE EFFECTS ON HEALTH OF RESIDENCE NEAR PETROCHEMICAL PLANTS

Roberta Pirastu and Roberto Pasetto

Introduction

Petrochemical plants have often been built close to cities, and residences in neighbourhoods close to these plants is, therefore, considered to pose a health hazard. In most instances, the larger the plants the greater the influence on the daily life of residents and the greater the perceived risk to health. With specific reference to petrochemical plants, it has recently been shown that the perceived risk to health may be a predictor of poor health outcomes at least as important as that of residential distance from petrochemical plants. Also, environmental hazards could indirectly affect health through the perception of risk – for example, through chronic stress and the sequelae of that stress expressed in poorer health outcomes (Peek et al., 2009).

In Europe, potentially polluting activities are estimated to have occurred at nearly 3 million sites. EIONET (European Information and Observation Network of the European Environment Agency) estimates that soil contamination is present in almost 250 000 sites, a number expected to grow. For many sites, further investigation is needed to assess the damage and whether soil remediation is required. In Europe, the oil industry is one of the main economic activities that cause soil contamination, and its contribution has recently been estimated to be about 17% of the total contribution (EEA, 2010).

Italy has several thousand contaminated sites. Until 2008, 54 of them were marked as areas of special national concern, because of pollution documented in qualitative and/or quantitative terms and because of the potential adverse effects on health for the resident populations. In seven sites, petrochemical plants are listed among pollution sources: in four of them refineries are also present, whereas in other four sites only refineries are present (Pirastu et al., 2010).

The main objective of this chapter is to review the epidemiological evidence of potential adverse effects on health associated with residence near *petrochemical plants*. The term petrochemical plant is used in a broad sense and includes oil refineries and petrochemical industries.

Epidemiological evidence of occupational effects: petrochemical industry and refineries

Before describing how exposure to petrochemical industry and refinery activities affect neighbourhood communities, a brief description will be given of the evidence on adverse effects on health of occupational exposure in these industries.

In 1989, the International Agency for Research on Cancer (IARC, 1989) classified occupational exposures in petroleum refining as "probably carcinogenic to humans" (Group 2A); the evaluation was based on *limited* evidence for skin cancer and leukaemia. Subsequent studies confirmed an increased risk of skin cancer (Wong & Raabe, 2000; Sorahan, Nichols & Harrington, 2002) and lymphohaematopoietic neoplasms (Divine, Hartman & Wendt, 1999; Consonni et al., 1999; Satin et al., 2002; Gun et al., 2004). An increase in risk was also observed for cancer of the lung (Bertazzi et al., 1989; Boffetta, Jourenkova & Gustavsson, 1997; Rosamilia, Wong & Raabe, 1999; Lo Presti et al., 2001), bladder (Lo Presti et al., 2001; Fano et al., 2006), kidney (Wong & Raabe 2000) and liver (Wong & Raabe 2000). The latest mortality study of workers employed in a Gela petrochemical plant showed that residence in Gela might have contributed to an increase in the risk of lung cancer (Pasetto, Comba & Pirastu, 2008) (for more information, see Chapter 10).

The most recent meta-analysis of occupational studies of workers involved in the manufacture or application of chemical products was financed by the American Chemistry Council. The analysis measured weak to moderate excesses of lung and bladder cancers likely caused by occupational exposure to known human carcinogens and also recorded a 10–15% increase in lymphatic and haematopoietic neoplasms (Greenberg et al., 2001). Any adverse effects on health other than cancer, however, were not systematically reported in epidemiological studies of petrochemical plant workers.

In the 1960s, health effects associated with the presence of asbestos in petrochemical plants were first reported (Eisenstadt & Wilson, 1960). In the 1980s, the evidence was corroborated (Lilis et al., 1980; IARC, 1989; Finkelstein, 1996). In Italy, the risk of mesothelioma was documented in refineries in the Liguria Region (Gennaro et al., 1994, 2000).

Selected review of epidemiological studies of residents living near petrochemical plants

The articles included in the review were collected by an informal search of the PubMed database, using the following terms: *petrochemical industry, refinery, environmental exposure, epidemiology*; no time restriction was applied. Additional articles were found by checking the references of the articles selected. Only studies where the exposure was specifically from a petrochemical plant – without any other industrial environmental exposures – were considered. In case of more than one study on the same population, the most recent article was examined. The present review consists of 28 articles on epidemiological studies, which looked at the following adverse health outcomes: lung cancer, respiratory diseases, leukaemia, non-Hodgkin's lymphoma, Hodgkin's disease, multiple myeloma, bladder cancer and perinatal conditions. For each investigation, the main characteristics – that is, study design and population, classification of exposure, starting year of plant operation, study period, and major results – are reported in Tables 6–11.

Of the studies reviewed, 10 were conducted in Taiwan, China, 7 in the United States, 3 in the United Kingdom and the remaining studies in Argentina, Brazil, Canada, Croatia, Finland, Italy, South Africa and Sweden. The topic of focus for 11 investigations was incidence, and for 7 it was mortality; in the remaining articles, prevalence was measured. In investigations of environmental epidemiology, the time of exposure is also relevant information: it is assumed to be the start of plant operation and is reported in 10 of the studies selected.

The following paragraphs cover the outcomes considered in the investigations collected. Of the six studies that analysed lung cancer (Table 6), three adopted an ecological or small-area design (Kaldor et al., 1984; Sans et al., 1995; Yang et al., 2000) and three a case-control design (Yang et al., 1999; Belli et al., 2004; Simonsen et al., 2010). Two studies examined risk in women only (Yang et al., 1999, 2000). Each of the six studies reported – with variable precision of estimates – at least one positive association between residence in the neighbourhood of petrochemical plants and lung cancer.

Respiratory diseases were the main topic of nine investigations (Ware et al., 1993; Yang et al., 1997, 1998; Chen et al., 1998; Liao et al., 2009; Smargiassi et al., 2009; Wichmann et al., 2009; White et al., 2009; de Moraes et al., 2010), eight of which were cross-sectional studies, and eight focused on children. Independent of the exposure classification adopted, these studies results showed an increased risk of different respiratory symptoms, both diagnosed or self-reported; among them, wheezing, phlegm and/or cough were mentioned (Table 7).

The association between residence near petrochemical plants and leukaemia (Table 8) in children was the outcome analysed in two ecological studies (Lyons et al., 1995; Knox & Gilman, 1997) and one case-control study (Weng et al., 2008). Five more surveys, using an ecological design, observed leukaemia in adults (Kaldor et al., 1984; Pekkanen et al., 1995; Sans et al., 1995; Gazdek et al., 2007; Barregard, Holmberg & Sallsten, 2009); four additional studies adopted a case-control design (Linos et al., 1991; Shore et al., 1993; Speer et al., 2002; Yu et al., 2006). In 8 of 12 investigations, the risk of leukaemia was associated with residence in proximity to petrochemical plants, while 4 studies did not measure any increase among children (Lyons et al., 1995) and adults (Pekkanen et al., 1995; Sans et al., 1995; Speer et al., 2002).

Table 6. Epidemiological studies of residence near petrochemical plants: lung cancer

Reference and location	Study design and population	Exposure	Start of plant operation	Study period	Results
Kaldor et al. (1984) California, United States	Ecological study Incidence	Residence in areas were classified in four groups, to model exposure to sulfur dioxide, hydrocarbons and nitrogen oxides. Group 1: no industrial exposure Groups 2 and 3: industrial exposure different from that of the petrochemical industry Group 4: exposure to petroleum and chemical industry emissions	NS	1969–1977	Rates per 100 000 population in the four groups of areas Increasing trend in rates for males (*P* = 0.02) in areas with high levels of exposure, but not for females
Sans et al. (1995) South Wales, United Kingdom	Small-area study Mortality	Residence within 7.5 km of a petrochemical plant	1963	1981–1991	Within 0–3 km of a petrochemical plant, the standardized mortality ratio (SMR) = 1.07 (95% confidence interval (CI): 0.92–1.24).
Yang et al. (1999) Taiwan, China	Case-control study Mortality: housewives	Residents in municipalities were assigned a petrochemical and non-petrochemical air pollution exposure index (which gives the proportion of the total population employed in the petrochemical industry).	NS	1991–1994	For the highest petrochemical air pollution exposure index, the odds ratio (OR) = 1.66 (95% CI: 1.05–2.61).
Yang et al. (2000) Taiwan, China	Ecological study Mortality: women	Residence in municipalities near the oldest Taiwanese refinery	1946	1971–1996	Increasing trend in SMR from 1976 to 1993 In 1993, 37 years after the start of plant operation, SMR = 144.6.
Belli et al. (2004) Italy	Case-control study Mortality	Varies with distance between petrochemical plant centroid and main residence	NS	1996–1997	Less than or equal to 2 km, OR = 3.1 (95% CI: 0.83–12.00).
Simonsen et al. (2010) Louisiana, United States	Case-control study Incidence	Residence close to current and closed industries, including petrochemical sites	NS	1998–2001	Residence within a buffer less than 0.8 km of any petrochemical site showed an adjusted lung cancer OR = 1.45 (CI: 0.61–3.48). No unambiguous results for different distances

NS: not specified.

Non-Hodgkin's lymphoma was considered in two case-control studies (Linos et al., 1991; Johnson et al., 2003) and one small-area study (Sans et al., 1995); the prevalence of Hodgkin's disease was studied by Dahlgren, Klein & Takhar (2008), and one small-area study (Sans et al., 1995) and two case-control investigations (Speer et al., 2002; Gazdek et al., 2007) looked at multiple myeloma. These studies are described in Table 9, and each one of them measured an increased risk.

The association of bladder cancer with residence near petrochemical plants was analysed in three studies (Table 10). The less recent study was based on a small-area approach and reported negative results (Kaldor et al., 1984); two case-control investigations reported positive associations, with some uncertainties in the risk estimate (Belli et al., 2004; Tsai et al., 2009).

Table 11 contains three studies that examined the relationship between exposure to pollutants from petrochemical plants and perinatal conditions. Of these three studies, one is a case-control study

(Oliveira et al., 2002) and one is a small-area study (Yang et al., 2004). The first study reported a positive, but imprecise association between low birth weight and residence within 10 km of a petrochemical plant; the second found a positive association with preterm delivery and living within 3 km of a refinery.

Information on confounding factors is not described in the tables. In most cases: small-area and ecological investigations were adjusted for socioeconomic factors; case-control studies accounted for confounders specific to the outcome of the study; and studies of respiratory diseases were adjusted for the set of confounders ascertained (such as education, smoking and dampness in the home).

Table 7. Epidemiological studies of residence near petrochemical plants: respiratory diseases

Reference and location	Study design and population	Exposure	Start of plant operation	Study period	Results
Children					
Ware et al. (1993) West Virginia, United States	Cross-sectional study of 7590 children in 74 elementary schools	Schools near petroleum industry were characterized by location as: (a) in valley near and far, out of valley near and far (b) petroleum related compound indicator (sum of five petroleum-related compounds).	NS	1988	Physician's diagnosis of respiratory symptoms Incidence of: Asthma (%): In valley near (10.4) , far (11.2) Out of valley near (9.5), far (8.5) Trend test: $P = 0.01$ Persistent wheezing (%): In valley near (14.1), far (15.1) Out of valley near (12.2), far (12.7) Trend test $P = 0.04$ Change in process-related compounds were associated with bronchitis: OR = 1.05 (95% CI: 1.02–1.08)
Yang et al. (1998) Taiwan, China	Cross-sectional study of 470 children in an exposed area and 611 children in a control area	Residence in 19 counties near the major petrochemical manufacturing industry Control area: unpolluted rural county	Basic petrochemical industry started in 1968	1994–1995	Asthma: OR = 2.76 (95% CI: 1.19–6.39) Upper respiratory symptoms: OR = 1.51 (95% CI: 1.10–2.08)
Chen et al. (1998) Taiwan, China	Cross-sectional study of 4697 primary school children	Residence in three petrochemical industrial and two urban areas Control area: rural	NS	1994	Nasal symptoms: Area 1: OR = 1.17 (95% CI: 0.88–1.54) Area 2: OR = 1.59 (95% CI: 1.21–2.09) Area 3: OR = 1.59 (95% CI: 1.19–2.14)
Wichmann et al. (2009) La Plata, Argentina	Cross-sectional study of 1183 children (6–12 years of age)	Residence: (a) close to the petrochemical plant (b) in a heavy traffic region (c) in two relatively unpolluted regions: semi-rural and residential	NS	2005–2006	Asthma: OR = 2.76 (95% CI: 1.96–3.89) Asthma exacerbation: OR = 1.88 (95% CI: 1.25–2.83) Wheezing: OR = 1.93 (95% CI: 1.39–2.67)

Table 7 (concluded)

Reference and location	Study design and population	Exposure	Start of plant operation	Study period	Results
Liao et al. (2009) Taiwan, China	Cross-sectional study of: 7040 children in 2002 4622 children in 2007	Residence in four areas: (a) TaiHao polluted by a petrochemical plant (b) close to a waste incinerator (c) coastal area (d) rest of the country	NS	2002 and 2007	TaiHao area has increased prevalence of: Wheezing (3.7%, P < 0.05) Nocturnal dry cough (3.6%, *P* < 0.05)
Smargiassi et al. (2009) Canada	Time stratified case-crossover study of children (2–4 years of age): 1579 emergency department visits 263 hospitalization records	Residence within 0.5–7.5 km of a refinery stack	NS	1996–2004	Asthma, emergency department visit: OR = 1.10 (95% CI: 1.00–1.22) Asthma hospitalization: OR = 1.42 (95% CI: 1.10–1.82) Increment of sulfur dioxide interquartile range Visits more pronounced for same day (lag 0) peak sulfur dioxide levels
White et al. (2009) Cape Town, South Africa	Cross-sectional study of 2361 children (11–14 years of age)	(a) Distance from the midpoint of the refinery (b) Meteorologically estimated exposure to refinery emissions	NS	February–August 2002	Asthma symptoms associated with distance from the refinery: ever wheeze at rest: OR = 1.06 (95% CI: 0.97–1.16) Asthma symptoms associated with meteorologically estimated exposure: ever wheeze at rest: OR 1.81 (95% CI: 1.18–2.79)
de Moraes et al. (2010) Rio Grande do Norte, Brazil	Cross-sectional study of 209 children and adolescents (0–14 years of age)	Lived for at least a year within a 5 km radius of Guamarè Petrochemical Complex	NS	2006	Living in an exposed community (downwind of the petrochemical complex) Wheezing in last 12 months due to living in exposed community: OR = 2.01 (95% CI: 1.01–4.01)
Adults					
Yang et al. (1997) Taiwan, China	Cross-sectional study of 436 subjects (30–64 years of age) in an exposed area and 488 subjects in a control area	Residence in communities in close proximity to the major petrochemical industries	1968	1996	Phlegm: OR = 2.01 (95% CI: 1.19–3.42) Wheezing: OR = 1.65 (95% CI: 0.88–3.10) Acute irritative symptoms: Eyes: OR = 2.16 (95% CI: 1.43–3.25) Throat: OR = 1.52 (95% CI: 1.05–2.20)

NS: not specified

Table 8. Epidemiological studies of residence near petrochemical plants: leukaemia

Reference and location	Study design and population	Exposure	Start of plant operation	Study period	Results
Children					
Knox & Gilman (1997) United Kingdom	Ecological study Mortality	Residence at birth and death by distance index points, including refineries	NS	1953–1980	Proximity to oil refineries SDR (standardized density ratio) = 1.27, *P* <0.001
Lyons et al. (1995) South Wales, United Kingdom	Ecological study Incidence	Residence around the chemical site: two circles (less than 1.5 km and 1.5–3.0 km)	1963 petrochemical plant, with similar industrial process since 1950s and expansion in 1972	1974–1986 1987–1991	"None of the comparisons showed a significant excess of leukaemias or lymphomas for any period of years"
Weng et al. (2008) Taiwan, China	Case-control study Child (0–19 years of age) Mortality	Residence in municipalities was assigned a petrochemical and a non-petrochemical air pollution exposure index, which corresponds to the number of employees in the petrochemical industry per total population.	NS	1995–2005	Petrochemical air pollution exposure index less than or equal to 0.01: OR = 1 Petrochemical air pollution exposure index 0.02–0.12: OR = 1.35 (95% CI: 0.97–1.87) Petrochemical air pollution exposure index 0.13–8.95: OR = 1.90 (95% CI: 1.26–2.87)
Adults					
Kaldor et al. (1984) California, United States	Ecological study Incidence	Residence in areas classified in four groups on modelling exposure to sulfur dioxide, hydrocarbons, and nitrogen oxides. Group 1: no industrial exposure Groups 2 and 3: industrial exposure different from that of the petrochemical industry Group 4: exposure to petrochemical industry emissions	NS	1969–1977	Rates per 100 000 population in the four groups of areas Increasing trend in rates for males in areas with high levels of exposure (*P* = 0.09), but not for females
Linos et al. (1991) Iowa and Minnesota, United States	Case-control study Incidence	Residence within 3.2 km and 0.8 km of a factory emitting fumes	NS	1980–1983	The risk of developing leukaemia was greater among people who resided near chemical and petroleum plants: OR = 2.0 (95% CI: 1.0–4.2).
Shore et al. (1993) Denmark, Canada and United States	Case-control study Incidence 610 cases 618 population controls	Residence within 8 km of a factory or industry	NS	January 1986–June 1990	Residential proximity to petroleum refining was associated with: Acute myeloid leukaemia: OR = 0.6 (95% CI: 0.1–3.9) Acute lymphatic leukaemia: OR 2.3 (95% CI: 0.2–14.3).

Table 8 (concluded)

Reference and location	Study design and population	Exposure	Start of plant operation	Study period	Results
Pekkanen et al. (1995) Finland	Ecological study Incidence	Residence near an oil refinery included in a petrochemical complex	NS	1983–1986	No significant association between distance from oil refinery and leukaemia or any cancer
Sans et al. (1995) South Wales, United Kingdom	Small-area study Mortality	Residence within 7.5 km of a petrochemical plant	1963	1981–1991	Within 0–3 km of a petrochemical plant, SMR =0.85 (95% CI: 0.41–1.57).
Speer et al. (2002) California, United States	Case-control and GIS analysis of incidence 604 cases of acute myeloid leukaemia 643 cases of multiple myeloma 7122 colon cancer controls	Residence in a census tract with a petroleum refinery waste dump [a]	NS	1984–1993	GIS analysis: no obvious geographic clustering
Yu et al. (2006) Taiwan, China	Case-control study of Incidence 0–29 years of age 171 cases and 410 controls	Residential petrochemical exposure assigned using GIS tools	NS	Nov. 1997–June 2003	For one unit increase in the log-transformed exposure opportunity score, the adjusted OR = 1.54 (95% CI: 1.14–2.09)
Gazdek et al. (2007) Croatia	Geographical study Incidence 16 cases	Residence in industrial areas near Djurdjevac and residence in areas free of oil–gas fields	1980: start of oil–gas exploitation	1971–1980 1981–2000	In Djurdjevac, where oil–gas fields are present, for chronic myeloid leukaemia the rate ratio = 3.5 (95% CI: 1.32–10.08) (European population used as reference)
Barregard, Holmberg & Sallsten (2009) Sweden	Ecological study Incidence	Residence: (a) in two parishes potentially exposed to volatile organic compounds from a refinery (b) in five parishes unaffected by refinery's emissions	1975	1975–1984 1985–1994 1995–2004	Incidence of leukaemia in the exposed parishes: 1975–1984: the standardized incidence ratio (SIR) = 1.57 (95% CI: 0.78–2.81) 1985–1994: SIR = 0.44 (95% CI: 0.08–1.29) 1995–2004: SIR 2.24 (95% CI: 1.35–3.49) 1975–2004: SIR = 1.47 (95% CI: 1.01–2.07)

NS: not specified
[a] Census tracts are small, relatively permanent statistical subdivisions of a county.

Table 9. Epidemiological studies of residence near petrochemical plants: non-Hodgkin's lymphoma, Hodgkin's disease and multiple myeloma

Reference and location	Study design and population	Exposure	Start of plant operation	Study period	Results
Non-Hodgkin's lymphoma					
Linos et al. (1991) Iowa and Minnesota, United States	Case-control study Incidence 622 cases 1130 population controls	Residence within 3.2 km and 0.8 km of a factory emitting fumes	NS	1980–1983	Residence near petroleum refining: OR = 1.5 (95% CI: 0.7–3.2)
Sans et al. (1995) South Wales, United Kingdom	Small-area study Mortality, including a general population sample of 115 721 people	Residence within 7.5 km of a petrochemical plant	1963	1981–1991	Within 0–3 km of a petrochemical plant, SMR = 1.07 (95% CI: 0.61–1.87)
Johnson et al. (2003) Canada	Case-control study Incidence 1499 cases 5039 population controls	Residence within 3.2 km and 0.8 km of an industrial source for more than 3 decades	NS	April 1994–December 1996	Years lived within 3.2 km of a petroleum refinery: Less than or equal to 10 years: OR = 1.00 (95% CI: 0.76–1.32) Between 10 years and less than 20 years: OR = 1.29 (95% CI: 0.89–1.87) Greater than or equal to 20 years: OR = 1.17 (95% CI: 0.76–1.80)
Hodgkin's disease					
Dahlgren, Klein & Takhar (2008) Missouri, United States	Prevalence study	Residence within 1.6 km of a non-operational refinery	1900, closing in early 1980s	Current prevalence	Residence within 1.6 km: 155.46 cases per 100 000 population United States population: 22 cases per 100 000 population
Multiple myeloma					
Sans et al. (1995) South Wales, United Kingdom	Small-area study Mortality	Residence within 7.5 km of a petrochemical plant	1963	1981–1991	Within 0–3 km of a petrochemical plant: SMR = 2.15 (95% CI: 1.25–3.67)
Speer et al. (2002) California, United States	Case-control and GIS analysis of incidence of multiple myeloma 643 cases 7122 colon cancer controls	Residence in a census tract with petroleum refinery waste dump	NS	1984–1993	Risk of 1.6 cases per 1.60 km per 10 years residence near the large chemical dump
Gazdek et al. (2007) Croatia	Geographical study Incidence 34 cases	Residence near (Djurdjevac region) and free of oil–gas fields	1980: start of oil–gas exploitation	1971–1980 1981–2000	In Djurdjevac, where oil gas fields are present, for multiple myeloma: rate ratio = 1.7 (95% CI: 0.91–3.20) (European population used as reference)

NS: not specified

Table 10. Epidemiological studies of residence near petrochemical plants: bladder cancer

Reference and Location	Study design and population	Exposure	Start of plant operation	Study period	Results
Kaldor et al. (1984) California, United States	Small-area study Incidence	Residence in areas were classified in four groups for modelling exposure to sulfur dioxide, hydrocarbons, and nitrogen oxides, to distinguish petrochemical exposures from other environmental exposures	NS	1969–1977	Rates per 100 000 population in the four groups of areas did not show a significant trend in males and females
Belli et al. (2004) Italy	Case-control study Mortality	Varies with distance between petrochemical plant centroid and main residence	NS	1996–1997	Less than or equal to 2 km: OR = 3.90 (95% CI: 0.33–47.00)
Tsai et al. (2009) Taiwan, China	Case-control study Mortality	Residence in municipalities assigned a petrochemical and non-petrochemical air pollution exposure index	NS	1995–2005	Petrochemical air pollution exposure index less than or equal to 0.01: OR=1 Petrochemical air pollution exposure index 0.02–0.12 : OR = 1.48 (95% CI: 1.10–1.99) Petrochemical air pollution exposure index 0.13–8.95 : OR = 1.68 (95% CI: 1.22–2.31)

NS = not specified

Table 11. Epidemiological studies of residence near petrochemical plants: perinatal conditions

Reference and location	Study design and population	Exposure	Start of plant operation	Study period	Results
Oliveira et al. (2002) Municipality of Montenegro, Brazil	Case-control study 17 113 births	Residence of mother at birth: distance from the petrochemical plant categorized in three regions: (a) Region 1: within 10 km (b) Region 2: 10–20 km (c) Region 3: reference – beyond 30 km	1982	1983–1998	Low birth weight in Region 1: Unadjusted OR = 1.66 (95% CI: 1.01–2.12) Adjusted OR = 1.50 (95% CI: 0.90–2.50) No association with stillbirths and malformations
Yang et al. (2004) Taiwan, China	Small-area study 1 243 065 singleton births	Residence within 3-km-radius circles of three refineries 51 boroughs (smallest administrative district in Taiwan, China)	Three refineries: 1946, 1969, 1976	1994–1997	Increased risk of preterm delivery for residence near oil refinery: OR = 1.14 (95% CI: 1.01–1.28)

Comments and concluding remarks

The present review of the epidemiological literature on the adverse effects on health due to residence in the neighbourhood of petrochemical plants shows consistent evidence of an association with respiratory system diseases, including lung cancer. For leukaemia, an association is suggested. For non-Hodgkin's lymphoma, Hodgkin's disease, multiple myeloma, bladder neoplasms, and perinatal conditions, associations with problematic interpretations are reported.

The study characteristics warrant some comments. The study design (of small-area and/or ecological, case-control and cross-sectional studies) and the measures of disease frequency (mortality, incidence, prevalence) adopted in the articles reviewed can be considered appropriate for the respective cause(s) being studied. This is particularly true of respiratory symptoms, which are the topic of a number of cross-sectional prevalence studies that account for confounding factors. Lung cancer is investigated both in small-area and/or ecological and case-control mortality studies that adjust for socioeconomic factors and smoking. It should be noted that small-area and/or ecological, and case-control studies of lymphohaematopoietic malignancies are appropriate because, in most cases, they track incidence, which is a proper measure of diseases with high survival rates. These studies also account for relevant confounding factors.

As already noted, the starting year of petrochemical plants and the duration of exposure are essential for appraising risks to health, especially for chronic diseases characterized by long latency periods. Unfortunately, most articles do not report these data.

Uncertain assessment of exposure is the main limitation in the studies reviewed, because they have scarce or no data on specific exposures and no evaluation of exposure patterns over time. In most of the surveys based on individual-level data, exposure is estimated on the assumption that residence closer to potential sources of exposure entails a higher health risk. The choice of distance for cut-off points for different exposure levels, however, is rarely substantiated, and residential history is not generally reconstructed.

In epidemiology, a distinction has traditionally been made between group level (ecological) and individual level studies, the former considered to be an exploratory means of generating preliminarily test hypotheses. Several epidemiologists call for renewed emphasis on understanding differences in health status between populations, thus re-establishing a public health perspective. Some suggested improvements in the methodology of ecological studies (Morgenstern, 1998), including mixed design (Wakefield, 2008), could make investigations more suitable for testing hypotheses. Future ecological studies on the adverse effects on health of residence near petrochemical plants could benefit from such improvements in methodology.

A final remark is needed about the great (not fully exploited) potential of studies of health risks of residence near petrochemical plants in countries with a long-standing tradition in epidemiology (such as those in Europe and North America). In 2008, the United States and Italy, ranked, respectively, 1 and 15 among top world oil consumers (EIA, 2010). In 2010, the total number of oil refineries in the world was more than 650: about 140 in the United States and 200 in Europe (True & Koottungal, 2009). Additional epidemiological studies could clarify and disentangle the complexity of factors at play in the health of populations living in the neighbourhood of petrochemical plants.

4. GENERAL GUIDANCE ON INTERPRETING VITAL STATISTICS IN POLLUTED AREAS

Benedetto Terracini and Roberta Pirastu

Introduction

Interpreting vital statistics in polluted areas requires the proper tools. Among the tools in use are ecological studies – that is, studies in which the units being investigated are not individuals, but are groups of people (Last, 2007). Such studies analyse mortality and hospital discharge record statistics on residents in areas polluted by contaminants originating from industrial and/or waste treatment and disposal activities. In industrialized European countries, a handful of vital statistics may be useful for these studies. Among these statistics are those on mortality, which have been widely available for a long time and can be broken down by territorial units, such as municipality and, where available, sub-municipal partitions, such as administrative divisions, neighbourhoods or census tracts. In the EU pathology registries (such as cancer registries and registries of congenital malformations) are operating, but, for example, in Italy, France, Spain and other countries, they do not cover the whole national population.

For several years in most European countries, statistics on hospital discharge records by disease have been developed for administrative needs. These records have also been used for epidemiological studies, although the quality of diagnoses is variable between countries and within the same country.

The gaps in the tools available need to be filled. For the time being, the use of other routine statistics, such as those on drug prescriptions, is at the experimental stage.

Ecological studies in environmental epidemiology

In polluted areas, the main purpose of ecological studies is to assess whether the health of residents has been adversely affected by environmental contamination. Each contamination event has a history of its own that involves the following factors:

- the time of occurrence and duration of the event(s) leading to contamination;
- the length of the interval(s) between the event(s) and the perceived need for epidemiological knowledge;
- the availability of environmental measures;
- the toxic properties of the contaminating agents identified and their interactions; and
- the workability of a retrospective reconstruction of the sequence of environmental and social changes.

In principle, an approach to health statistics based on a hypothesis that aims at causal inference is preferable to an approach based on simple descriptive studies. Also, the specificity and robustness of the hypothesis depend on the details provided for the above-mentioned factors.

Contamination occurs under a wide range of conditions. One extreme is represented by a sudden event in a limited geographical area, leading to a point source emission of a limited number of identifiable contaminants with (at least partially) known toxicological properties. Such events as the explosion in Bhopal in 1984 belong to this category (Satyanand, 2008). On the basis of previous knowledge, the nature and incidence of the effects can, to an extent, be predicted; and in such instances, vital statistics can be used prospectively through an adequate analytical design based on sound hypotheses, including an estimate of the statistical power of the analysis.

A set of more common conditions is that in which the environment has been progressively (and perhaps covertly) contaminated by a heterogeneous mixture of pollutants that originate in industrial activities (often a variety of them) or waste treatment and/or disposal activities. In this case, contamination has permeated several environmental matrices over a period of years, leading to multiple sources of exposure to a variety of external agents. For such events, awareness of the status of the environment takes place late, at a time when the adverse effects on health of the contamination, if any, have already begun and the retrospective timing of the contamination may be difficult or impossible to discover. In general, the hypotheses about the possible long-term effects on health that can be formulated are vague, as is the planning of a sound approach to health statistics. Also, quantifying the exposure of residents to hazards can only be made through the use of proxies. This may come to light in different ways. For example, epidemiological investigations may be prompted by the results of environmental analyses and/or by the detection of an excess occurrence of disease; in some instances, the populations' or physicians' perception of the existence of a risk – on occasion simply a persistent unpleasant smell – can instigate an investigation.

The three Sicilian areas that are the focus of the present book are examples of the latter condition. Environmental exposures can be described only in very broad terms: it is known that a number of polluting industrial facilities and activities have been operating in each of the three high-risk areas – petrochemical and chemical plants, refineries, waste dumps, shipyards and harbour activities. Given these conditions, the hypotheses for which health statistics would be approached are crude and obscure.

Pollution of the general environment by agents specifically linked to certain diseases represents another situation, one in which vital statistics can be approached rapidly and confidently with a robust hypothesis. This is the case, for instance, in the occurrence of mesotheliomas in populations living in the vicinity of asbestos plants (Hansen et al., 1993) or of soft tissue sarcomas around industrial plants and incinerators that contaminate the general environment with dioxins (Zambon et al., 2007). The asbestos-cement plants in Milazzo (Fazzo et al., 2010a) and Syracuse are examples of specific associations between exposure and disease. They may have contaminated the surrounding areas, contributing to an increased risk of mesothelioma – possibly not yet apparent, because of the long latency of the disease.

Limitations of vital statistics

Vital statistics have their limitations. Each one is able to provide information only on the events it is designed to record. Most ecological studies in polluted areas are based on files of deaths, hospital discharge records and/or registration of specific pathologies (such as cancer and congenital malformations) – that is, they concentrate on severe conditions. Systematic surveys of the occurrence of non-lethal conditions that do not require hospital admission are far less common. Occasionally, studies based on the records of emergency departments have led to important new knowledge: the best known episode of this is that of the outbreak in Barcelona of severe asthma, caused by atmospheric dispersion of soybean dust (Antó, 1989). As yet, however, most countries do not systematically collect and register visits to emergency departments. Therefore, in contaminated areas, population data on the occurrence of so-called minor (but potentially harmful) medical conditions are not easily available from vital statistics. Such data can be obtained through specific surveys, where physicians are contacted, or through surveys on risk perception among the general public.

Another limitation of health statistics is the size of the population for which data are available. As mentioned above, in many countries vital statistics can be broken down by municipality for the whole country and at smaller administrative levels in only some areas. Since the administrative boundaries of municipalities seldom correspond to the distribution of environmental pollutants, misclassification of exposure (and loss of statistical power) is common. Also, the area and population size of municipalities vary widely. Therefore, for reasons other than environmental contamination, the territorial units used for making comparisons in ecological studies may be very different. For example, of 44 sites in Italy included in the mortality study of residents in polluted sites – the SENTIERI Project (Pirastu et al., 2010) – population size ranged between 79 and 316 532 residents, the latter being a regional capital.

Mortality statistics and statistics on hospital discharge records have used succeeding versions of the International Classification of Diseases (ICD). The ICD provides some guarantee of the homogeneity and comparability of results obtained in different places. However, particularly for cancer (but not exclusively), the resolution power of the ICD is far lower than that of classifications based on pathological diagnoses, such as succeeding versions of the ICD for Oncology. Also, some associations between environmental agents and cancer are limited to specific pathological variants of the disease (such as wood dust and adenocarcinoma of the nose and nasal sinuses). The problem is solved for populations served by cancer registries where the histological type of cancer is systematically recorded. Under other circumstances, the mere analysis of vital statistics based on the distribution of cancer sites can be misleading. Moreover, health statistics alone may not be sufficient and may need to be supplemented with additional procedures, such as the assessment of the *best pathological evidence* (Comba et al., 2003).

In the majority of countries, overall death rates are unlikely to be biased, because reporting deaths is thorough. Therefore, results of analyses of overall mortality, which is an important indicator of living conditions, can be analysed with confidence. On the contrary, the reliability of analyses based on the cause of death (or hospital diagnosis) may require a preliminary assessment of the data quality. In Italy, mortality data are available for the whole country, and the validity of the cause of death certification has been documented for specific diseases – also at the regional level (Barchielli, De Angelis & Frova, 1996; Bruno et al., 1996; Conti et al., 2005). The effects of *bridge coding* ICD-9 to ICD-10 on mortality statistics have also been studied (Brocco et al., 2010). Moreover, databases reporting initial, intermediate and final cause of death – together with national mortality databases – have recently been explored for the correct identification of rare diseases (Ascoli et al., 2009).

As mentioned earlier in this chapter, the main use of hospital discharge records is administrative, and their validity, when employed in ecological studies, has not been systematically evaluated. Reports on the health status of residents at high risk of environmental contamination in areas of Sardinia (Biggeri et al., 2006) and Sicily (Cernigliaro et al., 2008) comment on the critical aspects of this novel utilization of hospital discharge records to highlight epidemiological patterns and issues needing further investigation.

Interpreting vital statistics and inferences on causality

The routine production of good quality mortality data and other health statistics on residents in polluted areas is essential, but such data production is not driven by hypothesis. On the contrary, the attention given to analysing and interpreting statistics (and occasionally reporting them to the media) reflects the investigators' expectations and beliefs and their ability to express hypotheses. Instead, hypotheses should be formulated from knowledge of the nature of contaminants and their hazardous properties. Given the low specificity of analyses based on multiple comparisons, a distinction should be made between associations that are consistent with expectations and unexpected associations. This does not mean that the latter associations are necessarily chance findings, but they affect the implementation of public health measures to a lesser extent than do the former. The relevance of unexpected associations to local conditions depends on whether or not similar findings have been reported in studies of environmental epidemiology on conditions of contamination similar to the one being investigated.

Although each contaminated area has its own characteristics, an effort should be made to identify conditions similar to those under investigation. In this respect, the key point is the trade-off between internal validity, guaranteed by a methodologically sound design, and external validity, which safeguards generalizability of study results. An effort in this direction was made for epidemiological studies on residents of areas adjacent to petrochemical plants (see Chapter 3).

On the other hand, *statistical significance* should not be considered too rigidly. For example, in an area where the asbestos industry was active in the past, one death from pleural cancer in a member of the general population (versus, suppose, 0.01 expected) corresponds to a two-sided *P* value of 0.05, which should not be dismissed as an irrelevant finding. In the choice of CIs, on the basis of the possible agents that had been polluting a local area, a distinction should be made between *expected* and *unexpected* findings.

Thus, when considering indicators of risk excesses for specific conditions, we propose the following distinctions be made.

- For excesses that reflect associations that correspond to a priori hypotheses, the association may be so specific – for example, between asbestos and pleural cancer – that statistical significance may not be required. These circumstances leave no doubt about the need to implement remediation procedures.
- For excesses not foreseen in the a priori hypothesis that nevertheless a posteriori are found to be consistent with findings reported in the published literature, the weight of these observations should be assessed by considering their consistency with previous findings and the strength of the association, as well as its biological plausibility, without discharging the possibility of publication bias.
- For other excesses that do not find a parallel situation in the published literature and cannot be explained on the basis of current knowledge of mechanisms of action of environmental agents, these findings should be recorded (and reported to the scientific community), but their relevance to local conditions is debatable. These results should also be conveyed to the public, accompanied by comments on their limitations – in terms of causality of the association and its resulting actions.

Usually, in addition to excesses of cases of given diseases, health statistics also indicate a number of deficits of other diseases. These, of course, should not be interpreted as indicators of a *protective* effect of the environmental contamination. However, the overall consideration of deficits of other diseases may help in assessing the reliability of the causes of death recorded through death certificates in a given area.

Estimates of mortality from all causes are of the utmost importance. Given that the occurrence of death is reported thoroughly, these data are unlikely to be biased. They are strongly influenced by factors that, strictly speaking, do not pertain to the conventional idea of *environment*, such as poverty and urbanization. Nevertheless, they provide an excellent indicator of the social degradation of the population being investigated, which is a driving force of environmental degradation. Also, as a first step towards understanding the causes of excess total mortality, the estimates of its association with the environment can be adjusted for the role of poverty. The adjustment for this factor can be made through the use of several indices of deprivation that have been reported in the literature since the mid-1990s (Carstairs, 1995; Pasetto, Sampaolo & Pirastu, 2010).

The importance of excess mortality from all cancers combined is problematic. Traditionally, the prevailing idea has been that each environmental carcinogen acts on a limited number of target organs through a specific biological mechanism. Recently, the idea has been challenged by the role of epigenetic mechanisms – that is, mechanisms other than changes in the underlying DNA sequence – in environmental carcinogenesis (Counts & Goodman, 1995). Such mechanisms might be implemented by agents that are not conventionally considered to be carcinogenic, such as endocrine disruptors (Crews & McLachlan, 2006). As for the interpretation of results of analyses of vital statistics, excesses of all cancers considered together should not be dismissed, but the contribution made by excesses for specific cancer sites requires attention.

Disease excesses among residents in polluted areas are measured by comparing them with local (such as regional) rates or with disease rates of residents in surrounding noncontaminated areas. The identification of an adequate comparison population is problematic, because death rates are also influenced by other factors, such as urbanization, diet, culture and smoking habits. These other factors may be difficult to define, quantify and keep under control as possible confounders in ecological studies. For the study carried out in Sicily, two populations were selected: (a) residents in administrative units adjacent to those under investigation; and (b) the regional population. The rule of thumb recommended is to assess the consistency between estimates obtained from the set of comparisons.

Gender-, age- and time-specific comparisons may add confidence to making inferences. Disease excesses limited to men usually point to occupational exposure. Mortality by age class can also be informative. For example, in a Sardinian mining area, the SMR for pneumoconiosis (a disease of the lungs caused by inhalation of dust and characterized by inflammation, coughing and fibrosis) was 838 and 427, respectively, among men up to 59 years of age and men 60 years of age and older; this observation points to the increased risk that persists among younger people also, even after mine closure.

Analyses of health statistics recorded over long periods of time can be broken down by calendar periods or by cohorts of birth. This allows associations for limited calendar periods, which may be hidden if diluted over the whole population, to be identified. Also, causal inferences are strengthened by the consistency of findings between analyses of different statistics – for example, excess hospitalizations for asthma and excess prescriptions of antiasthmatic drugs.

Finally, a major potential source of error in interpreting vital statistics is the ecological fallacy – that is, an association between variables on the aggregate level does not necessarily represent an association at the individual level. This bias occurs because vital statistics do not characterize, within and between areas, the variability in exposures to environmental contaminants and to potential confounders. A variety of forms of ecological fallacy are known to be possible (Wakefield, 2008). It is generally agreed that the only solution to the ecological inference problem, which does not require assumptions that should be ruled out, is to supplement data at the ecological level with data at the individual level.

Health statistics and policy-making

Under any given condition, scientists should be responsible for the study design, statistical analysis and inferential process. Their role also includes the overall assessment of the evidence of causality, considering their own results together with others that precede them. In polluted areas, however, the final users of analyses and interpretations of health statistics are those who decide whether the findings warrant public health action. Policy-making requires a proper balance between scientific evidence and political, social and economic considerations. Policy-makers (and other stakeholders) should request scientists to prepare detailed reports that clearly describe the nature of the data, the assumptions made and the methods used. Preferably, risks should be reported by epidemiologists, using more than one metric (absolute, relative and attributable). Also, estimates and evaluations of the evidence should be based on transparent methods, specifying the level of uncertainty and the rationale behind the choices made, such as the range of CIs and the period covered by the statistics used (Walker, Bryce & Black, 2007). Moreover, data should be made available with sufficient detail to enable the analyses to be reproduced by other experts.

Whether or not action should wait for peer review of the relevant study by independent investigators is arguable (Bianchi, 2008). In the eyes of policy-makers and the general public, a favourable peer review may strengthen the awareness of the need for action. The review process, however, should not take too much time so that decisions, if any, are delayed.

The context in which epidemiological studies are carried out is also important. *Weak* findings, rather than representing weak (or debatable) associations, may reflect limited availability or poor quality of basic information, commonly considered to be essential to obtain clear-cut results from an epidemiological study – for example, measurements of environmental exposures and adequate reference populations. Under certain circumstances, tension may appear between the scientific and action-oriented perspectives of epidemiology. In polluted areas, the main issue for public health and the inhabitants of these areas is not whether some studies show or do not show causality, but it is the need to prevent disease and promote health (Hurtig & San Sebastian, 2005).

5. EPIDEMIOLOGICAL DATA FROM HEALTH STATISTICS

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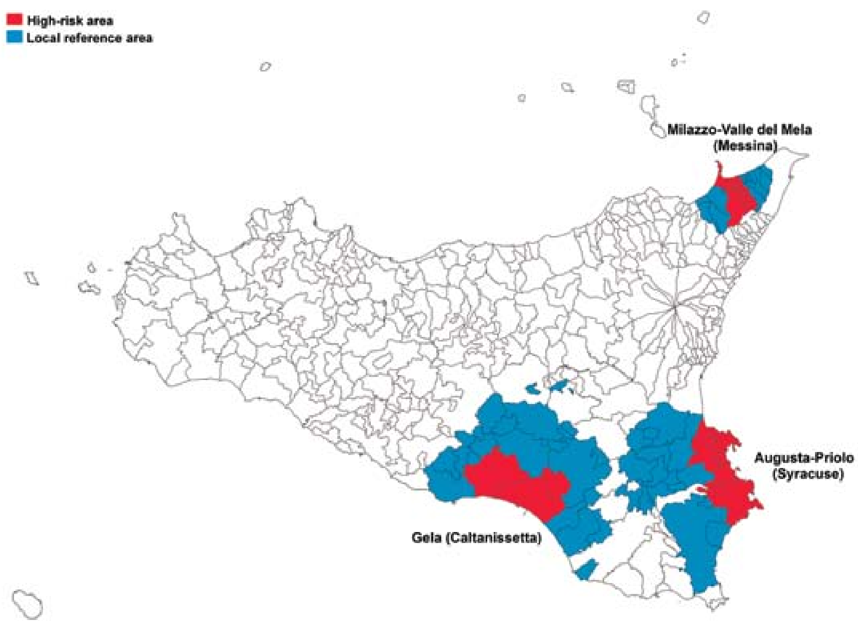
Introduction

Law No. 349 of 8 July 1986, which established the Italian Ministry of the Environment, officially recognized a number of high-risk areas across Italy (Parliament, 1986). Over the last two decades, other areas have been added to the list. The current number of high-risk areas is 53, including 4 in Sicily, of which the contamination of 1 area, Biancavilla, is of natural origin (Comba, Gianfagna & Paoletti, 2003). For the other three sites (named after the major cities in each area – that is, Augusta–Priolo, Gela and Milazzo–Valle del Mela), the inclusion in the list of areas was a consequence of the establishment of industrial activities around half a century ago (see Chapter 8). The nature of the environmental contamination in these areas is described in Chapters 6, 7 and 15 of the present book.

The present chapter deals with the health status of the population of these areas, as described by current health statistics, including the Cancer Registry of the Province of Syracuse. Additional information was retrieved from previous specific estimates of the occurrence of congenital malformations in Gela and in the Province of Syracuse. Also, mortality data for the years 1995–2002 and hospital discharge data for the years 2001–2006 were analysed in depth in a previous report (Cernigliaro et al., 2008).

The locations of the three areas in Sicily are shown in Fig. 3. The Augusta–Priolo territorial units at high risk of environmental crisis include a number of relatively small cities characterized by the presence of (or proximity to) large petrochemical facilities and smaller industries associated with petrochemical activities (Fig. 4). Industrialization in the City of Syracuse is more diversified. Thus, analyses in this area were carried out separately for the City of Syracuse and for the rest of the area.

Fig. 3. High-risk areas in Sicily



7 The chapter is the outcome of shared intellectual work. The work was possible thanks to the fundamental collaboration of other colleagues. Salvatore Scondotto and Gabriella Dardanoni of the Sicilian Epidemiological Observatory coordinated the data collection, Antonello Marras (Sicilian Epidemiological Observatory) assisted in the management of the mortality dataset. Franco Tisano and Lia Contrino of Local Health Unit No. 8 of Syracuse contributed to the elaboration of cancer data for the Province of Syracuse.

Material and methods

Mortality and hospital discharge records

In Italy, as already noted, the smallest territorial unit for which health statistics are systematically available are the municipalities. Table 12 lists the cities included in each of the three areas at high risk of environmental crisis in Sicily (hereafter referred to as "areas" in this chapter) and their population at the 2001 National Census.

Table 12. Population of the cities included in the high-risk areas

Augusta–Priolo		Gela		Milazzo–Valle del Mela	
City	Population 2001	City	Population 2001	City	Population 2001
Augusta	33 826	Butera	5 368	Condrò	523
Floridia	20 685	Gela	72 590	Gualtieri Sicaminò	2 018
Melilli	12 228	Niscemi	27 585	Milazzo	32 108
Priolo Gargallo	11 807	--	--	Pace del Mela	6 117
Syracuse	123 657	--	--	San Filippo del Mela	6 952
Solarino	7 203	--	--	San Pier Niceto	3 085
–	–	--	--	Santa Lucia del Mela	4 701
Total	**209 406**	**Total**	**105 543**	**Total**	**55 504**

Health statistics on residents in each area have been compared with two reference populations. One reference, common to all areas, was the 2001 population of the Sicily Region (regional reference). In addition, to allow for local comparisons, a *local reference area* was defined for each area, which included residents of the cities neighbouring each area: 16 cities for Augusta–Priolo and Syracuse, with a total population of 178 780; 19 cities for Gela, with a total population of 323 767; and 17 cities for Milazzo–Valle del Mela, with a total population of 96 087 (Fig. 4–6).

Mortality data for the period 1985–2002 were retrieved from the Italian National Institute of Statistics (Istat). Rates were age standardized, using the direct method on the age structure of the European population.[8] Cross-sectional analyses focused on the years 1995–2002. Only the primary cause of death was considered, coded according to ICD-9. SMRs were estimated, using each of the two control populations. Unless otherwise specified, SMRs reported in Tables 13–20 were standardized for socioeconomic status through a deprivation index calculated for each city. This index was based on the distribution of work categories, school attendance, unemployment, immigration and building conditions (Cernigliaro et al., 2008). Using this deprivation index, the estimated proportion of residents exhibiting a high or very high deprivation index was: 41% in all of Sicily; 42% in the Augusta–Priolo area (including the City of Syracuse); 95% in the Gela area; and 33% in the Milazzo–Valle del Mela area. Additional analyses were carried out on the trend in overall mortality for the 18-year period 1985–2002 and on changes in the mortality pattern by birth cohort.

8 Direct and indirect standardization are among a number techniques used to adjust age-specific rates. With the availability of these rates, the use of direct age standardization has become the predominant technique in epidemiology. Direct standardization produces an age-adjusted death rate, which is a weighted average of the age-specific rates, for each of the populations to be compared. The weights applied represent the relative age distribution of the selected external population (the standard). This allows, for each population, a single summary rate that indicates the number of events that would have been expected if the populations being compared had had identical age distributions.

Fig. 4. Augusta–Priolo high-risk area and local reference area

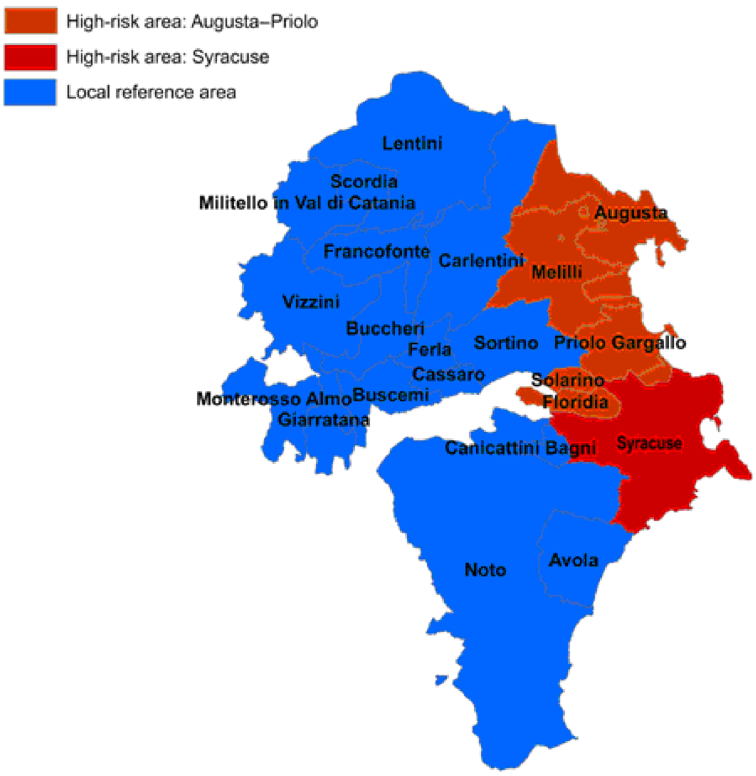


Fig. 5. Gela high-risk area and local reference area

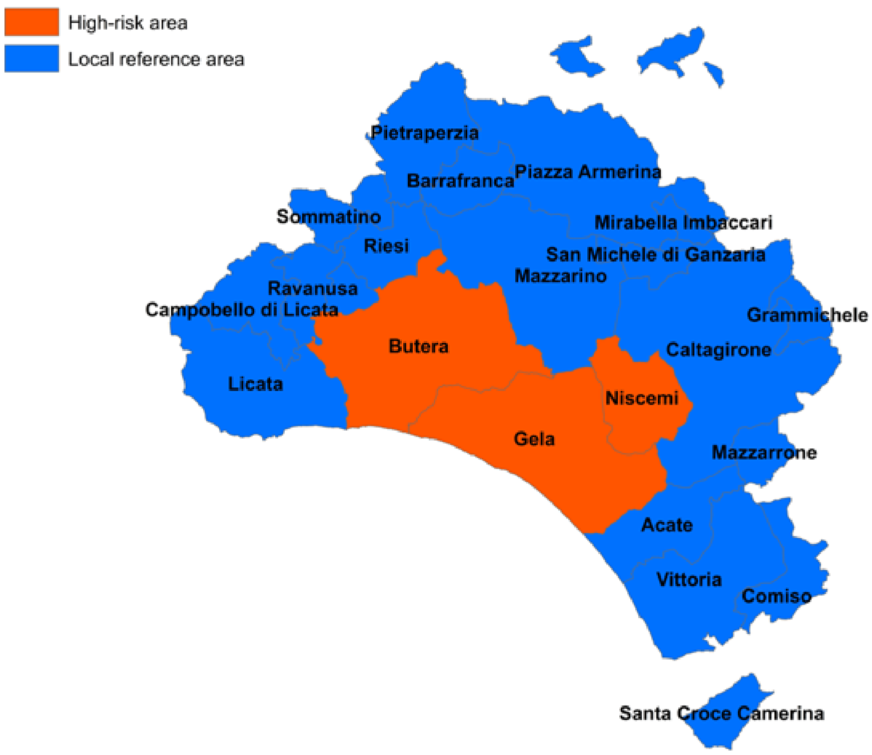
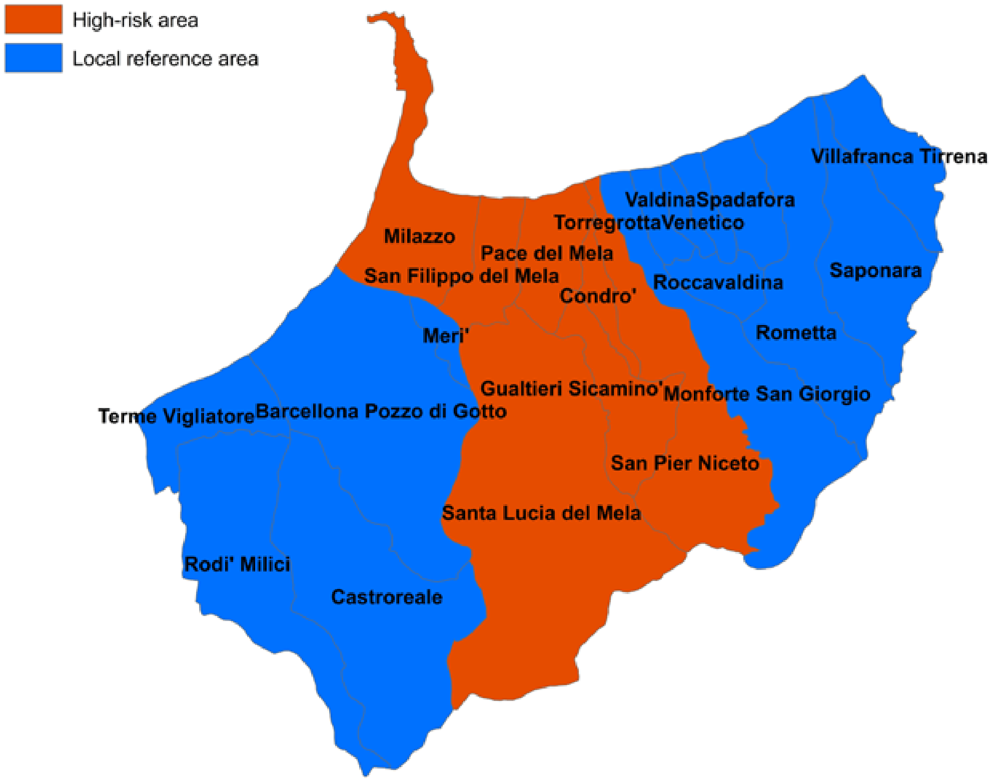


Fig. 6. Milazzo–Valle del Mela high-risk area and local reference area



Hospital discharge records for the years 2001–2006 were analysed in parallel with mortality data. This corresponded to the first period of exhaustive registration of hospital discharges, so the overall quality of registration may be imperfect, due to incomplete validation. The present chapter considers only those estimates of the hospital discharge statistics deemed to be useful for the interpretation of results of analysis of mortality statistics.

Cancer registration in the Province of Syracuse

Since 1998, the population of the Province of Syracuse (397 000 in 2001) has been served by a population-based cancer registry. The Province contains 21 cities, 6 of which (including Syracuse) are in the Augusta–Priolo area and are considered to be at high risk of environmental crisis. The cancer registry has published incidence rates for the periods 1999–2001 and 2002–2005 (Madeddu et al., 2009), with cases coded according to ICD-10. For the period 2002–2005, 84% of the cases were confirmed histologically, 1.5% of cases for males and 2.9% for females were reported only as death certificates, and the mortality-to-incidence ratio was 0.45 for males and 0.43 for females.

Surveys on congenital malformation in Gela and Syracuse

Bianchi et al. published two reports (2004, 2006). One was a retrospective survey of residents in the Province of Syracuse for the period 1991–2000. The other dealt with prevalence estimates, based on the inclusion of congenital malformations in children born to residents of Gela in a specific registration in all of Sicily during the period 1991–2002. The second report includes a retrospective survey of all birth medical records. In both reports, the criteria for inclusion of cases did not fully correspond to those used internationally. In particular, cases of termination of pregnancy due to prenatal diagnosis of congenital malformations were not included for the City of Syracuse and were only partly included for Gela. Also, the techniques intended to achieve an exhaustive collection of cases and diverse diagnostic capacities may have differed from those used in more consolidated registries. Nevertheless, for each case identified, the acceptability of including the documents available was controlled by an experienced clinical geneticist with knowledge of congenital malformations. In the Province of Syracuse, prevalence was estimated separately for the whole Province and for the cities of Augusta, Priolo and Melilli.

Table 13. Augusta–Priolo area: SMR for selected causes for males, 1995–2002

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
All causes (001–999)	2739	2870	95§ (91.9–99.1)	2702	101 (97.6–105.2)
Infectious and parasitic diseases (001–139)	15	13	116 (64.7–190.7)	13	111 (62.2–183.3)
All cancers (140–239)	746	651	115* (106.6–123.2)	728	102 (95.2–110.1)
All cancers: 0–14 years of age (140–239)	2	24	8§ (0.9–30.0)	3	66 (7.4–238.8)
Stomach (151)	35	39	89 (62.1–124.0)	47	75 (52.4–104.6)
Colon and rectum (153–154)	73	39	185* (144.9–232.5)	67	109 (85.1–136.5)
Liver and intrahepatic bile ducts (155–156)	62	78	79 (60.6–101.3)	67	92 (70.7–118.2)
Larynx (161)	12	9	132 (68.2–230.9)	15	80 (41.0–138.9)
Trachea, bronchus and lung (162)	218	180	121* (105.3–138.0)	196	112 (97.2–127.3)
Pleura (163)	19	3	556* (334.6–868.4)	5	369* (221.8–575.7)
Bone and articular cartilage, and connective and other soft tissue (170–171)	3	6	54 (10.8–156.6)	7	44 (8.9–129.6)
Melanoma of the skin (172)	5	4	123 (39.6–286.5)	6	90 (29.1–210.4)
Prostate (185)	68	52	131* (101.7–166.0)	61	111 (85.9–140.2)
Testis (186)	0	1	0§ (0.0–0.0)	1	0§ (0.0–0.0)
Bladder (188)	37	32	114 (80.6–157.7)	37	100 (70.6–138.2)
Brain and nervous system (191, 192, 225)	17	24	71 (41.4–113.7)	19	89 (51.7–142.3)
Thyroid gland (193)	0	0	0§ (0.0–0.0)	2	0§ (0.0–0.0)
Lymphatic and haematopoietic tissue (200–208)	64	43	150* (115.8–192.0)	60	106 (81.8–135.7)
Lymphosarcoma and reticulosarcoma, and other malignant neoplasms of lymphoid and histiocytic tissue (200, 202)	21	11	186* (114.9–284.0)	20	108 (66.6–164.4)
Hodgkin's disease (201)	0	6	0§ (0.0–0.0)	2	0§ (0.0–0.0)
Multiple myeloma (203)	15	5	301* (168.1–495.7)	10	155 (86.7–255.8)
Leukaemia (204–208)	28	21	135 (90.0–195.7)	29	98 (65.1–141.6)
Diabetes mellitus (250)	110	132	84 (68.7–100.7)	103	107 (87.6–128.4)
Mental disorders (290–303, 305–319)	37	24	156* (109.8–214.9)	25	145* (102.2–200.2)
Diseases of the nervous system and sense organs (320–389)	45	37	121 (88.5–162.3)	51	89 (64.9–119.0)
Diseases of the circulatory system (390–459)	1153	1266	91§ (85.9–96.5)	1124	103 (96.7–108.7)
Ischaemic heart disease (410–414)	332	373	89§ (79.7–99.1)	361	92 (82.3–102.3)
Cerebrovascular disease (430–438)	439	332	132* (120.0–145.1)	348	126* (114.6–138.5)
Diseases of the respiratory system (460–519)	187	208	90 (77.5–103.8)	216	87 (74.7–100.0)

Table 13 (concluded)

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
Acute respiratory infections, pneumonia and influenza (460–466, 480–487)	35	10	353* (245.8–490.8)	25	139 (96.8–193.4)
Chronic pulmonary diseases (416, 490–496)	125	170	74§ (61.2–87.6)	151	83§ (68.7–98.3)
Asthma (493)	0	0	0§ (0.0–0.0)	10	77 (33.3–152.4)
Pneumoconiosis and asbestosis (500–505)	3	0	0§ (0.0–0.0)	5	55 (11.1–161.5)
Diseases of the digestive system (520–579)	117	122	96 (79.2–114.7)	122	96 (79.3–114.7)
Chronic liver disease and cirrhosis (571)	71	67	105 (82.3–133.0)	72	99 (76.9–124.3)
Nephritis, nephrotic syndrome and nephrosis (580–589)	38	23	163* (115.2–223.5)	32	118 (83.7–162.3)
Symptoms, signs and ill-defined conditions (780–799)	48	43	113 (82.9–149.2)	46	104 (76.5–137.6)
Injury and poisoning (800–999)	145	239	61§ (51.2–71.4)	156	93 (78.3–109.2)

[a] Obs.: number of cases observed; Exp.: number of cases expected.
[b] * SMR > 100, $P < 0.05$; § SMR < 100; when Obs. = 0, CI is calculated to be 97.5%, one-tail test.
[c] Standardized by age and deprivation index.

Table 14. Augusta-Priolo area: SMR for selected causes for females, 1995–2002

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
All causes (001–999)	2352	2466	95§ (91.6–99.3)	2325	101 (97.1–105.4)
Infectious and parasitic diseases (001–139)	12	8	148 (76.6–259.2)	9	132 (68.0–230.1)
All cancers (140–239)	449	479	94 (85.2–102.7)	490	92 (83.3–100.4)
All cancers 0–14 years of age (140–239)	2	1	189 (21.2–680.5)	2	89 (10.0–320.9)
Stomach (151)	18	23	78 (46.2–123.4)	28	65 (38.3–102.1)
Colon and rectum (153, 154)	68	48	142* (110.5–180.4)	58	116 (90.3–147.5)
Liver and intrahepatic bile ducts (155,156)	43	49	89 (64.2–119.4)	48	89 (64.2–119.6)
Larynx (161)	3	0	863* (173.4–2521.4)	1	328 (65.8–956.9)
Trachea, bronchus and lung (162)	24	15	159* (102.0–237.0)	31	76 (48.9–113.7)
Pleura (163)	4	1	505* (135.9–1293.5)	2	170 (45.8–436.3)
Bone and articular cartilage, and connective and other soft tissue (170–171)	6	1	584* (213.3–1271.1)	5	118 (42.9–255.8)
Melanoma of the skin (172)	3	6	47 (9.4–136.7)	5	65 (13.1–190.4)

Table 14 (concluded)

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
Breast (174)	83	103	81 (64.3–100.1)	92	90 (71.7–111.6)
Gynaecological cancers (179–180, 182)	25	31	80 (51.5–117.5)	30	84 (54.5–124.3)
Ovary and other uterine adnex (183)	20	49	41§ (24.9–63.0)	20	101 (61.8–156.3)
Bladder (188)	7	4	185 (74.0–380.6)	7	105 (42.0–216.2)
Brain and nervous system (191,192, 225)	13	12	113 (59.8–192.3)	13	99 (52.8–169.8)
Thyroid gland (193)	2	2	109 (12.2–392.8)	4	56 (6.3–203.2)
Lymphatic and haematopoietic tissue (200–208)	35	34	104 (72.7–145.1)	43	81 (56.2–112.2)
Lymphosarcoma and reticulosarcoma, and other malignant neoplasms of lymphoid and histiocytic tissue (200, 202)	11	9	119 (59.5–213.7)	13	82 (41.1–147.4)
Hodgkin's disease (201)	1	1	91 (1.2–506.8)	2	65 (0.8–358.8)
Multiple myeloma (203)	10	3	343* (164.0–630.2)	8	124 (59.3–228.0)
Leukaemia (204–208)	13	20	64 (34.0–109.4)	20	64 (33.9–109.0)
Diabetes mellitus (250)	118	143	83§ (68.3–98.8)	135	87 (72.3–104.5)
Mental disorders (290–303, 305–319)	39	31	126 (89.7–172.5)	36	109 (77.2–148.5)
Diseases of the nervous system and sense organs (320–389)	55	45	123 (92.5–159.9)	51	109 (81.9–141.5)
Diseases of the circulatory system (390–459)	1168	1263	93§ (87.2–97.9)	1156	101 (95.3–107.0)
Ischaemic heart disease (410–414)	210	249	84§ (73.3–96.5)	238	88 (76.8–101.1)
Cerebrovascular disease (430–438)	512	447	115* (104.8–124.8)	430	119* (108.9–129.8)
Diseases of the respiratory system (460–519)	97	103	94 (76.3–114.8)	104	93 (75.3–113.3)
Acute respiratory infections, pneumonia and influenza (460–466, 480–487)	32	15	116* (147.8–305.0)	26	123 (84.4–174.2)
Chronic pulmonary diseases (416, 490–496)	48	58	83 (61.2–110.1)	56	85 (62.8–113.0)
Asthma (493)	7	11	62 (25.0–128.5)	6	109 (43.6–224.4)
Pneumoconiosis and asbestosis (500–505)	0	0	0§ (0.0–0.0)	0	0§ (0.0–0.0)
Diseases of the digestive system (520–579)	116	105	110 (90.9–132.0)	94	124* (102.4–148.7)
Chronic liver disease and cirrhosis (571)	74	60	123 (96.4–154.2)	49	152* (119.5–191.0)
Nephritis, nephrotic syndrome and nephrosis (580–589)	36	48	75 (52.5–103.8)	28	131 (91.6–181.1)
Symptoms, signs, and ill-defined conditions (780–799)	71	54	131* (102.1–164.9)	56	128 (99.6–160.8)
Injury and poisoning (800–999)	97	99	98 (79.5–119.6)	87	111 (89.9–135.3)

[a] Obs.: number of cases observed; Exp.: number of cases expected.
[b] * SMR > 100, $P < 0.05$; § SMR < 100; when Obs. = 0, CI is calculated to be 97.5%, one-tail test.
[c] Standardized by age and deprivation index.

Table 15. City of Syracuse: SMR for selected causes for males, 1995–2002

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
All causes (001–999)	4008	3941	102 (98.6–104.9)	3846	104* (101.0–107.5)
Infectious and parasitic diseases (001–139)	35	16	225* (156.6–312.7)	24	144* (100.5–200.7)
All cancers (140–239)	1136	1013	112* (105.7–118.8)	1016	112* (105.4–118.5)
All cancers 0–14 years of age (140–239)	3	3	117 (23.5–340.9)	2	121 (24.4–354.6)
Stomach (151)	61	64	95 (72.7–122.1)	62	99 (75.5–126.9)
Colon and rectum (153–154)	93	92	101 (81.2–123.3)	96	97 (78.2–118.7)
Liver and intrahepatic bile ducts (155–156)	86	102	84 (67.4–104.1)	89	97 (77.5–119.7)
Larynx (161)	12	16	74 (38.4–129.8)	17	69 (35.5–120.1)
Trachea, bronchus and lung (162)	337	227	149* (133.1–165.2)	272	124* (111.0–137.8)
Pleura (163)	16	3	606* (346.1–983.9)	7	246* (140.5–399.3)
Bone and articular cartilage, and connective and other soft tissue (170–171)	11	12	92 (46.0–165.2)	9	120 (59.5–213.7)
Melanoma of the skin (172)	13	5	252* (134.2–431.3)	7	185 (98.3–315.9)
Prostate (185)	86	80	107 (85.5–132.0)	87	99 (79.2–122.3)
Testis (186)	2	0	0§ (0.0–0.0)	1	170 (19.1–612.6)
Bladder (188)	56	45	126 (95.0–163.3)	51	111 (83.4–143.5)
Brain and nervous system (191–192, 225)	31	39	80 (54.4–113.7)	29	108 (73.2–153.0)
Thyroid gland (193)	5	2	219 (70.4–510.0)	2	252 (81.3–588.6)
Lymphatic and haematopoietic tissue (200–208)	90	86	105 (84.4–129.0)	85	106 (85.5–130.7)
Lymphosarcoma and reticulosarcoma, and other malignant neoplasms of lymphoid and histiocytic tissue (200, 202)	30	32	95 (63.9–135.3)	26	114 (76.6–162.1)
Hodgkin's disease (201)	2	4	47 (5.3–168.9)	3	69 (7.8–250.5)
Multiple myeloma (203)	16	13	128 (73.0–207.6)	15	104 (59.3–168.5)
Leukaemia (204–208)	42	37	113 (81.2–152.3)	40	105 (75.9–142.3)
Diabetes mellitus (250)	163	107	152* (129.3–176.8)	148	110 (94.0–128.6)
Mental disorders (290–303, 305–319)	57	44	131 (98.8–169.0)	40	142* (107.2–183.4)
Diseases of the nervous system and sense organs (320–389)	113	59	192* (158.0–230.4)	82	138* (114.0–166.4)
Diseases of the circulatory system (390–459)	1571	1623	97 (92.1–101.7)	1582	99 (94.5–104.4)
Ischaemic heart disease (410–414)	471	520	91§ (82.6–99.2)	495	95 (86.8–104.2)
Cerebrovascular disease (430–438)	425	498	85§ (77.5–93.9)	511	83§ (75.5–91.5)
Diseases of the respiratory system (460–519)	324	253	128* (114.7–143.0)	329	99 (88.1–109.8)

Table 15 (concluded)

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
Acute respiratory infections, pneumonia and influenza (460–466, 480–487)	52	20	261* (195.1–342.5)	37	142* (106.2–186.5)
Chronic pulmonary diseases (416, 490–496)	182	188	97 (83.3–112.0)	223	82§ (70.1–94.3)
Asthma (493)	0	0	0§ (0.0–0.0)	16	44§ (17.7–91.0)
Pneumoconiosis and asbestosis (500–505)	8	0	0§ (0.0–0.0)	12	68 (29.2–133.8)
Diseases of the digestive system (520–579)	185	201	92 (79.2–106.2)	174	107 (91.7–123.0)
Chronic liver disease and cirrhosis (571)	95	120	79§ (64.2–97.0)	102	93 (75.3–113.7)
Nephritis, nephrotic syndrome and nephrosis (580–589)	48	21	226* (166.5–299.4)	43	111 (81.5–146.6)
Symptoms, signs, and ill-defined conditions (780–799)	44	205	22§ (15.6–28.8)	66	67§ (48.5–89.5)
Injury and poisoning (800–999)	215	240	90 (77.9–102.3)	224	96 (83.4–109.5)

[a] Obs.: number of cases observed; Exp.: number of cases expected.
[b] * SMR > 100; *P* < 0.05; § SMR < 100; when Obs. = 0, CI is calculated to be 97.5%, one-tail test.
[c] Standardized by age and deprivation index.

Table 16. City of Syracuse: SMR for selected causes for females, 1995–2002

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
All causes (001–999)	3714	3884	96§ (92.6–98.7)	3740	99 (96.1–102.5)
Infectious and parasitic diseases (001–139)	20	28	70 (42.9–108.5)	18	110 (67.1–169.7)
All cancers (140–239)	821	748	110* (102.4–117.5)	751	109* (102.0–117.0)
All cancers 0–14 years of age (140–239)	2	0	0§ (0.0–0.0)	2	93 (10.5–337.1)
Stomach (151)	34	39	88 (61.0–123.2)	40	85 (58.8–118.7)
Colon and rectum (153–154)	103	73	141* (115.0–170.9)	92	112 (91.0–135.2)
Liver and intrahepatic bile ducts (155–156)	70	71	99 (77.0–124.8)	71	99 (77.2–125.1)
Larynx (161)	2	2	94 (10.6–341.0)	2	115 (12.9–413.8)
Trachea, bronchus and lung (162)	49	38	129 (95.1–169.9)	39	125 (92.7–165.7)
Pleura (163)	7	4	169 (67.9–349.0)	5	150 (59.9–308.0)
Bone and articular cartilage, and connective and other soft tissue (170–171)	9	7	121 (55.1–229.0)	8	112 (51.2–212.8)
Melanoma of the skin (172)	4	7	56 (15.0–143.2)	6	65 (17.4–165.3)

Table 16 (concluded)

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
Breast (174)	145	135	108 (90.9–126.8)	138	105 (88.8–123.8)
Gynaecological cancers (179–180, 182)	49	50	99 (72.9–130.4)	49	100 (73.8–131.8)
Ovary and other uterine adnex (183)	37	27	138 (97.4–190.7)	31	118 (83.3–163.2)
Bladder (188)	20	14	147 (89.8–227.1)	12	164* (100.3–253.6)
Brain and nervous system (191–192, 225)	23	21	110 (69.9–165.6)	20	116 (73.5–174.0)
Thyroid gland (193)	2	4	46 (5.2–166.9)	6	32 (3.6–114.2)
Lymphatic and haematopoietic tissue (200–208)	61	67	91 (69.5–116.7)	68	90 (69.0–115.9)
Lymphosarcoma and reticulosarcoma, and other malignant neoplasms of lymphoid and histiocytic tissue (200,202)	24	21	112 (71.6–166.4)	22	109 (69.6–161.6)
Hodgkin's disease (201)	2	0	0§ (0.0–0.0)	2	101 (11.3–364.3)
Multiple myeloma (203)	13	8	160 (85.2–273.8)	13	101 (53.8–173.1)
Leukaemia (204–208)	22	38	59§ (36.7–88.7)	31	72 (44.9–108.5)
Diabetes mellitus (250)	218	195	112 (97.4–127.7)	224	98 (85.0–111.3)
Mental disorders (290–303, 305–319)	59	80	74 (56.5–95.7)	61	97 (73.9–125.3)
Diseases of the nervous system and sense organs (320–389)	89	50	179* (143.9–220.5)	77	116 (93.2–142.8)
Diseases of the circulatory system (390–459)	1752	1755	100 (95.2–104.6)	1912	92§ (87.4–96.0)
Ischaemic heart disease (410–414)	313	332	94 (84.0–105.2)	367	85§ (76.1–95.2)
Cerebrovascular disease (430–438)	587	620	95 (87.2–102.7)	729	81§ (74.1–87.3)
Diseases of the respiratory system (460–519)	184	185	100 (85.7–115.0)	163	113 (97.4–130.7)
Acute respiratory infections, pneumonia and influenza (460–466, 480–487)	73	33	222* (173.7–278.6)	45	164* (128.2–205.7)
Chronic pulmonary diseases (416, 490–496)	63	113	56§ (42.7–71.1)	80	79 (60.8–101.2)
Asthma (493)	3	12	26§ (5.1–74.6)	10	31§ (6.2–89.8)
Pneumoconiosis and asbestosis (500–505)	0	0	0§ (0.0–0.0)	0	0§ (0.0–0.0)
Diseases of the digestive system (520–579)	184	155	119* (102.0–136.9)	151	122* (105.1–141.1)
Chronic liver disease and cirrhosis (571)	86	94	92 (73.6–113.6)	72	120 (95.9–148.0)
Nephritis, nephrotic syndrome and nephrosis (580–589)	27	39	69 (45.4–100.2)	40	67§ (43.9–97.0)
Symptoms, signs and ill-defined conditions (780–799)	79	381	21§ (16.4–25.9)	88	90 (71.4–112.4)
Injury and poisoning (800–999)	141	130	109 (91.4–128.0)	132	107 (90.2–126.4)

[a] Obs.: number of cases observed; Exp.: number of cases expected.
[b] * SMR > 100; *P* < 0.05; § SMR < 100; when Obs. = 0, CI is calculated to be 97.5%, one-tail test.
[c] Standardized by age and deprivation index.

Table 17. Gela area: SMR for selected causes for males, 1995–2002

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
All causes (001–999)	3439	3144	109* (105.8–113.1)	3370	102 (98.7–105.5)
Infectious and parasitic diseases (001–139)	20	19	106 (65.0–164.4)	19	106 (64.8–164.0)
All cancers (140–239)	911	834	109* (102.3–116.6)	948	96 (90.0–102.6)
All cancers 0–14 years of age (140–239)	4	6	66 (17.7–168.1)	5	81 (21.7–206.4)
Stomach (151)	74	55	134* (105.4–168.4)	55	134* (104.9–167.8)
Colon and rectum (153–154)	72	77	94 (73.2–117.8)	79	91 (71.0–114.3)
Liver and intrahepatic bile ducts (155–156)	78	86	91 (71.7–113.2)	94	83 (65.7–103.8)
Larynx (161)	30	17	179* (120.4–254.9)	20	149* (100.4–212.5)
Trachea, bronchus and lung (162)	262	241	109 (95.9–122.7)	270	97 (85.6–109.5)
Pleura (163)	11	4	281* (140.0–502.7)	8	139 (69.2–248.4)
Bone and articular cartilage, and connective and other soft tissue (170–171)	8	5	158 (68.1–311.8)	8	97 (41.8–191.2)
Melanoma of the skin (172)	5	2	203 (65.3–473.1)	6	81 (26.0–188.2)
Prostate (185)	57	60	94 (71.4–122.1)	72	79 (59.6–102.0)
Testis (186)	1	1	170 (2.2–947.2)	1	94 (1.2–521.7)
Bladder (188)	34	39	86 (59.7–120.4)	51	66[§] (45.8–92.4)
Brain and nervous system (191–192, 225)	28	19	147 (97.3–211.7)	23	124 (82.3–179.1)
Thyroid gland (193)	2	2	123 (13.8–444.1)	3	78 (8.8–282.2)
Lymphatic and haematopoietic tissue (200–208)	74	66	112 (87.8–140.4)	74	100 (78.4–125.3)
Lymphosarcoma and reticulosarcoma, and other malignant neoplasms of lymphoid and histiocytic tissue (200,202)	28	19	146 (96.6–210.2)	24	114 (76.0–165.4)
Hodgkin's disease (201)	1	4	23 (0.3–129.5)	4	27 (0.3–147.2)
Multiple myeloma (203)	13	13	98 (52.2–167.7)	12	108 (57.2–183.8)
Leukaemia (204–208)	32	29	109 (74.5–153.8)	34	95 (64.8–133.7)
Diabetes mellitus (250)	99	106	93 (75.9–113.6)	139	71[§] (57.7–86.4)
Mental disorders (290–303, 305–319)	43	24	178* (129.1–240.3)	31	137 (99.0–184.2)
Diseases of the nervous system and sense organs (320–389)	53	56	95 (71.4–124.8)	63	84 (63.2–110.3)
Diseases of the circulatory system (390–459)	1394	1272	110* (103.9–115.5)	1336	104 (98.9–110.0)
Ischaemic heart disease (410–414)	391	401	98 (88.2–107.8)	442	89[§] (79.9–97.7)
Cerebrovascular disease (430–438)	457	421	109 (98.9–119.1)	398	115* (104.4–125.7)
Diseases of the respiratory system (460–519)	234	307	76[§] (66.7–86.5)	262	89 (78.2–101.5)
Acute respiratory infections, pneumonia and influenza (460–466, 480–487)	22	39	57[§] (35.5–85.7)	34	65[§] (40.9–99.0)

Table 17 (concluded)

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
Chronic pulmonary diseases (416, 490–496)	164	228	72§ (61.3–83.8)	177	93 (79.0–108.0)
Asthma (493)	15	14	107 (60.0–176.8)	13	112 (62.9–185.4)
Pneumoconiosis and asbestosis (500–505)	3	5	62 (12.4–179.6)	2	134 (27.0–392.3)
Diseases of the digestive system (520–579)	190	151	126* (108.8–145.3)	168	113 (97.6–130.4)
Chronic liver disease and cirrhosis (571)	121	97	124* (103.1–148.4)	109	111 (91.9–132.4)
Nephritis, nephrotic syndrome and nephrosis (580–589)	31	34	91 (61.8–129.0)	38	81 (55.0–114.9)
Symptoms, signs and ill-defined conditions (780–799)	88	38	231* (185.4–284.9)	57	154* (123.6–189.8)
Injury and poisoning (800–999)	249	206	121* (106.5–137.1)	193	129* (113.2–145.8)

[a] Obs.: number of cases observed; Exp.: number of cases expected.
[b] * SMR > 100; *P* < 0.05; § SMR < 100; when Obs. = 0, CI is calculated to be 97.5%, one-tail test.
[c] Standardized by age and deprivation index.

Table 18. Gela area: (SMR) for selected causes for females, 1995–2002

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
All causes (001–999)	2856	2642	108* (104.2–112.1)	2635	108* (104.5–112.5)
Infectious and parasitic diseases (001–139)	15	18	84 (47.0–138.7)	13	113 (63.4–187.0)
All cancers (140–239)	595	533	112* (102.8–120.9)	598	100 (91.7–107.9)
All cancers 0–14 years of age (140–239)	2	5	37 (4.2–135.0)	4	46 (5.1–164.2)
Stomach (151)	25	38	65§ (42.0–95.9)	33	77 (49.5–113.0)
Colon and rectum (153–154)	92	54	170* (136.6–207.9)	72	128* (103.2–157.1)
Liver and intrahepatic bile ducts (155–156)	63	63	101 (77.4–128.8)	63	100 (76.6–127.6)
Larynx (161)	1	1	97 (1.3–538.0)	1	90 (1.2–499.7)
Trachea, bronchus and lung (162)	55	33	167* (125.6–217.0)	42	133 (99.8–172.4)
Pleura (163)	2	3	76 (8.5–273.1)	3	73 (8.1–261.7)
Bone and articular cartilage, and connective and other soft tissue (170–171)	8	5	166 (71.6–327.7)	6	135 (58.3–266.7)
Melanoma of the skin (172)	5	1	336* (108.2–783.5)	4	128 (41.1–297.5)
Breast (174)	98	101	98 (79.2–118.8)	111	88 (71.4–107.2)
Gynaecological cancers (179–180, 182)	40	34	117 (83.8–159.7)	35	115 (82.2–156.7)

Table 18 (concluded)

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
Ovary and other uterine adnex (183)	9	21	43§ (19.6–81.7)	22	41§ (18.6–77.4)
Bladder (188)	8	4	191 (82.4–377.0)	8	99 (42.5–194.6)
Brain and nervous system (191, 192, 225)	16	16	102 (58.5–166.2)	16	103 (58.7–166.8)
Thyroid gland (193)	1	3	33 (0.4–185.9)	4	24 (0.3–132.2)
Lymphatic and hematopoietic tissue (200–208)	44	44	100 (72.4–133.8)	53	84 (60.7–112.2)
Lymphosarcoma and reticulosarcoma, and other malignant neoplasms of lymphoid and histiocytic tissue (200,202)	11	10	115 (57.3–205.7)	17	66 (32.9–118.0)
Hodgkin's disease (201)	0	1	0§ (0.0–0.0)	2	0§ (0.0–0.0)
Multiple myeloma (203)	10	13	77 (37.1–142.4)	10	95 (45.6–175.3)
Leukaemia (204–208)	23	21	111 (70.4–166.6)	23	98 (62.0–146.9)
Diabetes mellitus (250)	182	195	94 (80.4–108.1)	168	109 (93.4–125.6)
Mental disorders (290–303, 305–319)	50	28	180* (133.9–237.9)	36	137* (101.8–180.8)
Diseases of the nervous system and sense organs (320–389)	38	56	67§ (47.6–92.4)	58	66§ (46.6–90.5)
Diseases of the circulatory system (390–459)	1399	1302	107* (101.9–113.2)	1225	114* (108.3–120.3)
Ischemic heart disease (410–414)	261	261	100 (88.2–112.8)	268	97 (85.8–109.8)
Cerebrovascular disease (430–438)	547	525	104 (95.7–113.3)	430	127* (116.7–138.3)
Diseases of the respiratory system (460–519)	110	126	87 (71.7–105.2)	125	88 (72.3–106.1)
Acute respiratory infections, pneumonia and influenza (460–466, 480–487)	22	35	62§ (39.0–94.4)	30	74 (46.5–112.5)
Chronic pulmonary diseases (416, 490–496)	49	66	74§ (54.8–97.9)	63	77 (57.2–102.2)
Asthma (493)	6	6	99 (36.1–215.1)	7	92 (33.6–200.0)
Pneumoconiosis and asbestosis (500–505)	0	0	0§ (0.0–0.0)	0	0§ (0.0–0.0)
Diseases of the digestive system (520–579)	131	124	105 (88.1–125.0)	119	110 (91.8–130.3)
Chronic liver disease and cirrhosis (571)	76	82	92 (72.7–115.5)	69	110 (86.8–137.9)
Nephritis, nephrotic syndrome and nephrosis (580–589)	26	28	92 (59.8–134.2)	31	84 (55.0–123.4)
Symptoms, signs, and ill-defined conditions (780–799)	124	40	311* (258.9–371.1)	65	190* (157.7–226.0)
Injury and poisoning (800–999)	87	93	94 (75.1–115.7)	95	92 (73.6–113.3)

[a] Obs.: number of cases observed; Exp.: number of cases expected.
[b] * SMR > 100; *P* < 0.05; § SMR < 100; when Obs. = 0, CI is calculated to be 97.5%, one-tail test.
[c] Standardized by age and deprivation index.

Table 19. Milazzo–Valle del Mela area: SMR for selected causes for males, 1995–2002

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
All causes (001–999)	2105	2028	104 (99.4–108.4)	2081	108 (96.9–105.6)
Infectious and parasitic diseases (001–139)	7	7	99 (39.6–203.6)	9	76 (30.4–156.3)
All cancers (140–239)	569	506	113* (103.5–122.2)	540	105 (96.8–114.3)
All cancers 0–14 years of age (140–239)	1	7	15[§] (0.2–82.7)	2	61 (0.8–337.6)
Stomach (151)	35	13	276* (192.3–384.1)	35	99 (68.8–137.3)
Colon and rectum (153–154)	58	44	133* (101.2–172.2)	53	110 (83.7–142.5)
Liver and intrahepatic bile ducts (155–156)	38	72	53[§] (37.3–72.3)	48	78 (55.4–107.6)
Larynx (161)	19	9	212* (127.5–330.9)	11	169* (101.7–264.0)
Trachea, bronchus and lung (162)	155	89	173* (147.0–202.7)	140	111 (94.2–129.9)
Pleura (163)	1	2	41 (0.5–228.8)	3	30 (0.4–165.3)
Bone and articular cartilage, and connective and other soft tissue (170–171)	2	11	18[§] (2.0–63.9)	5	41 (4.6–147.3)
Melanoma of the skin (172)	4	15	26[§] (7.1–67.7)	4	97 (26.2–249.5)
Prostate (185)	52	56	94 (69.8–122.6)	50	103 (77.1–135.4)
Testis (186)	0	0	0[§] (0.0–0.0)	1	0[§] (0.0–0.0)
Bladder (188)	28	46	61[§] (40.6–88.3)	28	101 (66.9–145.5)
Brain and nervous system (191–192, 225)	16	13	125 (71.4–202.9)	13	119 (68.0–193.4)
Thyroid gland (193)	1	0	0[§] (0.0–0.0)	2	61 (0.8–339.9)
Lymphatic and haematopoietic tissue (200–208)	52	54	96 (71.7–125.9)	45	115 (85.8–150.7)
Lymphosarcoma and reticulosarcoma, and other malignant neoplasms of lymphoid and histiocytic tissue (200, 202)	13	36	36[§] (19.0–61.0)	14	91 (48.5–156.0)
Hodgkin's disease (201)	1	0	607 (7.9–3375.5)	2	62 (0.8–344.3)
Multiple myeloma (203)	6	3	178 (65.1–387.9)	7	81 (29.5–175.6)
Leukaemia (204–208)	32	14	226* (154.4–318.7)	22	146 (99.7–205.9)
Diabetes mellitus (250)	63	84	75[§] (57.5–95.7)	78	80 (61.7–102.8)
Mental disorders (290–303, 305–319)	9	18	49[§] (22.2–92.4)	20	44[§] (20.1–83.6)
Diseases of the nervous system and sense organs (320–389)	41	43	96 (69.0–130.4)	38	107 (76.8–145.3)
Diseases of the circulatory system (390–459)	944	978	97 (90.5–102.9)	904	104 (97.9–111.3)
Ischaemic heart disease (410–414)	235	351	67[§] (58.6–76.1)	282	83[§] (73.0–94.7)
Cerebrovascular disease (430–438)	339	283	120[§] (107.3–133.1)	289	117* (105.1–130.4)
Diseases of the respiratory system (460–519)	149	189	79[§] (66.8–92.7)	176	85[§] (71.6–99.4)
Acute respiratory infections, pneumonia and influenza (460–466, 480–487)	18	13	141 (83.5–222.8)	20	91 (54.1–144.4)
Chronic pulmonary diseases (416, 490–496)	89	132	67[§] (54.1–82.9)	126	71[§] (56.8–87.0)

Table 19 (concluded)

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
Asthma (493)	0	0	0[§] (0.0–0.0)	8	74 (27.1–161.4)
Pneumoconiosis and asbestosis (500–505)	1	8	12[§] (0.2–66.2)	5	19 (0.2–105.4)
Diseases of the digestive system (520–579)	95	65	145* (117.5–177.6)	88	108 (87.4–132.0)
Chronic liver disease and cirrhosis (571)	50	45	112 (83.4–148.1)	49	103 (76.4–135.8)
Nephritis, nephrotic syndrome and nephrosis (580–589)	34	39	87 (60.2–121.5)	26	132 (91.6–184.8)
Symptoms, signs and ill-defined conditions (780–799)	28	28	99 (65.7–143.0)	35	80 (53.0–115.3)
Injury and poisoning (800–999)	105	44	240* (196.0–290.1)	109	96 (78.6–116.4)

[a] Obs.: number of cases observed; Exp.: number of cases expected.
[b] * SMR > 100; $P < 0.05$; [§] SMR < 100; when Obs. = 0, CI is calculated to be 97.5%, one-tail test.
[c] Standardized by age and deprivation index.

Table 20. Milazzo–Valle del Mela area: SMR for selected causes for females, 1995–2002

Causes (ICD-9 code)	Observations and comparisons [a, b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
All causes (001–999)	1981	1883	105* (100.6–109.9)	2109	94[§] (89.8–98.2)
Infectious and parasitic diseases (001–139)	8	8	96 (41.2–188.8)	7	118 (50.7–232.2)
All cancers (140–239)	393	311	127* (114.3–139.7)	399	98 (88.9–108.6)
All cancers 0–14 years of age (140–239)	0	0	0[§] (0.0–0.0)	1	0[§] (0.0–0.0)
Stomach (151)	22	21	103 (64.6–156.2)	24	93 (57.9–140.0)
Colon and rectum (153–154)	46	17	264* (193.1–351.8)	49	94 (68.9–125.6)
Liver and intrahepatic bile ducts (155–156)	39	25	159* (112.7–216.7)	40	99 (70.1–134.7)
Larynx (161)	0	0	0[§] (0.0–0.0)	1	0[§] (0.0–0.0)
Trachea, bronchus and lung (162)	17	26	65 (37.9–104.3)	25	69 (40.4–111.1)
Pleura (163)	1	1	190 (2.5–1055.3)	2	54 (0.7–298.1)
Bone and articular cartilage, and connective and other soft tissue (170–171)	1	3	36 (0.5–200.0)	4	25 (0.3–140.7)
Melanoma of the skin (172)	4	3	126 (33.8–321.8)	4	101 (27.2–259.3)
Breast (174)	65	65	100 (77.2–127.5)	72	91 (69.9–115.4)
Gynaecological cancers (179–180, 182)	27	10	283* (186.6–412.0)	24	110 (72.6–160.4)
Ovary and other uterine adnex (183)	19	4	519* (312.6–811.2)	16	121 (72.7–188.7)
Bladder (188)	3	11	26[§] (5.3–76.7)	6	50 (10.1–146.6)
Brain and nervous system (191–192, 225)	12	1	1997* (1030.9–3489.2)	10	120 (62.0–209.9)

Table 20 (concluded)

Causes (ICD-9 code)	Observations and comparisons [a,b]				
	Comparison with local reference [c]			Comparison with regional reference [c]	
	Obs.	Exp.	SMR (95% CI)	Exp.	SMR (95% CI)
Thyroid gland (193)	2	2	83 (9.3–298.8)	3	67 (7.5–242.1)
Lymphatic and haematopoietic tissue (200–208)	36	47	76 (53.5–105.8)	35	102 (71.7–141.7)
Lymphosarcoma and reticulosarcoma, and other malignant neoplasms of lymphoid and histiocytic tissue (200, 202)	6	14	42§ (15.2–90.7)	11	57 (20.6–122.9)
Hodgkin's disease (201)	0	2	0§ (0.0–0.0)	1	0§ (0.0–0.0)
Multiple myeloma (203)	8	1	1523* (655.9–3 001.8)	7	121 (52.2–248.9)
Leukaemia (204–208)	22	30	74 (46.3–111.8)	17	131 (82.2–198.8)
Diabetes mellitus (250)	111	113	98 (80.7–118.1)	120	93 (76.3–111.7)
Mental disorders (290–303, 305–319)	23	34	68 (43.3–102.5)	35	65§ (41.3–97.8)
Diseases of the nervous system and sense organs (320–389)	39	20	199* (141.7–272.4)	44	90 (63.7–122.4)
Diseases of the circulatory system (390–459)	1058	1118	95 (89.0–100.5)	1113	95 (89.4–100.9)
Ischaemic heart disease (410–414)	165	230	72§ (61.1–83.4)	221	75§ (63.6–86.8)
Cerebrovascular disease (430–438)	449	397	113* (102.9–124.1)	425	106 (96.1–115.9)
Diseases of the respiratory system (460–519)	106	44	239* (195.5–288.9)	96	111 (90.4–133.6)
Acute respiratory infections, pneumonia and influenza (460–466, 480–487)	27	10	263* (173.0–382.1)	24	110 (72.7–160.5)
Chronic pulmonary diseases (416, 490–496)	42	20	207* (149.0–279.5)	53	79 (56.9–106.8)
Asthma (493)	3	12	26§ (5.1–74.6)	6	50 (10.0–144.8)
Pneumoconiosis and asbestosis (500–505)	0	0	0§ (0.0–0.0)	0	0§ (0.0–0.0)
Diseases of the digestive system (520–579)	58	72	80 (61.0–103.9)	79	74§ (56.0–95.3)
Chronic liver disease and cirrhosis (571)	25	24	103 (66.4–151.5)	38	66§ (42.6–97.1)
Nephritis, nephrotic syndrome and nephrosis (580–589)	28	15	185* (122.6–266.8)	25	111 (73.5–159.9)
Symptoms, signs, and ill–defined conditions (780–799)	35	18	192* (134.0–267.6)	52	67§ (46.5–92.9)
Injury and poisoning (800–999)	58	58	100 (75.7–128.8)	79	74§ (55.9–95.1)

[a] Obs.: number of cases observed; Exp.: number of cases expected.
[b] * SMR > 100; $P < 0.05$; § SMR < 100; when Obs. = 0, CI is calculated to be 97.5%, one-tail test.
[c] Standardized by age and deprivation index.

Results

For males and females living in each area, Tables 13–20 report two sets of SMRs (based on the two reference populations) for the period 1995–2002. Table 21 describes the time-related changes of age-standardized rates of total mortality for four calendar periods. Finally, Table 22 describes changes in SMRs related to birth cohort. Also, the following paragraphs highlight the major findings in each area, including some information derived from hospital discharge records.

Table 21. Mortality rates by calendar period and gender in high-risk areas of Sicily

Period	Mortality rate[a]				
	Augusta–Priolo	Gela	Milazzo–Valle del Mela	Syracuse	Sicily
Males					
1985–1988	983.4	1079.9	833.7	1089.0	1009.3
1989–1993	864.4	896.5	811.8	865.6	864.2
1994–1997	805.4	856.2	770.3	799.3	791.6
1998–2002	704.5	792.3	693.7	738.8	736.2
Females					
1985–1988	707.9	817.6	678.0	681.2	720.8
1989–1993	557.7	633.5	522.1	533.4	568.6
1994–1997	518.3	551.3	483.4	500.1	512.2
1998–2002	471.7	543.8	432.3	462.8	477.6

[a] All rates are annual, per 100 000 population and age standardized for the European population.

Augusta–Priolo area

Overall mortality

For the period 1995–2002, mortality rates in the area did not differ significantly from those of the whole region, whereas in the local comparisons a statistically significant 5% protective effect was present in women (but not in men). As for the period of birth, SMRs show a marked tendency to decline among younger and younger age cohorts of men – which is limited to men in comparison with the local reference group.

Cancer

The number of excess deaths from cancer of the pleura in men (and possibly women) clearly indicates occupational exposure to asbestos as a significant problem in the area. The contribution of environmental exposure, however, cannot be ruled out. In men, the number of excess deaths from lung cancer is apparent in both sets (local and regional) of comparisons –although in the regional comparison, its statistical significance is borderline. Both local and regional comparisons suggest that the number of excess deaths from lung cancer were concentrated in the generations born before 1935 (DASOE, unpublished report, 2010). But past differences in the smoking habits of residents in the industrialized high-risk areas and residents in the less industrialized adjacent areas must also be considered. However, in considering definite asbestos exposure, the role of occupational exposure to lung carcinogens deserves to be investigated.

Non-neoplastic diseases

In the regional comparisons, excess deaths from cerebrovascular diseases are mirrored by a deficit in deaths from ischaemic heart diseases. This correspondence is a possible artefact of a systematic bias in death certification – also because data on hospitalization seem to indicate exactly the opposite phenomenon (DASOE, unpublished report, 2010). Also, deaths from acute respiratory diseases are consistently in excess in both genders in both sets of comparisons. Moreover, the number of excess deaths from psychiatric disorders is impressive, but is limited to men. Finally, a marked number of excess deaths from cirrhosis in women (compared with both the local and regional reference groups) is not shared by men. In this case, the most plausible hypothesis is the role of viruses.

Table 22. Total mortality by period of birth

Birth cohort	Augusta–Priolo			Gela			Milazzo–Valle del Mela			Syracuse		
	Freq.	SMR local	SMR regional	Freq.	SMR local	SMR regional	Freq.	SMR local	SMR regional	Freq.	SMR local	SMR regional
Men												
1915–1924	1641	1.08*	1.06*	1973	1.07*	1.06*	1193	1.03	0.94*	2474	1.14*	1.11 b*
1925–1934	1145	1.02	0.98	1406	1.00	1.00	839	1.00	0.95	1727	1.04	1.00
1935–1944	503	0.99	0.99	687	1.15	1.15*	320	0.99	0.93	794	1.03	1.03
1945–1954	218	0.89	0.87*	301	1.06	1.04	128	0.87	0.82*	361	0.97	0.97
1955–1964	138	0.84*	0.95	198	1.11	1.16*	61	0.81	0.70*	201	0.83*	0.94
P (trend)	NA	<0.01	0.06	NA	0.55	0.41	NA	0.08	0.14	NA	<0.01	0.01
Women												
1915–1924	1309	0.96	1.03	1661	1.08*	1.18*	1038	1.01	0.92*	2038	0.95*	1.02
1925–1934	667	0.89*	0.98	938	1.10*	1.18*	518	1.01	0.95	1037	0.89*	0.98
1935–1944	275	0.97	1.02	346	1.05	1.08	177	1.07	0.91	390	0.86*	0.91
1945–1954	135	1.03	1.01	140	0.82*	0.88	77	0.93	0.88	215	1.03	1.01
1955–1964	58	0.95	0.89	83	1.00	1.04	38	0.93*	0.92	105	1.13	1.06
P (trend)		0.91	0.54	--	0.12	0.03	--	0.78	0.93	--	0–85	0–53

Freq.: frequency; NA: not applicable.
* The 95% CI excludes 1.
Note. Reference SMRs are for the regional population, with no standardization for the deprivation index.

Additional observations from hospital discharge records

The regional comparisons estimate a number of excess hospitalizations for psychiatric disorders in both genders. Also, for both genders and both sets of comparisons, a number of excess hospitalizations (about 20%) for acute respiratory conditions and for liver cirrhosis were recorded in hospital discharge records.

City of Syracuse

Overall mortality

For the period 1995–2002 in the City of Syracuse (compared with the regional reference population), a 4% excess in mortality was present in men, but not in women. Temporal analyses showed that about a 10% excess in mortality in males for the period 1985–1988 (1089.0 for Syracuse versus 1009.3 for Sicily) displayed a tendency to decline (Table 21). On the contrary, for women, excesses in mortality were similar to those of the regional figures for men and consistently lower than those of the local reference population.

Cancer

The occurrence of a sizable number of deaths from cancer of the pleura in both genders clearly indicates exposure to asbestos as a significant problem in the area. In men, for the period 1995–2002, mortality from cancer at any site in the City of Syracuse was 10% higher than in the regional population. Of the approximate 20 extra deaths per year, 15 were deaths from cancer, and half of these were cancers of the lung or of the pleura. Also, women had a significant 9% increase in mortality from cancer, but the increase was distributed over a variety of cancer sites, including the bladder, with a statistically significant SMR of 1.64, based on 20 observed cases. A moderate excess of deaths from bladder cancer in men, however, was not statistically significant.

Non-neoplastic diseases

Deaths from psychiatric and neurological diseases increased significantly in men, but not in women. Also, deaths from acute respiratory diseases are consistently in excess in both genders in both sets of comparisons, and deaths from diseases of the digestive tract (other than liver cirrhosis) increased in both genders. Moreover, deaths from diseases of the urinary tract decreased in women, but not in men.

Additional observations from hospital discharge records

The excesses of pleural and lung cancer were confirmed by hospital discharge records, as were those of bladder cancer (in both genders in both sets of comparisons, with excesses in the range of 30–50%). Also, excesses of hospitalizations for acute respiratory diseases (about 30%) were detected in both genders in both sets of comparisons.

Gela area

Overall mortality

For at least 20 years, a significant excess in mortality has persisted among residents in the high-risk area of Gela, compared with both the local and the regional reference populations. For the period 1995–2002, the excess over the neighbouring populations corresponded to more than 20 men and more than 15 women dying every year. In both genders, the excess has been fairly constant since 1985. As for birth cohort, no trend is recognizable in men, whereas in women excesses over the regional population exceeded 10% in women born before 1934 and were smaller for younger women. The quality of mortality statistics, as indicated by the proportion of death certificates coded as ill-defined conditions, was poorer in Gela than in the other areas at risk.

Cancer

Marked excesses of death from all cancers were observed in both genders in local (but not regional) comparisons. The occurrence of a sizable number of deaths from cancer of the pleura in men clearly indicates occupational exposure to asbestos as a significant problem in the area. In both genders, local (but not regional) comparisons indicate marked excesses of death from cancer. The two sets of comparisons indicate significant excesses in the number of deaths from gastric and laryngeal cancer in men, but not in women, thus suggesting a role of either occupational exposures or tobacco smoke (or chance). Regional comparisons fail to confirm the significant excess in the number of deaths from lung cancer indicated by the local comparison (around 5 extra cases a year). The excess number of death from lung and gastric cancer in men over the local reference population were present at least since the late 1980s and persisted at least up to the generation born in the early 1940s (DASOE, unpublished report, 2010). In the regional comparisons, the risk of death from bladder cancer decreased significantly. In the two sets of comparisons, deaths from colorectal cancer for the period 1998–2005 increased in women, but not in men. This makes interpretation difficult, given that colorectal cancer is largely associated with dietary habits. Also, deaths from lung cancer in women increased: statistical significance, however, was attained only in the comparison with the local reference group.

Non-neoplastic conditions

A consistent significant excess in the number of deaths from psychiatric diseases was estimated in both genders in both sets of SMRs, but women had a mirror deficit of deaths from neurological disorders. In contrast to the other high-risk areas, mortality from acute respiratory conditions decreased consistently in both genders and in both sets of comparisons. Among deaths from diseases of the cardiovascular system, the excess number of deaths from cerebrovascular diseases (in regional comparisons) corresponds to a mirror deficit in deaths from ischaemic heart diseases. In this case, the possibility of artefacts caused by systematic errors in the process of death certification cannot be excluded.

Additional observations from hospital discharge records

In contrast to mortality data, for both genders and both sets of comparisons, hospital discharge records showed that hospitalization for acute respiratory diseases increased 20–50%. In addition, the number of boys and girls (0–14 years of age) discharged from a Sicilian hospital with a diagnosis of asthma was significantly higher than that of the local reference population (observed/expected: boys: 177/114; SMR: 1.56; observed/expected: girls 129/69; SMR: 1.87). No corresponding excesses were detected in the comparison with the regional population.

Milazzo–Valle del Mela area

Overall mortality

Compared with the regional population, a protective effect was persistently present in women living in the Milazzo–Valle del Mela area.

Cancer

Only deaths from laryngeal cancer in men appear to exceed expectations. Mortality statistics were not sensitive enough to detect the occurrence of asbestos-induced occupational mesotheliomas recognized in analytical epidemiological studies (see Chapter 10). Also, the low SMR for lung cancer in women is of borderline significance.

Non-neoplastic diseases

Comparisons with the regional population detected some statistically significant deficits in mortality from: psychiatric diseases in both genders; respiratory diseases in men; and neurological diseases, liver cirrhosis and violent deaths in women.

Additional information from hospital discharge records

Most of the deficits identified in the analysis of mortality were confirmed by hospital discharge records. Also, there was a 10–20% excess of borderline statistical significance in hospitalizations for acute respiratory diseases in both genders in both sets of comparisons.

Confounding by deprivation index

Table 23 shows two sets of SMRs (for the reference regional population) for overall mortality for the period 1995–2002 – that is, conventional SMRs and SMRs also standardized for the deprivation index. In each area and for each gender, the CIs of the two SMRs overlap, showing that there are not significant differences. However, some patterns are recognizable. In Gela, for both genders, the excess risk of death is markedly reduced when estimates are controlled for the deprivation index, thus suggesting an important role for the latter. However, an excess of deaths remains after controlling for socioeconomic status (using the deprivation index), which is more marked and statistically significant in women (significant SMR: 1.08), while in men statistical significance is borderline (not significant SMR: 1.02). Although some residual confounding by socioeconomic status cannot be excluded, a role for environmental factors can be soundly hypothesized, particularly for women.

In the Milazzo–Valle del Mela area, the protective effect of residence seems to be attributable (in part) to socioeconomic status, since the deprivation-index-adjusted SMR is somewhat higher than the conventional SMR (for women, SMRs remain statistically significant). On the contrary, in City of Syracuse men, controlling for the deprivation index highlights a possible effect of environmental factors (plausibly attributable to occupational factors, since a corresponding effect in women is much less obvious).

Table 23. Total mortality: comparison between SMRs standardized only by age and SMRs also standardized by deprivation index in high-risk areas, by gender, 1995–2002

Reference population: Sicily				
Area	**Men**		**Women**	
	Only age – standardized (95% CI)	**Standardized by age and deprivation index (95% CI)**	**Only age-standardized (95% CI)**	**Standardized by age and deprivation index (95% CI)**
Augusta	0.99 (0.95–1.03)	1.01 (0.98–1.05)	0.99 (0.95–1.04)	1.01 (0.97–1.05)
Gela	1.08* (1.05–1.12)	1.02 (0.99–1.06)	1.14* (1.10–1.18)	1.08* (1.05–1.13)
Milazzo–Valle del Mela	0.96 (0.92–1.00)	1.01 (0.97–1.06)	0.91 (0.87–0.95)	0.94 (0.90–0.98)
Syracuse	1.00 (0.97–1.04)	1.04* (1.01–1.08)	0.97§ (0.94–1.01)	0.99§ (0.96–1.03)
Reference population: local control				
Augusta	0.99 (0.95–1.03)	0.95 (0.92–0.99)	0.95§ (0.91–0.98)	0.95§ (0.92–0.99)
Gela	1.06* (1.02–1.09)	1.09* (1.06–1.13)	1.05* (1.01–1.09)	1.08* (1.04–1.12)
Milazzo–Valle del Mela	1.02 (0.98–1.06)	1.04 (0.99–1.08)	0.99§ (0.94–1.03)	1.05* (1.01–1.10)
Syracuse	1.00 (0.97–1.04)	1.02 (0.99–1.05)	0.93§ (0.90–0.96)	0.96§ (0.93–0.99)

* SMR > 1; § SMR < 1; *P* < 0.05

Congenital malformations

Province of Syracuse

For the period 1991–2000, in the Province of Syracuse, the prevalence of all malformations per 10 000 live births was 133.2, based on 594 cases (Bianchi et al., 2004). This prevalence is about two thirds that estimated for the same period by other more experienced Italian malformation registries, including those that are official members of the European Surveillance System for Congenital Malformations and the International Clearinghouse for Birth Defects (North-east Italy, Emilia-Romagna, Tuscany and Campania). Considering only residents in the cities of Augusta, Melilli and Priolo (geographically closer to the large petrochemical plants situated along the sea coast), the prevalence was 220.3 malformations per 10 000 live births. In these three cities, excess malformations, when compared with the whole Province, were found for hypospadias (prevalence, respectively, 40.6 and 21.5 malformations per 10 000 live births) and for the digestive tract (respectively, 23.4 and 11.2 malformations per 10 000 live births). The risk ratios for total malformations, hypospadias and malformations of the digestive tract were all significant (the 95% CIs excluded unity 1.00) (Bianchi et al., 2004).

City of Gela

During the period covered by the survey, 520 children born in the City of Gela had a total of 572 malformations, corresponding to a prevalence of 398 malformations per 10 000 live births – that is, almost twice as high as the prevalence of 205 malformations per 10 000 live births estimated in the Italian populations served by the conventional registries of congenital malformations. Statistically significant high-risk ratios were observed for malformations of the nervous system (risk ratio: 2.5), cardiovascular system (1.3) digestive tract (2.5), urinary system (2.2) and skin (3.4) and for severe hypospadias (2.4) and abdominal hernias (3.0). On the contrary, the risk ratio for Down syndrome was about 1.0.

Cancer registration in the Province of Syracuse

Tables 24 and 25 report the incidence rates of the major cancer types during the period 2002–2005 in the City of Syracuse, in the pool of the five cities included in the high-risk area of environmental crisis and in the whole Province of Syracuse. For comparison, the last column in each of these two tables reports the corresponding rates in the pool of Italian cancer registries early in the new millennium (AIRTUM, 2006). Most of the registries in this pool, in those years, were located in Central and Northern Italy. In 2009, the proportions for populations served by cancer registration were 48%, 26% and 16%, respectively, for Northern, Central and Southern Italy.

Over the four-year period 2002–2005, a total of 34 male and 7 female residents of the Province were diagnosed as having mesothelioma: among them, 12 males and 3 females were residents of the City of Syracuse, 13 males and 3 females were residents of the other five cities included in the high-risk area and 9 males and 1 female were residents of the rest of the Province.

None of the differences between the City of Syracuse, the five cities included in the at-risk area and the whole of the Province are statistically significant – that is, in all comparisons, the 95% CIs of the rates overlapped. However, when the rates were estimated for each city, a number of significantly increased rates (over to rest of the Province) were detected, particularly in Augusta. In this city, the annual age-standardized incidence rate per 100 000 population for all cancers in males was 603.8, which is greater than the corresponding rate in the pool of Italian registries (552.8). Augusta was also the city where the highest incidence rate per 100 000 population (based on 9 cases) for pleural mesothelioma in males was estimated: 12.0 versus 2.5 in the pool of Italian cancer registries.

Table 24. Cancer incidence rates for males, 2002–2005 [a]

Cancer site	City of Syracuse	Other cities included in the high-risk area [b]	Overall Province of Syracuse	Pool of Italian cancer registries 1999
All cancers	500.3	505.9	466.7	552.8
Stomach	11.0	15.4	15.0	27.4
Colon/rectum	50.5	44.2	47.8	61.7
Liver [c]	26.2	27.8	24.9	23.3
Pancreas	14.1	8.8	10.4	11.8
Larynx	11.6	7.5	9.8	12.5
Lung	69.4	58.2	64.1	78.5
Pleura	4.2	6.9	3.6	2.5
Prostate	59.2	56.2	52.9	76.2
Kidney [d]	9.5	12.0	9.7	18.3
Bladder	58.9	60.1	54.1	49.4
Brain	9.0	9.3	8.1	8.6
Thyroid	5.1	4.7	4.5	4.3
Lymphoma	21.0	20.0	17.9	21.0
Myeloma	5.9	7.9	6.1	6.2
Leukaemia	14.2	9.8	10.6	12.7

[a] The incidence rates are annual, per 100 000 population, and age standardized on the Italian population.
[b] This includes the cities of Augusta, Melilli, Priolo Gargallo, Floridia and Solarino.
[c] This includes the biliary tract.
[d] This includes the upper urinary tract.

Conclusions

The set of analyses in the present chapter provides a mixed picture, and many observations are puzzling. For instance, in the area of Augusta, the lower mortality of females living within the contaminated area compared with those living in the local reference area might reflect better access to medical attention, but it is not clear why the phenomenon should be limited to one gender. The only statistically significant finding in the analysis of the trends of mortality for birth cohorts has been the trend towards lower SMRs in the younger generations in the local comparison of females in Augusta and in Syracuse; again, why this should occur only in one gender is not clear.

In estimating the health status of residents in highly polluted areas, such as those described in the present book, there are two important reasons for focusing attention on overall mortality rates. First, overall mortality provides an extensive image of the major hazards to health to which a population is exposed. Second, recording mortality is exhaustive and not subject to diagnostic bias.

Residents in highly polluted areas are likely to belong to the poorer socioeconomic segment of society. Therefore, peculiar patterns in mortality may reflect the consequences of a mix of environmental (including occupational) exposures, behavioural traits associated with socioeconomic status and limited access to medical attention. Thus, poverty is a confounder of the association between environmental pollution and health (and vice versa), but the interaction between the two is difficult to disentangle. Poverty is associated with exposure to risks to health, such as poor dietary habits, tobacco smoke, obesity and sedentariness. Also, for residents in the poorer areas, the offer and quality of medical attention may be limited.

Table 25. Cancer incidence rates for females, 2002–2005 [a]

Cancer site	City of Syracuse	Other cities included in the high-risk area [b]	Overall Province of Syracuse	Pool of Italian cancer registries 1999
All cancers	374.6	390.3	362.3	453.1
Stomach	6.4	7.6	7.3	17.7
Colon/rectum	37.7	43.4	40.4	48.6
Liver [c]	18.6	19.4	17.2	14.3
Pancreas	12.6	12.9	10.8	11.0
Larynx	0.3	0.5	0.9	1.2
Lung	13.2	8.6	13.0	20.1
Pleura	1.0	1.8	0.7	0.8
Breast	95.4	98.3	93.4	122.0
Uterus [d]	28.4	25.6	28.4	28.0
Ovary	12.9	9.4	10.6	13.0
Kidney [e]	6.8	4.5	4.6	9.5
Bladder	9.4	10.6	8.1	11.1
Brain	4.7	4.4	6.3	7.1
Thyroid	15.8	18.2	17.1	13.7
Lymphoma	13.1	18.7	13.7	18.0
Myeloma	6.7	4.9	5.3	5.6
Leukaemia	6.5	7.1	8.0	9.5

[a] The incidence rates are annual, per 100 000 population, and age standardized on the Italian population.
[b] This includes the cities of Augusta, Melilli, Priolo Gargallo, Floridia and Solarino.
[c] This includes the biliary tract.
[d] The corpus and cervix are considered together.
[e] This includes the upper urinary tract.

In the present analyses, an attempt was made to estimate the burden of poverty through comparisons of indicators of risk of death that have and have not been standardized by an index of deprivation. Although standardization may have been imperfect, some patterns arise from the comparison. In Gela – the most deprived among the contaminated Sicilian areas – poverty contributes greatly to the excess of mortality; overall, it is difficult to envisage a unifying hypothesis based on all findings about this area. In the other two areas (Augusta–Priolo, including the City of Syracuse, and Milazzo–Valle del Mela), particularly in males, standardizing SMRs for the deprivation index highlighted (to a certain extent) the role of environmental contamination. Compared with the rest of Sicily, even after standardization for socioeconomic factors, females living in Milazzo–Valle del Mela seem protected somehow.

Also, ecological epidemiological studies in highly contaminated areas may be important for two reasons. They can be used to: (a) identify new, previously unsuspected, etiological associations; and (b) assess the impact of environmental contamination on the health of residents. In the case of the highly contaminated Sicilian areas, the formulation of new hypotheses is impaired by the paucity of information on the nature of contaminants to which residents are (and/or have been) exposed throughout life.

However, the health statistics presented in this chapter highlight some circumstances that require a public health intervention. A variety of agents are known to have highly contaminated the three high-risk areas, and evidence of an adverse effect on the health of the area's residents has been produced for all these contaminated areas. The evidence is particularly compelling for Gela.

In spite of the limitations imposed by the paucity of environmental data, some specific points can be derived from the analyses of current health statistics in the three contaminated areas.

The consequences of the presence of asbestos are obvious. Pleural cancer is an excellent indicator of previous occupational (and perhaps environmental) exposure to asbestos. The relevance of asbestos-induced pleural cancer is confirmed in the Province of Syracuse, which is served by a cancer registry. In males, the incidence rate of mesothelioma was higher in the Province of Syracuse than in Italy as a whole. Both the City of Syracuse and the other five cities included in the high-risk area contributed significantly to this excess. In Italy, the production, importation, exportation and trade of asbestos and materials that contain it were banned in 1992. Given the long latency period of asbestos-related cancers, excesses of mesotheliomas are expected over several decades. Unlike other regions of Italy (Cavariani et al., 2010), Sicily has no figures on the amount of anthropogenic asbestos-related materials present at the time of the ban or on the speed with which they are being removed from the environment. Asbestos-induced mesotheliomas will continue to occur as long as asbestos is present in the environment. At present, the priority is to verify the extent to which the post-ban removal of asbestos-containing materials from the environment has progressed, and work on verification is far from complete.

Other findings from the Province of Syracuse cancer registry deserve comment. Differences between the cancer incidence rates of the Province and the pool of Italian registries correspond to a north–south gradient, which is partly attributable to lifestyle, including the protective effect of the Mediterranean diet, which has been known for decades (Berrino & Muti, 1989). In the past, this diet was typical of southerners – which is no longer the case.

Also, findings from the files of hospital discharge records for 2001–2006 were given limited attention, because in those years the files had not yet been fully validated. Nevertheless, some observations provided by the hospital discharge records deserve attention and action, for the sake of public health. In all three areas, an excess of hospitalizations for acute respiratory conditions was recorded for both genders, which is consistent with the presence of poor air quality in industrially contaminated areas. With the exception of Gela, such excess is consistent with estimates based on mortality data. The excess risk for hospitalization for asthma of children living in Gela is likely to be caused by air pollution, although it might also reflect the limited availability of additional medical support outside the hospital in the same area. In any case, an immediate medical intervention is needed in the area to control children's respiratory health.

Worldwide, many many studies have suggested that congenital malformations are a possible adverse effect of exposure to environmental contamination, which makes the concern of residents in high-risk areas of Sicily quite understandable. Unfortunately, Sicily has lacked a continuous, quality-controlled population-based registry of congenital malformations. In the two above-mentioned surveys in Gela and Syracuse, both of which indicate an excess of congenital malformations, methods for registration did not completely correspond to international standards. Thus, overreporting cannot be excluded. Nevertheless, the eligibility of each case was controlled by an experienced geneticist.

Also, it is hard to believe that flaws in the registration mechanisms may have led to an artefactual twofold excess in a variety of categories of malformations. In particular, the high prevalence of hypospadias found in Gela and Augusta was in agreement with suggested causal associations with endocrine disruptors (Baskin, 2004). In an overall evaluation of the health effects intended to set priorities for rehabilitation and prevention, the available findings, albeit imperfect, cannot be dismissed.

Other specific aspects of the environment-related health of residents in the contaminated areas of Sicily will become visible through further consideration of the data currently available, as well as further analyses and integration of epidemiological knowledge into ad hoc studies. For the time being, health statistics add to social and environmental knowledge and emphasize the vital importance of rehabilitation in Sicily.

6. ENVIRONMENTAL POLLUTION IN AUGUSTA–PRIOLO AND GELA

Loredana Musmeci, Fabrizio Falleni, Maria Rita Cicero and Mario Carere

Introduction

The Italian National Institute of Health and the Italian Ministry of the Environment, Land and Sea carried out a project, from 2007 to 2009, to study the chemical quality of environmental matrices in the contaminated areas of Gela and Augusta–Priolo. The study evaluated the possible toxicological effects of chemical substances on the local human population.

The Gela and Augusta–Priolo areas are characterized by diffuse environmental contamination, due to the presence of large chemical industrial complexes. During the last few decades, these complexes have caused progressive contamination of the different environmental matrices through the presence of compounds that are mainly toxic, persistent and can bioaccumulate. The Gela and Augusta–Priolo areas have been included in the list of sites of national concern for which specific legislation is in force in Italy (Ministry of the Environment and Territory, 2000a, 2001a; Parliament, 2006).

All data on chemicals available in the scientific literature, regional reports, local projects and legislative monitoring plans in the Gela and Augusta–Priolo areas were collected to assess the risks the different exposure routes present to the local human population. Environmental data on soil, inland and marine waters, sediment, groundwater, drinking-water, air, and food were screened and evaluated for their relevance to the health of the local population.

During the period of the study, the following major European legislation on the protection of the environment and health was considered:

- Commission Regulation 1881/2006, setting the maximum levels for certain contaminants in foodstuffs (EC, 2006a) – in particular, the levels of some substances (relevant to the present study) in fish and shellfish to be placed on the market;
- Council Directive 98/83/EC on the quality of water intended for human consumption (EU, 1998), setting the threshold values for a long list of compounds in drinking-water;
- Directive 2000/60/EC (EU, 2000), establishing a framework for European Commission action in the field of water policy, to achieve a good chemical and ecological status in all European surface water by 2015 through a stepwise approach and technical milestones – such as the characterization of risks (pollution risks, for example), analyses of the pressures and effects of human activity, and the monitoring and design of action programmes – and also through obligations placed on Member States to manage water resources on a river–basin scale;
- Directive 2006/118/EC (EU, 2006) on the protection of groundwater against pollution and deterioration, which aims to protect groundwater resources by setting threshold values for a series of substances in groundwater; and
- Directive 2008/105/EC on environmental quality standards in the field of water policy (EU, 2008), setting standards for the list of European priority substances in surface water.

All these European laws have been transposed into national legislation and represent a key element for evaluating environmental contamination and for protecting human health.

The following four steps were applied to evaluate the risks environmental contamination present to the human population:

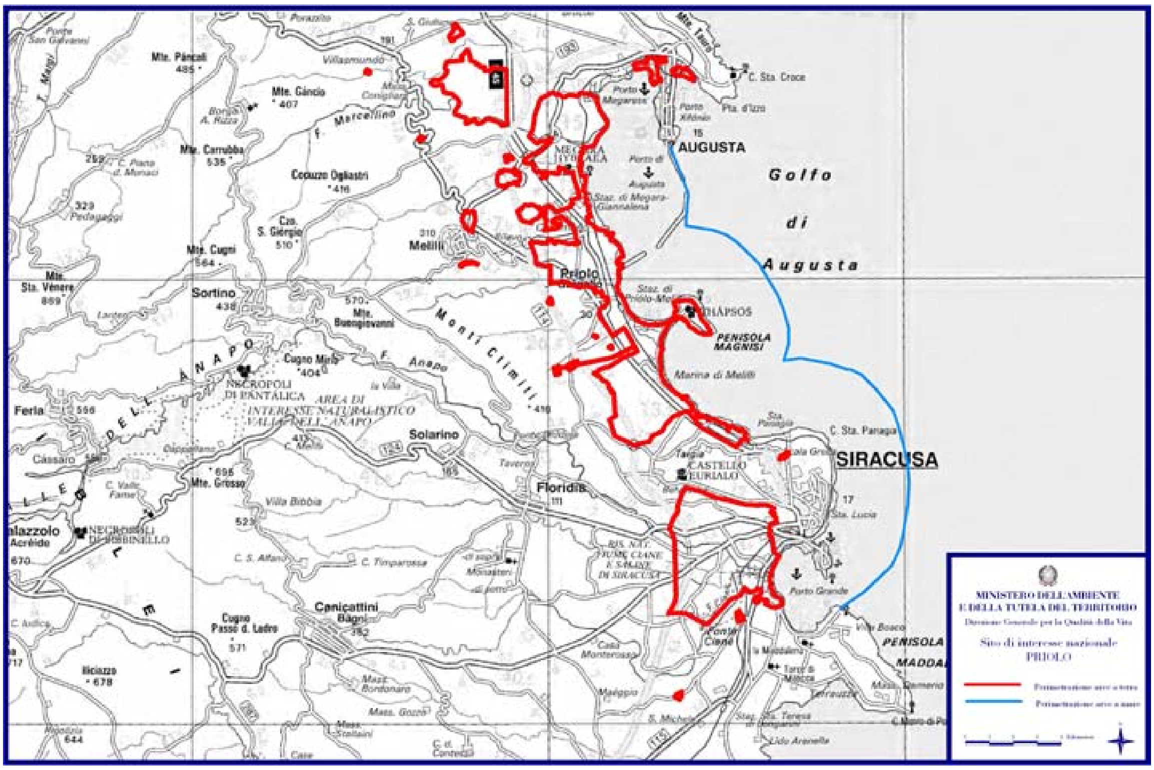
1. select local priority substances of concern in the two areas;
2. elaborate on the toxicological profiles of these substances, focusing on the adverse effects on human health;

3. compare the levels of concentration of these substances with the threshold values or quality standards present in the legislation or in scientific studies; and
4. draft preliminary hazard assessments for these substances.

Description of the Augusta–Priolo and Gela areas

The contaminated area of Augusta–Priolo includes the municipalities of Augusta, Priolo, Melilli and Syracuse. In 1998, it was included in the list of national sites of concern for remediative action. In January 2000 a ministerial decree elaborated the boundaries of the site, as shown in Fig. 7.

Fig. 7. The national remediation site of the Augusta–Priolo area [a]



[a] Red indicates land areas; blue indicates marine areas.
Source: Adapted from an unpublished Ministry of the Environment and Territory map.

The Augusta–Priolo area includes:

- an industrial complex with large enterprises, mainly refineries;
- a coastal–marine area that includes the harbour areas of Augusta and Syracuse;
- several waste landfills, including hazardous wastes;
- the former settlement of Eternit in the City of Syracuse, where asbestos was produced; and
- the Saline di Priolo and Augusta wetland.

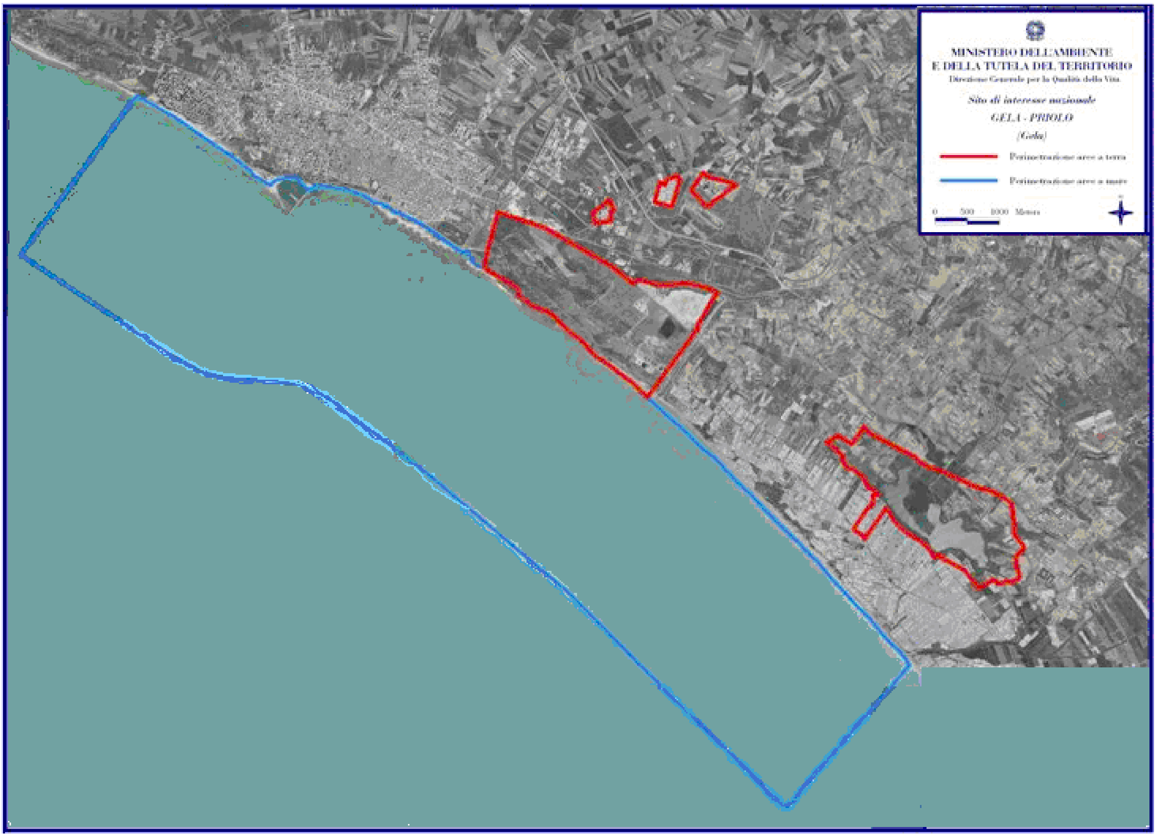
The marine area is relevant because it includes the Harbour of Syracuse and the Gulf of Augusta and extends 3 km into the open sea (see Fig. 7). The Gulf of Augusta covers an area of 23.5 km^2 with a maximum depth of 14.9 m; it is bounded partly by two old dams.

The ministerial decree of January 2000 (Ministry of the Environment and Territory, 2000a) elaborated the boundaries of the Gela site of national concern; it includes the area of the municipality of Gela. Within the boundaries (Fig. 8) are both private and public areas. The private areas cover 5 km^2, while the public areas (marine) cover 46 km^2.

Within the Gela site of national concern are:

- a relevant industrial complex with large enterprises, mainly petrochemical plants and refineries;
- a stockpiling centre and pipelines;
- industrial-waste landfills; and
- the Biviere di Gela Wetlands – an area of European relevance for biodiversity.

Fig. 8. National remediation site of Gela [a]



[a] Red indicates land areas; blue indicates marine areas.
Source: Adapted from an unpublished Ministry of the Environment and Territory map.

Selection of priority substances for the two areas

In the Augusta–Priolo area, the following criteria were applied to select the local priority contaminants:

- the presence of dangerous substances in the land areas and sediments;
- consideration of the levels of concentration detected that exceed 10 times the legislated values of Italian Legislative Decree 152/06 (Parliament, 2006); and
- the diffusion of contaminants in the areas that are the subject of the present study.

In the final selection, the Italian National Institute of Health evaluated the toxicological properties of the dangerous substances in the Augusta–Priolo area (Table 26). In particular, the study emphasized the correspondence between the types of contaminants and soil, groundwater and sediments; this correspondence is very relevant for total hydrocarbons greater than 12 carbon atoms in length, for mercury and for hexachlorobenzene. The priority contaminants are listed in Table 26.

Table 26. Priority contaminants in the Augusta–Priolo area

Inorganic substances	Organic substances
Arsenic	Benzene, toluene, xylene and ethylbenzene
Cobalt	Vinyl chloride
Hexavalent chromium	Hexachlorobenzene
Mercury and its compounds	Hydrocarbons with less than 12 carbon atoms
Lead	Hydrocarbons with more than 12 carbon atoms
Copper	Polycyclic aromatic hydrocarbons
Zinc	Polychlorinated dibenzodioxins and/or polychlorinated dibenzofurans
--	Tetrachloroethylene
--	Trichloroethylene

In the Gela area, the following criteria were applied to select the local priority contaminants (Table 27):

- assessment of the concentration levels of contaminants detected;
- analysis of the diffusion of contaminants in the environment; and
- evaluation of the levels of contamination that exceed the legislated values for soil and groundwater.

The contaminants include: heavy metals; benzene, toluene, ethylbenzene and xylene; and organic compounds, mainly persistent ones (Table 27).

Table 27. Priority contaminants in the Gela area

Inorganic substances	Organic substances
Arsenic	1,2-Dichloroethane
Cadmium	Benzene, toluene, ethylbenzene and xylene
Cobalt	Vinyl chloride
Hexavalent chromium	Hexachlorobenzene
Mercury and its compounds	Hydrocarbons with less than 12 carbon atoms
Nickel	Hydrocarbons with more than 12 carbon atoms
Lead and its compounds	Polycyclic aromatic hydrocarbons (benzo[*a*]pyrene, benzo[*b*]fluoranthene, benzo[*a*] anthracene)
Vanadium	Polychlorinated biphenyls
Copper	--

Toxicological profiles of contaminants

For the priority substances of the Augusta–Priolo and Gela areas, simplified toxicological profiles were considered, with the specific aim of describing the possible effects caused by the substances through ingestion (consumption of drinking-water and fish products) or inhalation. The profiles include:

- physicochemical properties;
- descriptions of the toxicological effects on people and the toxicity threshold, both for ingestion and inhalation;
- descriptions of the adverse effects on the endocrine and reproductive systems and on development;
- mutagenic and carcinogenic effects;

- exposure routes and environmental dispersion;
- ecotoxicity properties – in particular, the EU water framework directive (EU, 2000) priority substances; and
- national and international legislation.

Information was collected from different validated sources:

- WHO guidelines (such as those on drinking-water);
- EU risk assessment reports on the European chemical Substances Information System – Report Risk Assessment web site (EC JRC IHCP, 2011); and
- toxicological profiles produced by the United States Agency for Toxic Substances and Disease Registry (ATSDR, 2011).

Drafts of the profiles were needed to evaluate the association between the contamination of the different environmental matrices and the risks to human health in the Gela and Augusta–Priolo areas. Information available from the toxicological profiles, such as threshold values, was compared with the different levels of contamination present in the different matrices, and some exposure scenarios were considered.

Environmental data in the Augusta–Priolo area

Levels of pollution and exposure assessment

In the Augusta–Priolo area, the data collected showed chemical contamination of all environmental matrices. From the breadth of contamination, it is possible to assume a multiple exposure scenario in which the resident population was exposed to the pollutants during the last few decades through inhalation and ingestion (of drinking-water, fish products, and agricultural and zootechnical products). The concentrations of the dangerous substances detected are different orders of magnitude above the threshold values foreseen by environmental and health legislation; also, some pollutants were detected in high concentrations in fish products and in wells used for irrigation.

In the Augusta–Priolo area, people were exposed by ingesting fish and shellfish; and the Ministry of Health has certified that lead, cadmium and mercury exceed the legislated European limits in these marine products (Nicotra et al., 2007). Some reports have also highlighted eutrophication in the coastal waters that border the Augusta–Priolo area.

The characterization of marine sediments in the Gulf of Augusta by the Italian National Environmental Protection Agency has highlighted massive contamination of the Gulf with heavy metals (such as mercury) and organochloride compounds (such as hexachlorobenzene). Also, chemical lipophilic substances tend to accumulate in the sediment and contaminate organisms found at the bottom of water bodies and the whole food chain, including edible aquatic species that people consume. In the Augusta–Priolo area, exposure to contaminated agricultural products has also been hypothesized to be a risk to people, because of the massive contamination of the soil and the groundwater used for irrigation.

With regard to air pollution, an environmental biomonitoring study, performed by the local environmental agency, investigated the air quality of the industrial area through bioaccumulation of contaminants in lichens (Mangiameli, 2005). The study highlighted contamination of industrial origin for different metals, such as zinc, copper, mercury, cadmium and chromium. Also, in 2008 (in July and October), a study on pine needles was carried out by the National Institute of Health, and the results for metals show that the contamination is still in place and that the contamination is comparable to that of other industrialized sites. Moreover, groundwater pollution inside the boundaries of the site of national concern was detected for some dangerous substances (such as trichloroethylene and tetrachloroethylene). The concentrations of the pollutants detected in groundwaters are different orders of magnitude above the legislated limits defined for the protection of human health related to the consumption of drinking-water.

Case study: lead

Instances of exceeding the legislated limits for lead were detected in all environmental matrices: groundwater, soil, sediment and marine coastal waters. Also, high values of lead in lichens – an index of air pollution – were detected. Exceeding the sanitary limits of fish products is highly relevant, because the fish and shellfish were collected in the marine area bordering the city and in the local fish market. Because of the consumption of fish products and also the consumption of crops irrigated with contaminated water or grown in contaminated soil, long-term exposure of the population to lead is a probable hypothesis. Moreover, exposure through inhalation has been hypothesized.

Table 28 shows the physicochemical properties of lead that are useful for understanding both the behaviour of the substance in the different environmental matrices and its environmental fate. In particular, the organic compounds of lead tend to bioconcentrate in aquatic organisms; in air, particulate matter tends to adsorb lead.

Table 28. Physicochemical properties of lead

Physicochemical properties	Description
Water solubility[a]	Nearly insoluble tetramethyllead Tetraethyl lead: 0.29 mg/l Lead oxide: 17 mg/l (cold water) Lead dichloride: 9.9×10^3 mg/l Lead nitrate: 376.5×10^3 mg/l Lead acetate: 443×10^3 mg/l
Partition coefficients:[b]	
K_p	1.46×10^5
log K_p (sediment–water)	5.65 l/kg
log K_p (suspended matter–water)	5.81
K_d (soil–water)	524 000 – 882 000 l/kg (suspended matter)

[a] The solubility of a chemical in water is the maximum amount of the chemical that will dissolve in pure water at a specified temperature and pressure.
[b] The partition coefficient, *K*, is the ratio of concentrations of a compound in the two phases of a mixture of two immiscible solvents at equilibrium; K_p: partition coefficient; K_d: distribution coefficient, which is another partition coefficient.
Source: Crommentuijn, Polder & van de Plassche (1997); Agences de l'Eau (1999).

With regard to fish and fish products, the exposure of the population to levels of lead was verified: values in fish up to 5.46 mg/kg fresh weight were detected in 2007 in the Magnisi Peninsula. Other high values were detected in fish sold in a local market (3.7 mg/kg): in mullets (1.75 mg/kg) and in the bream *Sarpa salpa* (1.89 mg/kg), with the value of the European regulation (EC, 2006a) of 0.3 mg/kg being exceeded as many as 20 times. Also, high levels were detected in cuttlefish. The presence of lead is of greater concern because high concentrations were detected in carnivorous fish that are at the top of the food-chain; usually, however, the levels of lead are highest in organisms found at the bottom of bodies of water. Organolead compounds, such as trialkyl- and tetraalkyl-lead compounds, are more toxic than inorganic forms and have been shown to bioconcentrate in aquatic organisms.

In the sediments of the Gulf of Augusta, lead concentrations are up to 5393 mg/kg, exceeding the national legislated limits that represent the environmental quality standard for bodies of surface water by almost a 100-fold (Parliament, 2006). The values detected are related to the first 50 cm of the sediments – that is, the layer of the sediment in which most of the aquatic organisms live. Because the environmental quality standard for sediment is difficult to achieve in historically contaminated sites, an approach developed through various stages with less stringent objectives should be considered to achieve a short-term workable standard (Carere et al., 2008). Lead is classified also as a European priority substance for aquatic environments under the European water framework directive (EU, 2000) and should be reduced in all sources of pollution by a certain deadline.

With regard to a drinking-water risk to health in the Augusta–Priolo site of national concern, concentrations of lead more than 25 times the legislated limits for remedial action were detected in groundwater. The drinking-water value of lead, used also for remediation, is based on a tolerable daily intake of 3.5 µg/kg body weight for children (see Table 29). Also, as already mentioned, high concentrations of lead were detected in lichens, in a study performed by the Environmental Protection Agency of the Sicily Region.

Table 29. Augusta–Priolo: lead values detected by several institutions

Category	Maximum concentration	Normative Level	Source
Fish products	5.46 mg/kg	0.3 mg/kg	Ministry of Health
Soil	2360.4 mg/kg	100.0 mg/kg	Ministry of the Environment and Territory
Sediment	5393.0 mg/kg	30.0 mg/kg	Italian National Environmental Protection Agency
Groundwater	274 µg/l	10 µg/l	Ministry of the Environment and Territory
Surface water	160 µg/l	7.2 µg/l	European Commission Joint Research Centre

The presence of high levels of lead in the soil is another possible risk to the population in the sites of national concern: the values detected are up to 2360.4 mg/kg, exceeding the legislated values (based on the protection of human health for green use – for example, public parks) by more than 20 times. The legislated limits for lead are based on several laws that cover:

- drinking-water (Parliament, 2001)
- groundwater (Parliament, 2006)
- soil (Parliament, 2006)
- sediment (Ministry of the Environment, Land and Sea, 2009)
- fish products (EC, 2006a)
- surface water (EU, 2008).

The potential adverse effects on people of exposure to lead through the contamination of soil (see Table 30) depend also on the properties of the soil itself. The data available on the soil properties in the Augusta–Priolo site are not sufficient to evaluate the possible fate of lead in the soil; the environmental fate of lead involves the formation of lead complexes with binding sites on clay minerals, humic acid, other organic matter and hydrous iron oxides.

Table 30. Potential effects of lead

Carcinogenic effects	Non-carcinogenic effects
Inorganic lead compounds are probably carcinogenic to human beings (Group 2A-IARC), while organic lead compounds are not classifiable as to their carcinogenicity to human beings (Group 3-IARC) (IARC, 2006a).	Cardiovascular diseases Neuronal development defects Kidney diseases Endocrine and reproductive defects Haematological – for example, reduction of haemoglobin concentrations

The ability of soils to bind lead depends on soil pH and the cation exchange capacity of the soil components; knowledge of these parameters is fundamental to understanding the environmental fate of lead (Chaney, Mielke & Sterret, 1988). A risk to the population arises through the bioaccumulation of lead in edible vegetables. Lead may be taken up in edible plants from the soil via the root system, via direct uptake by leaves and movement within the plant and via surface deposition of particulate matter (Holmgren et al., 1993). The bioavailability to plants of lead in soil, however, can also be limited by the strong adsorption of lead to soil organic matter. Moreover, the bioavailability of lead tends to increase as the pH and the organic matter content of the soil are reduced. Most lead is retained strongly in soil, and very little is transported through runoff to surface water or through leaching to groundwater, except under acidic conditions.

Environmental data in the Gela area

Levels of pollution and exposure assessment

The analysis of contamination of environmental matrices in the Gela area leads to the hypothesis that the population is exposed through both inhalation and ingestion of contaminants.

The compounds that exceed legislated values in groundwater are arsenic, benzene, 1,2-dichloroethane, vinyl chloride and mercury, sometimes with values thousands of times higher than the thresholds included in national legislation for the remediation of contaminated sites and those for green and industrial uses (Musmeci et al., 2009).

With regard to ingestion, data on groundwater contamination inside the site of national concern suggest it is a relevant route of exposure for human beings. Although no data confirm that people have ingested contaminated water, it is possible that part of the population has consumed drinking-water from private wells. This type of water may also have been used for irrigation, because the Gela area is famous for intensive crop production – due to favourable weather conditions.

For drinking-water, the data available show iron, temperature and turbidity have sometimes exceeded legislated limits. Limited data, however, are available for dangerous substances and thus cannot guarantee an adequate assessment of the risk to the population.

For the air route, a study by Palermo University (Bosco, Varrica & Dongarrà, 2005) analysed metals in pine needles. The study highlighted industrial contamination with some heavy metals – an indicator of past pollution. During the years 2008 and 2009, the Italian National Institute of Health carried out an analogous campaign of environmental biomonitoring on a list of heavy metals (arsenic, cadmium, chromium, copper, mercury, nickel, lead, tin, vanadium and zinc); its results confirm that contamination is still ongoing.

Over time, and before the start of remediative measures, groundwater pollution contaminated the coastal marine area adjacent to the bodies of groundwater. Consequently, the population was at risk of ingesting contaminated fish products – a dietary staple of the local population.

The data on soil pollution within the boundary of the Gela site of national concern are also relevant. These data show that the legislated limits of Italian National Decree 152/06 (Parliament, 2006) were exceeded thousands of times. In theory, through water precipitation and condensation, contaminants can be transferred from the soil on which they are adsorbed to the air or groundwater, with a consequent risk to the population. For the local people, consumption of fruits and vegetables cultivated in contaminated soil is an added risk.

The analysis of the ARPA Sicily has highlighted contamination of the Gela and Dirillo river basins, where the limits for some pesticides, copper and zinc were exceeded (ARPA Sicily, 2007). In this case, also, exposure of the population to contaminants can be hypothesized – in particular, through ingestion of vegetables and fruit irrigated with surface waters. Furthermore, some congeners of polychlorinated biphenyls in the surface layers of the marine–coastal sediment in proximity to the Gela area were detected to slightly exceed legislated limits.

Case study: 1,2-dichloroethane

1,2-Dichloroethane has been detected in massive quantities in groundwater and soil within the boundaries of the Gela area of national concern. In particular, in the groundwater in 2006, maximum concentrations of 3252 mg/l were detected (Musmeci et al., 2009); the levels reported are significantly higher than the average concentrations in the contaminated sites (the average values for contaminated sites in the United States are 175 µg/l). The legislated normative limit for drinking-water consumption (Parliament, 2001) for this substance is 3 µg/l (Table 31). For the soil matrix, concentrations of 1000 mg/kg have been verified in comparison with a legislated limit of 0.2 mg/kg (green and residential use) and 5 mg/kg (industrial use).

Table 31. Environmental data and toxicological effects of 1,2-dichloroethane

Maximum concentration detected in the area	Normative level	Carcinogenic effects	Other effects
1000 mg/kg (soil) 3 252 mg/l (groundwater)	0.2–5.0 mg/kg (soil) 3.0 µg/l (groundwater)	Group 2B (IARC possible human carcinogen) Sarcoma Fibroma Squamous cell carcinoma Adenocarcinoma Endometrial tumour	Impaired development (cardiac and neural tube defects) Kidney disease Immunological system disorders Neurological disorders Cardiovascular insufficiency Liver disease Reproductive systems (reduction in gestation period)

Human exposure to 1,2-dichloroethane depends on the physicochemical properties of the substance (Table 32), but it also depends on the characteristics of the environmental matrices of the area investigated. When 1,2-dichloroethane is released in soil, it is expected to volatilize quickly and, based on its log K_{oc} (adsorption coefficient) values of 1.28–1.62, to have very high mobility in soil surfaces, making it available for transport into groundwater (Borisover & Graber, 1997).

Table 32. Physicochemical properties of 1,2-dichloroethane

Physicochemical properties	Description
Vapour pressure	8700 Pa (at 20 °C)
Henry's law constant [a]	111 Pa·m^3/mol
Solubility in water	8.6–8.8 g/l (at 20–25 °C)
Hydrolysis and/or photolysis	Range: from weeks to more than 20 years
log K_{oc} (organic carbon–water) [b]	1.28–1.62
Octanol–water partition coefficient [c]	1.79 (calculated)
Bioconcentration factor [d]	2–10

[a] Henry's Law constants characterize the equilibrium distribution of dilute concentrations of volatile, soluble chemicals between the gaseous and liquid phases.
[b] K_{oc} is the organic carbon–water partition coefficient.
[c] The octanol–water partition coefficient is the ratio of the concentration of a chemical in octanol and in water at equilibrium and at a specified temperature.
[d] The bioconcentration factor is the ratio of a contaminant concentration in biota to its concentration in the surrounding matrix (water). It measures the tendency of a substance in water to accumulate in fish tissue or in tissues of other organisms.
Source: de Rooij et al. (1998); EC (2005b).

Little information is available on the characteristics of the soil in the Gela area, and this lack of data makes the process and path through which 1,2-dichloroethane can affect human health less clear. Information, however, is available on the pH, the cation exchange capacity and the percentage of organic carbon

(Pedron & Petruzzelli, 2009): the pH is mostly basic and the percentage of organic carbon is low mainly, while cation exchange capacity is highly variable between the different national sites of concern. No information exists about the texture of the soil, which is the most relevant parameter for understanding the fate of organic pollutants and of 1,2-dichloroethane.

For the organic contaminants, biodegradation by microbial flora is the main process regulating bioavailability in the soil. Some studies, however, have highlighted that, as the concentration of 1,2-dichloroethane increases in a soil surface, the degree of biodegradation that takes place may decrease due to microbial toxicity at the enhanced contaminant level (Regno, Arulgnanendran & Nirmalakhandan, 1998).

In an area as highly contaminated as Gela, possible pathways of contamination can also include the adsorption of the pollutants on the roots and leaves of plants. Substances with low K_{ow} (octanol water partition coefficient), such as 1,2-dichloroethane, could in principle be transported in the aerial parts of the plant. Also, volatilization losses occur at a much slower rate for 1,2-dichloroethane present in subsurface soil.

In groundwater and surface water, biodegradation is the primary degradation process for removing 1,2-dichloroethane, since abiotic degradation processes, such as oxidation and hydrolysis, are too slow to be environmentally significant. The biodegradation half-life of 1,2-dichloroethane in aerobic water was reported to be 100 days, and the half-life in anaerobic water was reported to be 400 days.

In the context of implementing the water framework directive (EU, 2006), 1,2-dichloroethane is a European priority substance for water environments, and it is important that all Member States take measures to reduce its emission from all sources of pollution by a certain deadline.

All the toxicological doses reported in the 1,2-dichloroethane profile (ATSDR, 2001), including acute data, are significantly lower than the levels detected.

In Italy, the legislative limits for 1,2-dichloroethane are regulated by three laws on:

- drinking-water (Parliament, 2001)
- groundwater (Parliament, 2006)
- soil (Parliament, 2006).

Discussion and conclusions

Research on correlations between environmental chemical pollution and the health status of a population is usually complex, because it is determined by many factors that include, among other things, the properties of the pollutants, the exposure pathways, the temporal range of contamination and the social status of the population. In the present study, preliminary simplified hazard assessments have been presented for several chemical substances detected in environmental matrices, and two case studies have been described briefly. The analysis of contamination of the environmental matrices in the Augusta–Priolo and Gela areas leads to the hypothesis that the resident population has been exposed to a series of contaminants, both through inhalation and ingestion – for example, through consumption of drinking-water and fish products. With the aim of adopting a precautionary approach, the maximum values detected were compared with the international and national limits and with the toxicity values of international organizations and institutions, such as WHO and the Agency for Toxic Substances and Disease Registry, to determine the hypothetical risk incurred by a population exposed to such contamination.

This preliminary hazard assessment has some unavoidable limitations, due to the lack of availability of certain data. In particular, only few data are available on the diet of the population (such as crops, zootechnical products and drinking-water). Such data are needed to elaborate a complete human health risk assessment, in compliance with procedures standardized at the international level. The evaluation of the contaminants in food represents the basis for the *exposure assessment* step of the risk analysis of chemical compounds (Granata et al., 2011). Also, few data on soil outside the perimeter of the site are available, making it difficult to evaluate the transport and environmental fate of the pollutants.

In some cases, for substances of major concern (such as 1,2-dichloroethane), levels of pollution that exceed all the national and international legislated limits have been detected. These exposure levels are related to analytical data detected in a certain period and in a specific sub-area. However, it is not possible to accurately determine the period of exposure, although we think this period has been long. Most of the data investigated are related to the period 2001–2006 but, for example, the contamination of deep levels of the sediment in the Augusta–Priolo area indicate that the pollution in the sea started some decades ago.

Another aspect to consider is that, over a period of years, the population was exposed to a mixture of pollutants, and there are no data available on the interaction and effects of exposure to such mixtures. This preliminary hazard assessment took into account only a limited number of compounds that are part of traditional monitoring programmes based on a list of substances included in legislation and alternative monitoring tools are needed (Fasulo et al., 2012). The substances have been selected on the basis of the quality of the data and of their presence in different matrices and on the extent to which they exceed the limits seen as protecting human health. In many cases, these limits are much higher than those needed to protect aquatic and terrestrial ecosystems.

The evaluation of the data available has permitted us to comment on the very high levels of contamination in the two areas examined – in particular, in the soil and groundwater within the boundaries of the sites of national concern. Over the years, this contamination has moved away from its point of origin. Many pollutants, due to their physicochemical properties, have moved and passed from one environmental matrix to another (from air to soil and to water). They have been carried by the wind or have interacted with groundwater and surface water and migrated to areas far away. In the Augusta–Priolo area, for example, the legislated health limits for fish and shellfish have been exceeded. This is a sign that the contamination has moved into the food-chain, thus increasing the number of people it potentially involves and affects.

In conclusion, the health of the people in these sites of national concern is at risk. We therefore believe that, in the areas investigated (taking into account the limits of the present study), there is evidence that remedial action – for example, the decontamination of groundwater resources – is urgently needed, in addition to existing actions (Musmeci et al., 2009). Also, we believe that, in the meantime, action is needed to communicate knowledge of the risk to the public, to protect vulnerable parts of the population. Furthermore, we believe that it is necessary to perform a risk assessment of the areas where agricultural activities can be done without creating a risk to consumers.

7. AIR QUALITY IN INDUSTRIAL AREAS: GENERAL PROBLEMS AND RESULTS FROM CASE STUDIES IN THE AUGUSTA–PRIOLO, GELA AND MILAZZO–VALLE DEL MELA AREAS

Gaetano Settimo

Introduction

The sites in the Augusta–Priolo, Gela and Milazzo–Valle del Mela areas with a heavy concentration of industrial activities — in particular, petrochemical operations — are often close to populated areas. This represents a series of critical issues, due to the possible presence of emissions of toxic pollutants and to the potential high concentration of several substances in the environment (such as polychlorinated dibenzo-*p*-dioxins and dibenzofurans, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and heavy metals). It is then important to correlate the atmospheric concentrations to a number of aspects of these industries: emissions; technological cycles and their related means of discharge; processing; and treated raw and intermediate materials. Data on diffuse emissions, (due mainly to moving and storing raw materials) and fugitive emissions (due to leaks from pumping units) agree with the environmental pressure on the areas in Sicily investigated. Organic and inorganic micropollutants (metals and heavy metals) are the most characteristic emissions, besides sulfur dioxide (SO_2) and nitrogen oxides. These emissions are related both to the processing of raw materials (including their movement and transportation) and to the combustion and treatment of effluents.

According to the data of the Italian National Inventory of Emissions and their Sources (INES), Sicily is the second region in Italy, after Puglia, with the highest industry-related emissions of nitrogen oxides, sulfur dioxide and benzene. Emissions of nitrogen oxides account for 32 568 tonnes a year, those of sulfur dioxide for 61 459 tonnes a year, and those of benzene for 140 823 kg a year (INES, 2006). In July 2009, the ARPA Sicily reported that 90% of arsenic, cadmium, mercury and nickel came from "industrial combustion" from large plants, such as power plants and refineries, located mostly in high-risk areas (Anzá et al., 2010). The European Commission reported that the main sources identified in the Augusta–Priolo area are tied to industrial activities (EC, 2010a). Also, the EU raised objections to the requested postponement of the mandatory application of daily and/or annual limit values for PM_{10} and nitrogen oxides. Objections were raised since there was no evidence that appropriate measures had been adopted within the time frame of the year 2005 or that such measures could be obtained by the year 2011, the deadline for the requested postponement (EC, 2010a).

The main objectives of this chapter are to:

- discuss the legislative framework within which air pollution monitoring in industrial areas is organized; and
- analyse the results of real cases of industry-related air pollution in the Augusta–Priolo (Province of Syracuse), Gela (Province of Caltanissetta) and Milazzo–Valle del Mela (Province of Messina) areas of Sicily.

The legislative framework for air pollution

It is important to discuss the laws and other legal tools applicable to contamination. In this context, Europe will be discussed, giving consideration to the differences that exist. The European experience, emerging from a long-term process and after some terrible disasters, is important when considering several issues, such as limits or target values for air pollutants.

One important reference for the evaluation of air quality — and the exposure of the population to air pollutants — is the values indicated by national norms. The Italian norm on the limitation of atmospheric pollutants from industrial plants refers in general to Legislative Decree 152/06 (Parliament, 2006). Three fundamental norms operate currently in the EU (EC, 1996a, 2008a,b). One relevant aspect is the concept of *best available techniques* (Parliament, 2006; EC, 2008a) (see also Chapter 15). The reference document guidelines for refineries were published by the European Commission (EC, 2003a). In Italy, a national reference document guideline was adopted in 2007 (Ministry of the Environment, Land and Sea, 2007). The number of pollutants regulated, however, is smaller than the number of those present in the atmosphere.

Different directives from the EU and subsequent national decrees have helped manage different air pollutants. In particular, the European Commission provided directives (EC, 1996a, 1999a, 2000a) to deal with air quality limit values for sulfur dioxide , oxides of nitrogen, (in particular, nitric oxide and nitrogen dioxide), PM_{10} and benzene. These directives were subsequently adopted by Ministerial Decree 60/02 (Ministry of the Environment and Territory & Ministry of Health, 2002), which also includes limit values for lead (see Table 33).

Table 33. Limit values for air pollutants in Italy

Pollutant	EU goal (attainment date)	EU limit or target value (averaging period)
Sulfur dioxide	Protection of human health (1 January 2005)	350 μg/m³ (1 hour) (not to be exceeded more than 24 times per calendar year) 125 μg/m³ (daily mean) (not to be exceeded more than 3 times per calendar year)
Sulfur dioxide	Protection of vegetation and natural ecosystems (19 July 2001)	20 μg/m³ (annual mean)
Nitrogen dioxide	Protection of human health (1 January 2010)	200 μg/m³ (hourly mean) (not to be exceeded more than 18 times per year) 40 μg/m³ (annual mean)
PM_{10}	Protection of human health (1 January 2005)	50 μg/m³ (daily mean) (not to be exceeded more than 35 times per calendar year) 40 μg/m³ (annual mean)
Lead	Protection of human health (1 January 2005)	0.5 μg/m³ (annual mean)
Benzene	Protection of human health (1 January 2010)	5 μg/m³ (annual mean)
Carbon monoxide	Protection of human health (1 January 2005)	10 mg/m³ (maximum daily 8-hour mean)

Source: Ministry of the Environment and Territory & Ministry of Health (2002).

The EU has also produced a directive on arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (EC, 2004a); these are known human carcinogens for which respective thresholds for damaging consequences to human health have yet to be identified (EC, 2004a). Table 34 shows values for arsenic, cadmium, nickel and benzo[*a*]pyrene in the PM_{10} fraction averaged over a calendar year, as regulated by the directive. EU Member States have to take all necessary measures, provided they do not incur excessive costs, to respect such target values by 31 December 2012.

The collection of information on total atmospheric depositions is among the objectives of the European Commission (EC, 2004a), even though there is no agreement yet on the limit values and/or target values for these depositions and on ways to contain them. However, having a monitoring station for the total deposition of arsenic, cadmium, nickel, mercury, and benzo[*a*]pyrene at least every 10 000 km^2 has been recommended. While waiting for the European Commission to normalize methodologies (CEN, 2009, 2010), the Italian National Institute of Health published *Methods for the determination of arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons in atmospheric depositions* (Menichini, Settimo & Viviano, 2006). Italy successively adopted this methodology in Ministerial Decree 152/07 (Parliament, 2007). For $PM_{2.5}$, European Directive 2008/50/EC (EC, 2008b) introduced new limit values (see Table 35).

Table 34. Target values for some human carcinogens in air [a]

Pollutant	Target value (ng/m^3)
Arsenic	6
Cadmium	5
Nickel	20
Benzo[*a*]pyrene	1

[a] These are measured as the total content in the PM_{10} fraction averaged over a calendar year.
Source: Parliament (2007).

Table 35. Limit values for $PM_{2.5}$ in Italy

Averaging period	Limit value (µg/m^3)	Margin of tolerance	Target date for limit value
Stage 1			
Calendar year	25	20% on 11 June 2008, decreasing on the next 1 January and every 12 months thereafter by equal annual percentages, to reach 0% by 1 January 2015	1 January 2015
Stage 2			
Calendar year	20 [a]	To be reached with no margin of tolerance	1 January 2020

[a] The limit value is to be reviewed by the European Commission in 2013 in light of further information on health and environmental effects, technical feasibility, and experience.
Source: Parliament (2010).

A forthcoming directive, expected before 2015 and currently under discussion, will apply the principle that the level of exposure to pollutants must be the lowest reasonably possible to achieve. This level was already introduced in 2004 and defined as: "the concentration in the environmental air fixed to avoid, prevent or reduce the negative effects for human health and the environment overall that needs to be achieved as much as possible within a certain period of time" (EC, 2004a).

Aspects of the regulations for air quality: heavy metals and polychlorinated dibenzo-*p*-dioxins and dibenzofurans

At the international level, WHO developed guidelines for the European Region on some atmospheric pollutants that have, according to scientific knowledge, adverse consequences for people (MacIntosh & Spengler, 2000). These consequences are sufficiently documented for non-carcinogenic substances and carcinogenic substances. Such guidelines and unit risks (some reported in Table 36) are among the tools that can be used to establish mandatory substance-related regulations; the WHO European Centre for Environment and Health periodically revises these guidelines.

Table 36. Estimates of the risk to people of carcinogenic pollutants

Pollutant	Estimated unit risk per lifetime[a]
Arsenic	1.5×10^{-3} $(\mu g/m^3)^{-1}$
Benzene	6×10^{-6} $(\mu g/m^3)^{-1}$
Hexavalent chromium	4×10^{-2} $(\mu g/m^3)^{-1}$
Nickel compounds	4×10^{-4} $(\mu g/m^3)^{-1}$
Benzo[*a*]pyrene[b]	9×10^{-2} $(\mu g/m^3)^{-1}$

[a] Cancer risk estimates for continuous lifetime exposure to a concentration of 1 $\mu g/m^3$.
[b] Expressed as benzo[*a*]pyrene (based on a benzo[*a*]pyrene concentration of 1 $\mu g/m^3$ in air as a component of benzene-soluble coke-oven emissions).
Source: WHO Regional Office for Europe (2000).

In areas potentially affected by emissions from combustion plants — considering all emissions from technological cycles — it is advisable to measure various air pollutants, even if not mandated by law. In the evaluation and characterization of an area, the choice of indicators of air quality has to also take into account a series of pollutants that, in most cases, are not yet part of national regulations. This choice of indicators has to include an evaluation of the technological cycle and definitions of the elements that represent the main hygienic and health concerns and also those that better characterize the specific technological cycle. Since hazardous metals (arsenic, cadmium, chromium, copper, lead, manganese, nickel, mercury, vanadium and zinc), polychlorinated dibenzo-*p*-dioxins and dibenzofurans, dioxin-like polychlorinated biphenyls, and polycyclic aromatic hydrocarbons come from the principal emission sources in the industrial areas, it may be worthwhile to characterize atmospheric depositions and their contents in terms of them.

Particularly strong attention should be given to micropollutants — organic and non-organic — because they could involve soil, water and, therefore, the food chain (SCF, 2000, 2001; SCAN, 2001; SCOOP, 2004; EC, 2006a, EFSA; 2010). The atmospheric deposition of polychlorinated dibenzo-*p*-dioxins and dibenzofurans on soil is the main factor responsible for the contamination of the food chain. For this reason, the measurement of the pollutants, measured with sediment meters, constitutes a good environmental control system. Polychlorinated dibenzo-*p*-dioxins and dibenzofurans are persistent organic pollutants. The Stockholm Convention on Persistent Organic Pollutants, not yet ratified by Italy, has the goal of reducing to a minimum the global emissions of these substances in the environment, because their toxicity is lasting and they represent a risk to human health and the environment, even when there are only traces of them in the atmosphere.

It is important to remember that polychlorinated dibenzo-*p*-dioxins and dibenzofurans have a similar chemical structure and physicochemical properties: polychlorinated dibenzo-*p*-dioxins include 75 different congeners and polychlorinated dibenzofurans include 135 different congeners, of which 17 are toxic (see Chapter 10). The 17 toxic cogeners have chlorine in the molecule in positions 2, 3, 7, 8.

To better confront the problem of evaluating the exposure to (and risk of) these components, equivalent toxicity factors have been calculated (such as the international toxicity equivalency factor, I-TEF) and compared with the most toxic cogener of the group (2, 3, 7, 8-tetrachlorodibenzo-*p*-dioxin). The I-TEF has been formally adopted in the EU and in other countries.

In areas with potential depositions from emissions from combustion plants, such as those in the Augusta–Priolo, Gela and Milazzo–Valle del Mela areas, it is necessary to monitor and measure such pollutants, following protocols utilized in other countries. In European countries other than Italy, such as Belgium and Germany (Van Lieshout et al., 2001; LAI, 2004; Cornelis et al., 2007), environmental legislation shows reference values for deposition of polychlorinated dibenzo-*p*-dioxins and dibenzofurans and dioxin-like polychlorinated biphenyls in air (Table 37).

Table 37. Reference values for dibenzo-*p*-dioxins, dibenzofurans and dioxin-like polychlorinated biphenyls

Country or region	Concentration in ambient air (fg WHO-TEQ/m^3, unless otherwise indicated)	Air deposition (pg WHO-TEQ/m^{2}day^{-1}, annual average)
Belgium [a]	–	10 pg I-TEQ/m^{-2}day^{-1}
Region Fiandre [b,c]	–	8.2
Germany [d]	150	4
United States [e]	600 fg I-TEQ/m^3	–
Japan [f]	600	–
Canada [g]	5 pg I-TEQ/m^3	–

I-TEQ: international toxic equivalents; WHO-TEQ: WHO toxic equivalents.
Source: [a] EC (1999a); [b] Cornelis et al. (2007); [c] VMM (2010); [d] LAI (2004); [e] ATSDR (1994); [f] Ministry of the Environment of Japan (1999); [g] Ontario Ministry of Environment and Energy (1985).

In Italy, starting in 1988, the National Consulting Committee for Toxicology of the Ministry of Health confronted these problems and indicated maximum tolerable limits for mixtures of polychlorinated dibenzo-*p*-dioxins and dibenzofurans, expressed in the international toxicity equivalency units of the United States Environmental Protection Agency of 1987. For ambient air, the maximum tolerable limit for this mixture is 40 fg/m^3 (Di Domenico, 1988). The growing attention on such micropollutants resulted in the implementation of many research and control initiatives; for some of these initiatives, it also resulted in a definition of objective of quality (EC, 2008b; Parliament, 2010). Therefore, it is essential that samples be assessed for weight and organic and inorganic pollutant concentrations. For Europe, the European Commission strategy for dioxins, furans and polychlorinated biphenyls (EC, 2001, 2004b, 2007, 2010b) is worth considering. This strategy points out the importance of monitoring polychlorinated dibenzo-*p*-dioxins and dibenzofurans and dioxin-like polychlorinated biphenyls. Some of the main strategy objectives are:

- to reduce human short-term exposure to polychlorinated dibenzo-*p*-dioxins and dibenzofurans and polychlorinated biphenyls and to maintain medium- and long-term safe levels for the latter;
- to reduce the effects on the environment of polychlorinated dibenzo-*p*-dioxins and dibenzofurans and polychlorinated biphenyls;
- to reduce human intake values below 14 pg WHO-TEQ/kg of body weight per week.

Monitoring, with the possibility of integrating diverse methods of sampling, allows the results to be checked and evaluated and the major areas involved in the depositions from emissions to be identified. Over a period of years, it also allows the correlations among the different pollutants to be studied and the exposure of the population to these pollutants to be evaluated. Moreover, collecting and examining data related to industrial emissions may allow a first evaluation of the quantities of micropollutants in the different areas. As much as possible, it is also important to take into account the evolution of industrial plants over the years, for both type of processing and the application of national norms (President of the Republic, 1988a; Parliament, 1990, 2005a, 2006). Although it may be possible to check and intervene for pollutants measured constantly by traditional monitoring stations, it is more difficult to evaluate the pollution produced by industrial emissions.

Areas under investigation in Sicily

The areas investigated in Sicily include the following.

- The Augusta–Priolo area, which represents the largest industrial area in Sicily, covers 550 km^2 and includes six municipalities: Augusta, Floridia, Melilli, Priolo Gargallo, Solarino and Syracuse.
- The Gela industrial area, of about 670 km^2 and about 1 km south-east of the Gela's urban area, includes the municipalities of: Gela (about 80 000 people), Niscemi (about 26 000 people) and Butera (about 5000 people).

- The Milazzo–Valle del Mela area covers 184.91 km^2 and includes seven municipalities: Condrò, Gualtieri Sicaminò, Milazzo, Pace del Mela, San Filippo del Mela, San Pier Niceto and Santa Lucia del Mela.

Tables 38 and 39 report the main production processes – petrochemicals and electric power, respectively – located in the areas studied, namely:

- five petrochemical—refinery plants: Ente Nazionale Idrocarburi (Eni) SpA in Gela; ERG SpA; ERG Nord and ERG Sud in Priolo (51% ERG SpA and 49% Lukoil Oil Company); Mediterranea Refinery plant in Milazzo (50% Kuwait Petroleum Italia and 50% Agip Petroli SpA); and ESSO in Augusta (100% Exxon Mobil Corp.) (Table 38);
- eight electrical power plants: Enel SpA in Priolo Gargallo and in Tifeo Augusta; Edipower in San Filippo del Mela (50% Edison SpA, 20% A2A SpA, 20% Alpiq Holding Ltd and 10% IREN Energia SpA); SONDEL SpA in Milazzo (60% Edison SpA, 40% Enipower SpA); Gela's thermoelectric central, located inside the Gela Refinery (which also uses petcoke as fuel);[9] ISAB Energy SRL in Priolo (51% ERG SpA Power & Gas Division, 49% Edison SpA); Group ERG (adjacent to the ERG SpA South Refinery); ERG SpA Nuove Centrali (New Centrals), with ERG Nord plants and ERG Sud plants located inside the Priolo Gargallo refineries (Table 39);
- base chemical plants: Polimeri Europa in Gela (100% Eni SpA) and in Augusta–Priolo (100% Eni SpA); Sasol Ltd plant in Augusta;
- one cement plant: Buzzi Unicem SpA in Augusta (production capacity: 1.2 Mtonnes/year; storage capacity: clinker (the incombustible residue, fused into a lump, that remains after the combustion of coal) 40 000 t, cement 23 000 t);
- one incinerator plant: for hazardous and nonhazardous waste and for municipal solid waste (GESPI SRL in Augusta; capacity: 60 000 t/year);
- one metal recovery plant: Ecological Scrap Industry SpA in Giammoro (capacity: 33 000 t/year);
- one closed asbestos plant: Eternit SpA; and
- other lesser activities.

Air quality in the Augusta–Priolo area

Law No. 349 of 8 July 1986 (Parliament, 1986), which officially recognized a number of high-risk areas across Italy, and the decree passed in January 1995 (Parliament, 1995) have helped to define an environmental remediation plan for the land included in the definition of high-risk area in environmental crisis.

The high-risk Augusta–Priolo area is monitored by three air quality monitoring systems, belonging to three different institutions (Table 40), as follows.

1. The Province of Syracuse has 10 stations for chemical parameters (6 of them also provide meteorological parameters): Scala Greca, Augusta, Ciapi, Priolo, Melilli, San Cusumano (also measuring chlorine), Belvedere, Priolo Scuola, Belvedere Castello and Augusta Monte Tauro.
2. CIPA has 12 stations for chemical parameters (3 of them also provide meteorological parameters): San Focà, Brucoli, Belvedere, Floridia, Faro Dromo, Oligastro, Villasmundo, Melilli, Syracuse, Bondifè, Augusta and CIPA.
3. Enel SpA has seven stations for chemical parameters (one also provides meteorological parameters): Syracuse, Floridia, Sortino, Priolo (Mostringiano), Melilli, Villasmundo and Priolo (power plant).

Awaiting the Sicily Region's establishment of an environmental remediation plan, in March 2005, the Province Syracuse, the Municipality of Syracuse, and Syracuse's Department of ARPA Sicily agreed on preventing the emission peaks of environmental pollutants: sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, benzene and PM_{10}.

9 Petcoke or petroleum coke is a black solid obtained mainly by cracking and carbonizing petroleum derived feedstocks in oil refinery coker units or other cracking processes. Other coke is traditionally derived from coal.

Table 38. Petrochemical plants in the three high-risk areas of Sicily and their capacity

Company plants	Nominal capacity
Augusta–Priolo petrochemical site	
ERG Priolo Gargallo, ERG Nord and ERG Sud	
Refinery	11.4 + 8.0 Mtonnes/year
Storage	4 million m^3
ESSO Refinery Augusta	
Refinery	8.9 Mtonnes/year
Storage	3 million m^3
SASOL Ltd Augusta	
Refinery:	1.12 Mtonnes/year
Paraffins	0.65 Mtonnes/year
Olefines	0.22 Mtonnes/year
Alcohol	0.13 Mtonnes/year
Other	0.12 Mtonnes/year
Polimeri Europa	
Ethylene	0.75 Mtonnes/year
Typical feedstock mixture:	
Ethane	2%
Butane	1%
Naphtha	65%
Gas oil	32%
Gela petrochemical site	
Eni SpA	
Refinery	5.3 Mtonnes/year
Storage	1.36 million m^3
Coke storage	0.09 Mtonnes/year
Liquefied petroleum gas	0.08 Mtonnes/year
Distillates	3.20 Mtonnes/year
Fuel oil and petcoke	0.90 Mtonnes/year
Polimeri Europa	
Ethylene	0.25 Mtonnes/year
Typical feedstock mixture:	
Ethane	25%
Propane	5%
Naphtha	70%
Milazzo petrochemical site	
Mediterranea Refinery	
Refinery	9.8 Mtonnes/year
Storage	3.75 million m^3

Mtonnes: a million metric tonnes.
Source: Unione Petrolifera (2011).

Table 39. Electrical power plants in the three high-risk areas of Sicily

Company and location	Electrical power (MW_e, unless otherwise indicated)	Fuels
Eni SpA in Gela 1 Gela 2	1691 (MWt) 252	Multiple fuels or petcoke
Enel SpA in Priolo Gargallo	790	Natural gas
ERG Nuove Centrali in Priolo Gargallo	552	Natural gas
ISAB Energy SRL in Priolo Gargallo	570	Asphalt feed for gasification
Enel SpA in Tifeo Augusta	210	Fuel oil
ESSO in Augusta	76	Natural Gas-Fuel oil
Edipower in San Filippo del Mela	1280	Fuel oil
SONDEL SpA in Milazzo	160	Natural gas

Source: Various sources adapted from company web sites.

Table 40. Air-quality monitoring in the industrial area of the Province of Syracuse

Monitoring station	Type[a]	Measurement												
		CO	C_6H_6	CH_4	PM_{10}	Pb	SO_2	O_3	H_2S	Non-CH_4 HC_s	NO	NO_x	NO_2	Meteo rological
Scala Greca	IU	—	—	X	—	—	X	X	X	X	X	X	X	X
Augusta	IS	—	—	X	X	—	X	—	X	X	X	X	X	—
Ciapi	IS	X	—	X	X	—	X	—	X	X	X	X	X	X
Priolo	IS	—	X	X	X	—	X	X	X	X	X	X	X	—
Melilli	IS	—	—	X	X	—	X	X	X	X	X	X	X	X
San Cusumano	FR	—	X	X	X	—	X	X	X	X	X	X	X	X
Belvedere	IU	—	—	X	X	—	X	—	X	X	X	X	X	—
Priolo Scuola	M	—	—	X	—	—	—	—	—	X	—	—	—	X
Belvedere Castello	M	—	—	—	—	—	—	—	—	—	—	—	—	X
Augusta Monte Tauro	M	—	—	—	—	—	—	—	—	—	—	—	—	X

Abbreviations: CO: carbon monoxide; C_6H_6: benzene; CH_4: methane; PM_{10}: particulate matter with an aerodynamic diameter smaller than 10 µm; Pb: lead; SO_2: sulfur dioxide; O_3: ozone; HS: hydrogen sulfide; Non-CH_4 HC_s: non-methane hydrocarbons; NO: nitrogen monoxide; NO_x: nitrogen oxides; NO_2: nitrogen dioxide.
[a] Type of station: IU: urban–industrial; IS: suburban–industrial; FR: rural district; M: meteorological.
Note. X indicates the presence of a monitoring station and the long dash indicates its absence.
Source: Adapted from Regional Province of Syracuse (2010) data.

After 2005, the Province of Syracuse issued reports on air quality that cover various pollutants monitored in its industrial area, such as sulfur dioxide (Table 41) and PM_{10} (Table 42).

Table 42 shows data on PM_{10} for a number of monitoring stations. With regard to these data, some comments follow.

- In 2006, the Belvedere station recorded a daily value higher than 85 µg/m^3, in addition to other daily values higher than 60 µg/m^3; in 2007, it recorded a daily value of 200 µg/m^3, in addition to other daily values higher than 100 µg/m^3; and in 2008, it recorded a daily value higher than 100 µg/m^3.
- In 2006, the Melilli station recorded a 100 µg/m^3 daily value; in 2007, it recorded daily values of 195, 133 and 90 µg/m^3; and in 2008 it recorded daily values of 125, 94 and 99 µg/m^3. The number of daily peak values exceeding 50 µg/m^3 shows an increasing trend, from 3 occurrences of values exceeded in 2005 to 20 in 2007, and 17 in 2008.
- In 2006, the Augusta station recorded a daily value of 135 µg/m^3; in 2007, it recorded four daily values of 275, 201, 160 and 129 µg/m^3; and in 2008, it recorded three daily values of 125, 110 and 101 µg/m^3.
- In 2006, the Priolo station recorded a daily value of 111 µg/m^3; in 2007, it recorded daily values of 199 and 105 µg/m^3; and in 2008, it recorded a daily value of 106 µg/m^3.
- In 2005, the Ciapi station recorded three daily values higher than 50 µg/m^3; in 2006, it recorded three daily values higher than 100 µg/m^3, in addition to other daily values higher than 60 µg/m^3; in 2007, it recorded daily values of 263 and 120 µg/m^3; while in 2008 it recorded three daily values of 142, 101 and 102 µg/m^3.

- In 2006, the San Cusumano station recorded a daily value of 74 μg/m[3]; while in 2007, it recorded two daily values of 168 and 142 μg/m[3].
- Also, the whole Augusta–Priolo (Province of Syracuse) monitoring system quantified the PM_{10} concentration without measuring the relative composition of metals.

Table 41. Sulfur dioxide monitored in the Province of Syracuse

Monitoring station	Year	Recorded hourly peak values exceeding 350 μg/m³ (maximum value, in μg/m³)	Annual average concentration (in μg/m³)
San Cusumano	2005 2006 2007 2008	18 peak values (maximum: 483) 7 peak values (maximum: 738) 2 peak values (maximum: 482) 5 peak values (maximum: 505)	18.0 19.9 15.5 14.0
Melilli	2005 2006 2007 2008	1 peak value (maximum: 417) 1 peak value (maximum: 378) 2 peak values (maximum; 565) No peaks	14.0 15.0 13.5 10.0
Belvedere	2005 2006 2007 2008	No peaks No peaks 1 peak value (maximum: 384) No peaks	10.0 8.2 8.6 7.0
Augusta	2005 2006 2007 2008	No peaks No peaks No peaks No peaks	3.5 3.1 2.8 2.0
Ciapi	2005 2006 2007 2008	No peaks No peaks No peaks No peaks	1.7 2.2 1.6 3.0
Priolo	2005 2006 2007 2008	No peaks No peaks No peaks No peaks	7.9 9.9 6.1 6.0

Source: Adapted from Regional Province of Syracuse (2010) data.

Table 42. PM_{10} monitored in the Province of Syracuse, 2005–2008

Monitoring station	Number of times daily limit (50 μg/m³) exceeded				Annual average (in μg/m³)			
	2005	2006	2007	2008	2005	2006	2007	2008
Augusta	1	8	35	25	20	21	29	29
Ciapi	3	51	34	35	25	33	31	29
Priolo	3	15	18	19	23	25	25	24
Melilli	3	16	20	17	20	24	25	24
San Cusumano	2	13	17	6	21	21	24	19
Belvedere	3	16	18	20	23	25	26	26

Several times, during the years 2005–2007, the mean hourly information threshold and mean hourly alarm threshold for ozone were exceeded – particularly in 2006 (Table 43).

Table 43. Ozone monitored in the Province of Syracuse industrial area, 2005–2008

Monitoring station	Number of times mean hourly information threshold (180 µg/m³) exceeded				Number of times mean hourly alarm threshold (240 µg/m³) exceeded			
	2005	2006	2007	2008	2005	2006	2007	2008
Priolo	1	11	5	0	0	2	0	0
Melilli	19	81	34	7	2	17	10	1
San Cusumano	14	51	14	3	0	5	1	0
Scala Greca	0	0	1	0	0	0	0	0

Air quality in the Gela area

By decree, Gela was defined as a high-risk area in 1995 (Parliament, 1995). The 2005 environmental remediation plan for the Sicily Region stated that the presence of the industrial high-risk petroleum area was undoubtedly the determining factor that degraded the air quality in the area. Also, despite the presence of a great number of monitoring stations with good territorial coverage, the geographical location of the monitoring network for air quality evaluation had reliability problems with past measurements and the parameters monitored. Many of the pollutants to be monitored were already indicated 15 years ago. According to the decree (Parliament, 1995), areas with a major dispersion of all pollutants on the soil were: areas located north-east and south-west of Gela (close the high-risk petrochemical area and partially in Gela's urban area). It is possible that even if emissions remained within limit values that this situation could not ensure air quality protection (Parliament, 1995). The same decree stated that the petrochemical plant was a source of sulfur dioxide, nitrogen oxides and particulate matter that adversely effected air quality.

Also, micropollutants emitted by combustion plants included benzene, polycyclic aromatic hydrocarbons, lead, copper, vanadium, nickel and chromium (Parliament, 1995). The dispersion and concentration of these micropollutants cannot be evaluated overall, because of the lack of systematic and reliable monitoring.

In the decree (Parliament, 1995), a periodic monitoring programme on organic and inorganic pollutants was scheduled; also, periodic analysis of substances, both organic and inorganic, were to be carried out, in summer and winter, for one whole week at every site. The areas to be monitored were those close to urban areas and those close to the high-risk petrochemical area, where the diffusion models indicated major depositions of pollutants on soil. Environmental monitoring had to determine, at least, concentrations of volatile organic compounds (from benzene to isopropylbenzene) and inorganic substances (silica, lead, manganese, nickel, mercury, brome and vanadium) (Parliament, 1995).

Nowadays, in the Gela area, the Province of Caltanissetta controls the air quality monitoring network. In 1982, this network initially consisted of three stations, named: Agip Mineraria, Giardino Comunale and Parco Rimembranze. Despite some deficiencies, this network acquired a series of important data relevant to a first evaluation of the area's environmental situation, aiding in identifying possible critical situations that must be investigated and managed. In successive years, the network incorporated six more stations: five for chemical parameters and one for meteorological parameters (Table 44).

Also the Eni SpA Gela Refinery has its own air quality monitoring network, consisting of eight fixed stations: six for chemical parameters and two for meteorological parameters. Data collected by the network's meteorological stations have shown winds mainly blowing from the south-west and north-east and, in hours of inversion, winds coming from south-south-east, carrying pollutants from the high-risk petrochemical area to Gela's urban area.

Table 44. Monitoring system of air quality in the urban area of Gela

Monitoring station	Type[a]	Measurement									
		CO	C_6H_6	PM_{10}	SO_2	O_3	Non-CH_4 HC_s	NO	NO_x	NO_2	Meteorological
Gela											
Via Venezia	TU	X	—	X	X	X	X	X	X	X	—
Via Minerbio–Macchitella	TU	X	—	—	X	—	—	—	—	—	—
Agip Mineraria	IS	—	—	X	X	—	—	X	X	X	—
Agip Pozzo 57	IR	—	—	—	X	—	—	—	—	—	—
Cimitero Farello	IS	—	—	—	X	—	—	—	—	—	—
Ospedale di Gela–Via Palazzi	TU	X	X	X	—	X	X	X	X	X	—
Contrada da Piano Notaro–Via delle Ande	NA	—	—	—	—	—	—	—	—	—	X
Niscemi											
Liceo Scientifico	TU	—	—	—	X	—	—	—	—	—	—
Via Gori	TU	X	—	—	—	—	—	X	X	X	—

Abbreviations: CO: carbon monoxide; C_6H_6: benzene; PM_{10}: particulate matter with an aerodynamic diameter smaller than 10 µm; SO_2: sulfur dioxide; O_3: ozone; Non-CH_4 HC_s: non-methane hydrocarbons; NO: nitrogen monoxide; NO_x: nitrogen oxides; NO_2: nitrogen dioxide; NA: not applicable.
[a] Type of monitoring station: TU:Traffic Urban, IR:Industrial Rural, IS:Industrial Suburban.
Note. X indicates the presence of a monitoring station and the long dash indicates its absence.
Source: Settimo, Mudu & Viviano (2009).

Following requests from the general public in the last few years, new PM_{10} monitoring devices have enhanced the monitoring network. Table 45 shows a comparison of air quality data with current legislative limits for sulfur dioxide and PM_{10} for the years 2000–2007. In Table 45, the air monitoring statistics show low annual average values, but the presence of high peak measurements. With regard to sulfur dioxide – considered the main marker for pollution of industrial origin – a series of hourly peaks were recorded. In particular, the Agip Mineraria monitoring station recorded the highest concentrations of sulfur dioxide in the network – perhaps because of the large amount of pollution from industrial plants and the meteorological conditions in the area.

The data on benzene, which was measured only by one station (Ospedale di Gela–Via Palazzi), show a reduction in the pollutant over the years. Since 2002, the values recorded have been within the limit of 5 µg/m^3 (effective until January 2010). With regard to ozone, recorded at the Ospedale di Gela–Via Palazzi station, the analysis of a series of data recorded between 2000 and 2007 shows an increase in mean concentrations. The pollutants involved in ozone production are volatile organic compounds and nitrogen oxides, the source of which is mainly industrial plants and vehicular traffic in urban areas.

The only metals regulated by law are: lead (Parliament, 1983), arsenic, cadmium and nickel (Parliament, 2010). In Gela's air quality monitoring network, metals have never been systematically measured. With regard to lead, since January 2002, in Italy, the use of leaded gasoline is no longer allowed, and lead emissions from the industrial sector have been reduced.

Table 45. Gela monitoring stations: peak values for sulfur dioxide and PM_{10}, 2000–2007

Substance and station	Year	Recorded hourly peak values (μg/m³)[a]	Annual average (μg/m³)
Sulfur dioxide			
Via Venezia	2000	No peaks	1
	2001	No peaks	2
	2002	No peaks	1
	2003	No peaks	3
	2004	No peaks	2
	2005	No peaks	3
Agip Mineraria	2000	13 peak values (maximum: 818)	12
	2001	2 peak values (maximum: 500)	6
	2002	26 peak values (maximum: 887)	10
	2003	27 peak values (maximum: 795)	11
	2004	104 peak values (maximum: 1445)	21
	2005	–	6
	2006	3 peak values (maximum: 407)	7
	2007	2 peak values (maximum: 534)	8
PM_{10}			
Ospedale di Gela–Via Palazzi	2000	--	30[b]
	2001	4 peak values (maximum: 172)	23
	2002	14 peak values (maximum: 119)	29
	2003	28 peak values (maximum: 150)	35
	2004	19 peak values (maximum: 165)	33
	2005	11 peak values (maximum: 71)	29
	2006	No peaks	31
	2007	No peaks	33

[a] Recorded hourly peak values exceeding 350 μg/m³ for sulfur dioxide and 50 μg/m³ for PM_{10} are shown.
[b] In 2000, PM_{10} values were recorded for only 6 months, so the mean value given is for these 6 months.
Source: Adapted from unpublished raw data from the Province of Caltanissetta.

Air quality in the Milazzo–Valle del Mela area

On 4 September 2002, the Sicily Region issued a regional decree that established a high-risk area in the Milazzo–Valle del Mela district, which included the municipalities of Condrò, Gualtieri Sicaminò, Milazzo, Pace del Mela, San Filippo del Mela (Province of Messina), Santa Lucia del Mela and San Pier Niceto (Sicilian Region Department of Land and Environment, 2002).

Awaiting the start of the remediation plan, the Regional Special Office issued an important decree on September 2006 – "Remediation plan for air quality within the framework of the remediation plan of the high-risk area of the Mela District" – that lists the first set of actions to be taken (Sicilian Region Department of Land and Environment, 2006). The Regional Special Office also reported that the effectiveness of the intervention provided by the present measure will be verified a year after the start of operation of the interconnected monitoring system and that the intervention will be revised based on the experience acquired. Further administrative actions established by the Region followed. These actions aimed at introducing interventions that prevent and self-regulate emissions. Also, these actions were to be taken by the Edipower plant and Milazzo refinery as soon as pre-alarm, alarm and emergency threshold limits were exceeded.

The high-risk Milazzo–Valle del Mela area is controlled by four monitoring systems that belong to four different bodies (see Table 46):

1. Messina Province: six stations for chemical parameters: San Filippo del Mela (Archi), Condrò, Santa Lucia del Mela, Port of Milazzo, Pace del Mela Mandravecchia and Pace del Mela Giammoro;
2. ARPA Sicily: three stations for meteorological parameters, including two stations for chemical parameters: San Pietro di Milazzo Contrada Carrubbo and Zona Industriale Giammoro Contrada Gabbia;
3. Edipower: five stations for chemical parameters: Valdina Via Perre, San Pier Niceto, San Filippo del Mela, Pace del Mela and Milazzo Via Croce a Mare; and

4. Milazzo Mediterranea Refinery: two stations for chemical parameters.

Even if some data are missing, as is the case in the Gela area, the monitoring network allows an initial overview of the environmental situation, indicating the main problems with which authorities should deal. So far, it is still difficult to understand if the air quality monitoring systems active in the area are interconnected.

Table 46. Monitoring system of air quality in the industrial area of Milazzo–Valle del Mela

Monitoring station	Type[a]	Measurement												
		CO	C_6H_6	CH_4	$PM_{10}/PM_{2.5}$	Pb	SO_2	O_3	H_2S	Non-CH_4 HC_s	NO	NO_x	NO_2	Meteorological
San Filippo del Mela (Archi)	IU	—	X	—	—	—	X	—	X	—	X	X	X	X
Condrò	IR	—	—	—	—	—	X	—	—	—	—	—	—	X
San Filippo del Mela	IR	X	—	—	X	—	X	X	—	—	X	X	X	X
Santa Lucia del Mela	IR	—	—	—	—	—	X	—	—	—	X	X	X	—
Port of Milazzo	IU	X	—	—	X	—	X	X	—	X	X	X	X	X
Milazzo via Croce a Mare	IU	X	—	—	X	—	X	X	—	—	X	X	X	—
Valdina Via Perre	IU	X	—	—	X	—	X	X	—	—	X	X	X	X
Pace del Mela Giammoro	IU	—	X	—	—	—	X	—	—	—	—	—	—	—
Pace del Mela Mandravecchia	IR	—	—	—	—	—	X	—	—	—	X	X	X	X
San Pietro di Milazzo Contrada Carrubbo	BS	X	X	X	X	—	—	X	—	X	X	X	X	X
San Pier Niceto	IU	X	—	—	X	—	X	X	—	—	X	X	X	X
Zona Industriale Giammoro Contrada Gabbia	BS	X	X	—	X	—	X	X	—	—	X	X	X	X
Mediterranea Refinery 1 and 2	IU	—	—	—	—	—	—	—	—	X	—	—	—	—

Abbreviations: CO: carbon monoxide; C_6H_6: benzene; CH_4: methane; PM_{10}: particulate matter with an aerodynamic diameter smaller than 10 µm; Pb: lead; SO_2: sulfur dioxide; O_3: ozone; HS: hydrogen sulfide; Non-CH_4 HC_s: non-methane hydrocarbons; NO: nitrogen monoxide; NO_x: nitrogen oxides; NO_2: nitrogen dioxide; NA: not applicable.
[a] Type of monitoring station: IU: Industrial Urban, IR: Industrial Rural, IS: Industrial Suburban, SB: Background Suburban.
Note. X indicates the presence of a monitoring station and the long dash indicates its absence.
Source: Adapted from Sicilian Region Department of Land and Environment (2006).

The Sicily Region Special Office reported that the available monitoring data do not allow a full description of the contamination levels for each pollutant in the high-risk Milazzo–Valle del Mela area. The data available do not allow either air quality characterization or exposure risk categorization for residents and ecosystems. Moreover, average concentrations of sulfur dioxide that exceeded acceptable limits coincided with high sulfur dioxide maximum hourly values – mostly in summer and when particular meteorological conditions caused air stagnation. Additional attention is needed to continuously survey other parameters, such as ozone, nitrogen oxides, PM_{10}, $PM_{2.5}$, polycyclic aromatic hydrocarbons, benzene, volatile organic compounds and toxic metals (Triolo et al., 2008). From 2002, the total mass flows of pollutants show a general decline, but these pollutants still alter the normal environmental conditions and healthiness of the air in the high-risk area. The health risk to the population due to these pollutants and the risk to the ecosystems involved still remain.

In 2005, ARPA Sicily reported that the available air quality monitoring data do not allow a full description of the contamination levels for each pollutant (ARPA Sicily, 2005). The analysis of available information shows a relevant lack of measuring equipment, which makes the available data statistically irrelevant. In the last few years, air pollution monitoring has further deteriorated, because of equipment obsolescence and because the subsequent ordinances for further pollutants to be monitored was followed by no system adjustment.

In summary, some historical series are available for the high-risk Milazzo–Valle del Mela area, but they are useful only for two parameters: sulfur dioxide and particulate matter. Little is known, however, about the other pollutants included in the law in force.

In the closing remarks of the document entitled *Air pollution campaign through mobile laboratory measurement in Milazzo Municipality, Acque Viole, 08/03/2009–03/07/2009*, ARPA Sicily mentioned frequent hourly average concentration values for non-methane hydrocarbons, a consequence of the high values of the volatile organic compounds (ARPA Sicily, 2009a). Since these hourly average concentration values are highly abnormal and can be attributed to the activity of the Mediterranea Refinery, they represent a pollution sign that should be monitored, both for the olfactory nuisance that some of these non-methane hydrocarbons present and, most of all, for their adverse effects on health.

In the high-risk Milazzo–Valle del Mela area, collecting information and air quality data is difficult. Therefore, it is not possible to make any recommendation.

Conclusions

Well-known oil and energy multinationals and their associated companies, plus a few large national industrial operators are the main industrial actors in the three Sicilian high-risk areas of Augusta–Priolo, Gela and Milazzo–Valle del Mela. Data collected for these areas suggest that type, number of plants and potential production taking place are likely to have a significant adverse effect on the surrounding environment. Measurements performed by the air quality monitoring systems available have shown both critical aspects and exceeded national legislated limits for some of the pollutants (sulfur dioxide, PM_{10}, nitrogen dioxide and ozone) (Parliament, 2002).

Although the legislation for air pollution caused by many substances has been in force since the 1980s, a great deal of data on these substances has never been collected. Still, in 2009, ARPA Sicily reported that the fragmentation of the jurisdiction over the monitoring system causes lack of homogeneity of data management and transmission, making data unreadable and unusable (ARPA Sicily, 2009b). Also, although the law in force requests it (Parliament, 2010), further studies on air pollution are needed, particularly for the most critical pollutants or the ones that are not systematically monitored, such as $PM_{2.5}$, polycyclic aromatic hydrocarbons, heavy metals and ozone precursors.

Moreover, it appears that the sampling and analysis of lead and other metals have never been systematically performed, and such data gaps do not allow comparisons with the national law in force (Parliament, 2002). It is desirable that, in pursuance of recent Legislative Decree 155/10 (Parliament, 2010), the monitoring and analysis of such metals be assured. Monitoring the organic micropollutants polychlorinated dibenzo-*p*-dioxins and dibenzofurans, dioxin-like polychlorinated biphenyls, and polycyclic aromatic hydrocarbons was already planned in the old land remediation plan for the Gela and Augusta–Priolo areas, but the data from monitoring campaigns are not available. Considering the critical aspects of the three areas, it is of primary importance to better monitor the environment by optimizing the existing monitoring system (ARPA, provinces, municipalities, regions) and by installing $PM_{2.5}$ deposimeters and also monitors for heavy metals, polychlorinated dibenzo-*p*-dioxins and dibenzofurans, dioxin-like polychlorinated biphenyls, and polycyclic aromatic hydrocarbons. Particularly strong attention should be given to micropollutants, because organic and inorganic micropollutants accumulate in the environment, and this can adversely affect the population exposed, in terms of inhalation and ingestion (see Chapters 10 and 11).

8. SOCIOECONOMIC ENVIRONMENT: THE INDUSTRIALIZATION MODEL OF SICILIAN HIGH-RISK PETROCHEMICAL AREAS

Guido Signorino, Marina La Rocca and Elisa Gatto

Introduction

The aim of this chapter is to use the industrialization model to frame public health investigations of the three high-risk petrochemical areas of Sicily. The analysis proposed supports an evaluation of the socioeconomic sustainability of the industrialization model.

The relationship between economic factors and health has been considered from a number of perspectives. Several epidemiological studies have analysed in depth the theoretical and empirical aspects of deprivation, particularly in relation to *small areas* (Jarman, 1983; Bithell et al., 1995; Costa, Spadea & Cardano, 2004; Grisotto et al., 2007; Biggeri & Grisotto, 2009). In general, evidence shows that greater socioeconomic deprivation leads to worse health (Eibner & Evans, 2005; Subramanian & Kawachi, 2006). Similarly, low levels of economic development (in terms of gross domestic product per person) and of public intervention, as well as a less equitable income distribution, all produce less favourable outcomes for poorer communities (Xu, 2006). Also, beyond (and independent of) the effects of individual characteristics, the socioeconomic features of an area affect personal health (Wen, Browning & Cagney, 2003). On the other hand, in as much as health conditions affect people's productivity and their ability to adapt technology (Ersado, Amacher & Alwang, 2004 – as far as agriculture is concerned), the health of local populations should be carefully considered when assessing development projects.

Relatively little attention has been given to analysing macroeconomic conditions that can affect human health through their joint effect on the environment and society. Only recently have attempts been made to view the importance of local economic development patterns and structural changes to the evolution of population health (La Rocca, 2010). Assuming this orientation, the present chapter argues that actual development paths for territorial units are often the result of policy options that determine the socioeconomic *milieu* of a territorial unit and its productive organization; the choice of such options also affects the environment and public health.

Framing a territory's economic dynamics and assessing its development model help to deepen the analysis of the relationship between socioeconomic conditions and health. In this light, referring to the three high-risk petrochemical areas of Sicily, we propose:

- a dynamic analysis of the local productive organization that investigates, in particular, the evolution of the labour market (employment and migration) and that assesses the long-term socioeconomic sustainability of the petrochemical *industrialization model*; and
- a brief description of *sustainability* and of the data and methods used to conduct socioeconomic sustainability analysis.

Assessing the socioeconomic sustainability of the industrial model

According to the Brundtland Report, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition "contains within it two key concepts: the concept of 'needs' … and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs" (World Commission on Environment and Development, 1987:54).

Both human needs and environmental equilibrium are strongly related to human well-being and public health. This relationship makes it is possible to consider human health and sustainability as equivalent concepts (Griffith, 2006).

In general, industrial development has a twofold mixed effect on sustainability and human health: (a) given its effects on total productivity, it increases socioeconomic well-being and the effectiveness of public and private health expenditure and assistance; (b) however, given the degree to which it consumes natural resources and emits pollutants, it damages the environment and public health.

Similarly, the effects of petrochemical development on local and national economies are mixed and controversial. Structural change (Adelman, 2000), the transition to science-based production (Wright & Czelusta, 2004; Hemais, Barros & Rosa, 2005), the attraction of foreign investment (Omran & Bobol, 2003; Sánchez-Gil et al., 2004), and the construction of new competitive advantages on the international market (Teece, 1991; Chu, 1994) are all generally regarded as the principal positive contributions of the petrochemical industry to local and national socioeconomic development. On the other hand, given its level of capital intensity, the expansion of the petrochemical industry worsens income distribution, displaces traditional local activities (such as food and beverages, textiles and leather goods, wood products, paper products, and printing) and reduces the proportion of revenues that remains in the local area. Also, it is one of the main sources of pollution in the entire manufacturing sector and produces long-term adverse effects on human health. However, as far as the long-term adverse effects on human health are concerned, the short- and medium-term socioeconomic advantages of industrialization could be perceived as overcompensating for the increased risk to health, so that the construction of new petrochemical plants is often encouraged by local administrations and welcomed by populations, especially in low-income regions.

Other chapters in this book aim to deepen the understanding of the adverse effects of the petrochemical industry on human health in the three areas studied (see Chapters 5 and 9). In stressing the dynamic content of the concept of sustainability, the present chapter suggests a simple method of assessing the socioeconomic sustainability of the *petrochemical development model*. The interactive effect of members of different generations on sustainability suggests that sustainable development is development that maintains its socioeconomic benefits over time. Moreover, environmental and natural resource economists stress the need of *greening* national environmental accounting and the measurement of sustainable development, so as to consider the depletion of natural resources in the evaluation of national wealth and to estimate the actual ability of domestic productive systems to guarantee “non-decreasing utility – or consumption – over time” (Asheim, 1996; Asheim & Buchholz, 2004). More generally, development is sustainable from a socioeconomic perspective, if it does not diminish well-being over time.

Given that growth in occupational opportunities and reduced emigration were among the main goals (and major expectations) of industrialization policies in Sicily in the 1950s, the following sections discuss three aspects of the productive and social transformation that occurred locally due to the establishment of the petrochemical industry:

- the industrialization model in terms of the dynamic *specialization* of local economies, measured by the relative weight of petrochemicals within the local manufacturing sector and compared with the economies of Sicily and Italy;
- the effects of industrialization in terms of the evolution of sectoral occupational performances; and
- the effectiveness of petrochemical industrial development policies in inhibiting emigration, compared with the industrial policies of the whole of Sicily.

The first aspect is illustrated by comparing trends in local data with regional or national trends, to obtain a quantitative description of the size and magnitude of the local economy’s pattern of specialization in petrochemical activities. The labour force for this industrial sector is used to construct economic specialization indices, such as localization quotients (*LQ*s) (Isard et al., 1998) and manufacturing specialization indexes (*MSI*). Both measures are obtained by comparing the local sectoral employment rate with the regional or national sectoral employment rate as follows:

$$LQ = (E_{iL}/E_{L})/(E_{iR,N}/E_{R,N}) \text{ and}$$

$$MSI = (E_{iL}/E_{mL})/(E_{pR,N}/E_{mR,N}),$$

where E_i indicates employment in activity i; E indicates total employment; the suffixes L, R, N indicate, respectively, the local, regional or national system; E_m indicates employment in the manufacturing sector of the economy and E_p indicates employment in the petrochemical sector of the economy.

Values for *LQ* or *MSI* greater than one imply the percentage of the local labour force employed in the *i*th activity is larger than the same percentage at a higher scale (region or country), indicating that the activity under analysis represents a specialization sector for the local economy. Using census data from 1951 to 2001, 10-year-interval specialization indices are calculated in this chapter, to assess the local dynamics of specialization of the three high-risk areas of Sicily in the petrochemical sector.

To describe the occupational results of the petrochemical industrialization process, data on sectoral employment are compared with total and manufacturing employment rates. Moreover, the ratio of petrochemical employment to total and manufacturing employment is presented and discussed.

Given that industrialization generated expectations of a significant reduction in emigration, the effects of the economic dynamics are investigated by: (a) relating petrochemical employment and net migration paths within the three high-risk areas; (b) comparing migration dynamics of the three areas with the rest of Sicily for the period 1958–2005; and (c) estimating the correlation coefficients (r) in two examples: first, between petrochemical employment and net migration inside the three high-risk areas (10-year observations or averages, 1951–2001) and, second, between local and regional migration (yearly observations, 1958–2005 or 1958–1981).

In what follows, *socioeconomic sustainability* is assessed by investigating the length and persistence of the alleged positive effects of industrialization on employment and migration in the three high-risk petrochemical areas of Sicily. The analysis, indicators, data and interpretation of results discussed in the following sections are summarized in Table 47.

Table 47. Analysis, indicators, data and interpretation of results

Analysis	Indicator	Data	Interpretation
Specialization pattern	*LQ*	Sectoral employment and total employment at local, regional and national level, from Istat	*LQ* >1 indicates specialization.
	MSI	Sectoral employment and manufacturing employment at local, regional and national level, from Istat	*MSI* > 1 indicates specialization
Labour market	Percentage of petrochemical employment in total or industrial employment	Labour market statistics: sectoral, industrial and total employment, from Istat	Evaluation of the historical pattern
Migration	Correlation coefficient of local migration versus petrochemical employment	Petrochemical employment (data from Istat); net migration (10-year average of Istat data)	Low correlation coefficient ($r < 0.4$) indicates that petrochemical expansion did not affect local migration.
	Correlation coefficient of estimated local versus regional migrations	Local and regional net migration from yearly Istat data (two periods: 1958–2005 and 1958–1981)	High correlation coefficient ($r > 0.8$) indicates that local migration did not differ from the regional pattern.

The industrialization model

Industrial growth has many different sources. Therefore, identifying a unique model to interpret the start and development of industries is impossible. According to the *path-dependency model*, the historical, vocational, economic, social and institutional peculiarities of a territory constitute the basis for the local industrial pattern of development. For this reason, the experiences of industrial growth in Italy differ from area to area (Becattini & Bianchi, 1982) and adopt highly differentiated organizational patterns: large enterprises vertically integrated in the north-west; small enterprises in the north-east and central regions.

Following an extensive debate, and in accordance with (some aspects of) Perroux's *growth pole model*,[10] industrialization in the three high-risk industrial areas of Sicily started by localizing productive units with the following characteristics:

- large scale
- petrochemical, chemical and power production
- vertically integrated production
- capital-intensive techniques
- public or semi-public property – in the great majority of cases.

The political choice, then, was to encourage the establishment of heavy industries. This had a strong effect on the environmental that, in a couple of decades, began a trend of degradation. On the other hand, what can be called the *social investment* – that is, the flow of resources aimed at building *social capital* in the territory, which should represent the basis for activating the development process – did not accompany industrialization. As a result, the areas adjacent to industries became pure *geographical containers*, playing the role of suppliers of less qualified manpower. Also, the lack of integration within these adjacent areas is highlighted by the provision of intermediate goods and the destination of the final product not involving local businesses and industries (Centorrino & Signorino, 1987). In line with this, unlike other industrial areas of Sicily, the three petrochemical power zones of Augusta–Priolo, Gela and Milazzo–Valle del Mela did not generate new businesses outside the industrial sites (Ciacci, 1984).

Industrialization changed the productive structure of local economies: it increased the average number of workers per business, reduced traditional activities and developed new sectors (metallurgical and plastics). However, the job-related effects of this *development* model are confined to large plants. As a result of this and because of the increasing utilization of capital-intensive (and, later on, of labour-saving) technologies – following a pattern that was common to the whole Sicily and to southern Italian (*Mezzogiorno*) – the non-migrating workforce could only be employed in unproductive public administration (Sylos Labini, 1966, 1978).

Despite a heated debate (Trimboli, 2004), these political choices were not opposed by local populations, as plans for industrialization promised new hope for a better and wealthier future. Also, the occupational and economic benefits expected were estimated to more than compensate for environmental and health costs, which the public undervalued in the 1950s and 1960s. Moreover, the moderate environmental legislation in place misleadingly appeared to be a sufficient guarantee for land protection. If *social sustainability* is defined in terms of improvement of labour market conditions, feelings of social inclusion and a higher level of participation in policy-making mechanisms (Signorino & La Rocca, 2003), it is possible to assert that, in the first stage of industrialization, policies that favoured it were popular and welcomed by local populations.

At the beginning of the 1980s, employment started declining and environmental damage was clearly apparent, bringing epidemiological evidence that local populations had an increased risk of illness and poor health. Scientific evidence shows that petrochemical plants and refineries are among the major contributors to the environmental damage. The effects of petroleum refining are associated both with manufacturing operations and with the use of finished products. The major classes of processes typically carried out by refineries include: (a) desalting; (b) atmospheric distillation; (c) reforming (a catalytic process in which straight-chain molecules are

10 A growth pole refers to the concentration of innovative and technically innovative industries that stimulate economic development in related businesses and industries. François Perroux introduced this concept in 1950.

converted to branched forms for use as petrol) and extraction; and (d) waste recovery and treatment (see Box 1). The manufacturing operations are associated with adverse environmental effects on air, water and soil and on global warming (EPA, 1995). More specifically, the contamination process is related to: (a) unauthorized release of chemicals into bodies of surface water, air, soil and, indirectly, in the water-bearing strata of soil; (b) poorly functioning systems of control and abatement of emissions from industrial plants; and (c) production of toxic substances and/or waste in need of safe disposal (see Chapter 2).

Moreover, the presence of the petrochemical industry and other heavy industries (such as power production plants) caused an important change in the development path of the three high-risk areas of Sicily, linking the economic evolution of the local productive organization to the destiny of this specific sector. Also, after more than 50 years, evidence of environmental damage, economic slowdown and social discredit shows the petrochemical-driven development model to be unsustainable overall (Chapman, 1982).

In what follows, the economic specialization of the high-risk areas in the petrochemical industry is detected by estimating *LQ* and *MSI*, which compare the local weight of petrochemical employment with those of regional or national aggregates.

In this case, the equations for *LQ* and *MSI* are as follows:

$$LQ = (E_{pR}/E_{R})/(E_{pS,I}/E_{S,I}) \text{ and}$$

$$MSI = (E_{pR}/E_{mR})/(E_{pS,I}/E_{mS,I}),$$

where E_p indicates employment in the petrochemical sector of the economy, E indicates total employment and the suffixes R, S and I indicate, respectively, the high-risk areas, Sicily and Italy, and E_m indicates employment in the manufacturing sector of the economy.

As already noted, a value of *LQ* or *MSI* greater than one indicates that the local share of employment in the petrochemical sector divided by the total employment or employment in the manufacturing sector is higher than the regional or national share. This means that the petrochemical sector can be considered as a specialized activity of the local economy. Obviously, the higher the value of *LQ* or *MSI*, the stronger is the pattern of specialization of the local economy in the petrochemical sector.

Based on Istat census data from 1951 1961, 1971, 1981, 1991 and 2001, harmonized for changing classifications and made available by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina, Table 48 shows the 10-year values of both *LQ* and *MSI* for the three petrochemical areas, estimated over Sicily and Italy. These two economic specialization indices clearly show an important specialization pattern of the three high-risk areas of Sicily relative to both the regional and national economic system.

As the table shows, the initial weak specialization of the three areas increased dramatically, indicating that local petrochemical job quotas gradually became almost 10 times larger than national petrochemical occupational shares in 1981 (see the value of $LQ_{HRA/I}$ in the table column that corresponds to this year). This trend is much more evident when isolating the oil-derivative and refining activities, where *LQ* and *MSI* are zero in 1951 and fluctuate around values close to 40–45 in the following decades for the three high-risk areas, compared with Italy as a whole (see Table 49).

Effects of industrialization on employment

Fig. 9 shows the rise and fall of the petrochemical sector within the three industrial high-risk areas: Milazzo–Valle del Mela, Augusta–Priolo, and Gela. After a dramatic increase in the period 1951–1981, total employment was halved in the years that followed.

As a result of this dramatic change, the share of the petrochemical sector in industrial and total employment clearly decreased in the period 1981–2001 (see Fig. 10 and 11).

Table 48. *LQ*s and *MSI*s for all petrochemical activities, 1951–2001[a]

Indices[b]	Year					
	1951	1961	1971	1981	1991	2001
LQ (G/S)	–	1.23	9.15	10.95	11.17	8.46
LQ (A/S)	3.13	9.92	6.97	7.59	7.16	6.45
LQ (M/S)	5.20	1.93	1.56	2.04	2.59	4.07
***LQ* (HRA/S)**	**2.85**	**6.76**	**6.71**	**7.52**	**7.30**	**6.49**
LQ (G/I)	–	0.89	10.44	13.84	13.46	9.26
LQ (A/I)	1.50	7.14	7.94	9.59	8.63	7.07
LQ (M/I)	2.50	1.39	1.78	2.58	3.12	4.46
***LQ* (HRA/I)**	**1.36**	**4.87**	**7.65**	**9.51**	**8.80**	**7.11**
MSI (G/S)	–	1.64	5.81	6.22	6.64	5.27
MSI (A/S)	3.30	7.59	4.71	4.68	5.11	4.16
MSI (M/S)	4.55	1.38	1.33	1.44	1.76	2.81
***MSI* (HRA/S)**	**2.75**	**5.69**	**4.60**	**4.64**	**4.96**	**4.20**
MSI (G/I)	–	1.87	10.63	12.72	12.45	9.14
MSI (A/I)	2.33	8.64	8.62	9.57	9.59	7.21
MSI (M/I)	3.22	1.57	2.42	2.94	3.30	4.87
***MSI* (HRA/I)**	**1.94**	**6.48**	**8.42**	**9.47**	**9.30**	**7.28**

[a] The years shown in the table correspond to census years.
[b] The indices *LQ* and *MSI* are relative to the petrochemical sector, where G indicates the Gela high-risk area, A indicates the Augusta–Priolo high-risk area, M indicates the Milazzo–Valle del Mela high-risk area, HRA indicates all three high-risk areas, S indicates Sicily and I indicates Italy.
Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

Table 49. *LQ*s and *MSI*s for oil-derivative and refining activities, 1951-2001[a]

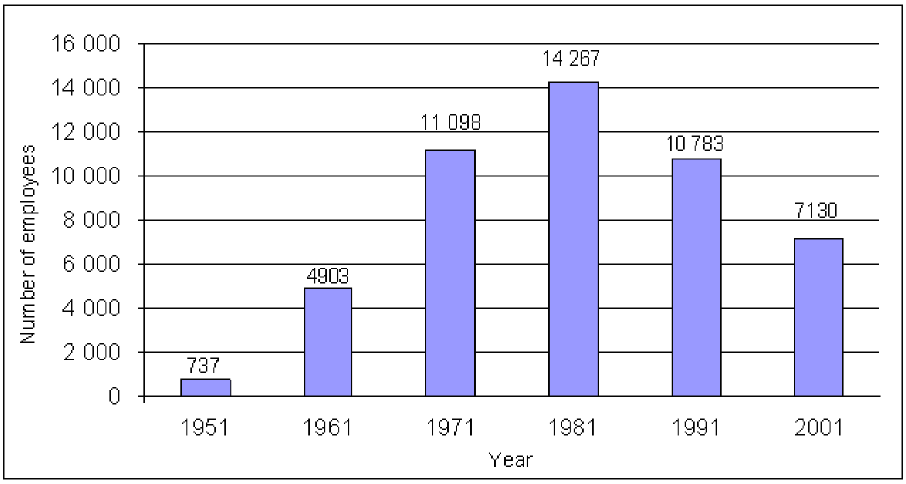
Indices[b]	Year					
	1951	1961	1971	1981	1991	2001
LQ (G/S)	–	9.92	32.37	29.56	17.04	12.93
LQ (A/S)	–	10.84	2.03	3.57	6.99	6.73
LQ (M/S)	–	9.63	5.55	5.59	4.88	7.18
LQ (HRA/S)	–	10.46	9.59	9.31	8.78	8.14
LQ (G/I)	–	12.87	143.51	142.67	83.36	61.73
LQ (A/I)	–	14.06	9.02	17.25	34.18	32.15
LQ (M/I)	–	12.49	24.61	26.97	23.85	34.30
LQ (HRA/I)	–	13.56	42.50	44.93	42.96	38.89
MSI (G/S)	–	13.22	20.54	16.80	10.13	8.06
MSI (A/S)	–	8.29	1.38	2.20	4.99	4.34
MSI (M/S)	–	6.91	4.72	3.93	3.31	4.96
MSI (HRA/S)	–	8.80	6.57	5.74	5.97	5.27
MSI (G/I)	–	27.12	146.06	131.11	77.09	60.88

Table 49 (concluded)

Indices[b]	Year					
	1951	1961	1971	1981	1991	2001
MSI (A/I)	–	17.02	9.79	17.20	37.96	32.80
MSI (M/I)	–	14.18	33.56	30.67	25.22	37.44
MSI (HRA/I)	–	18.05	46.75	44.77	45.43	39.82

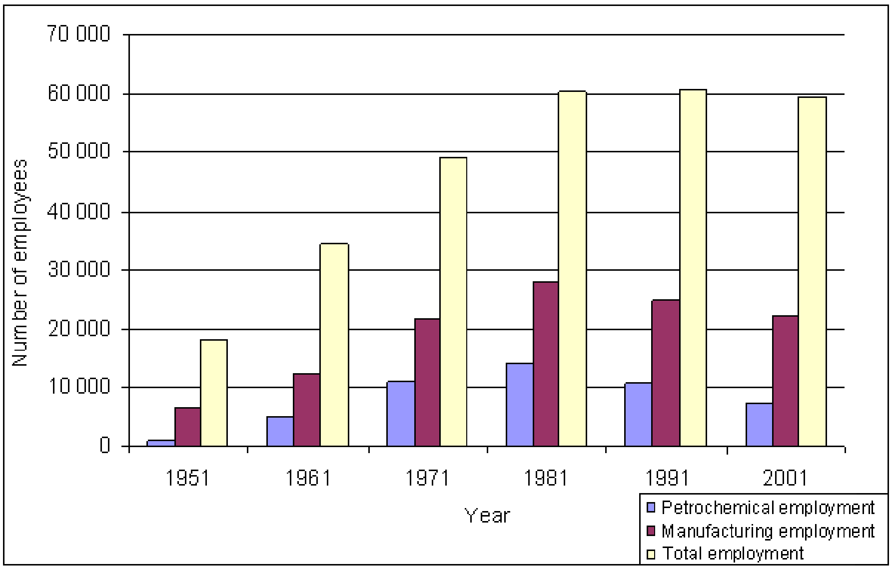
[a] The years shown in the table correspond to census years.
[b] The indices *LQ* and *MSI* are relative to the petrochemical sector, where G indicates the Gela high-risk area, A indicates the Augusta–Priolo high-risk area, M indicates the Milazzo–Valle del Mela high-risk area; HRA indicates high-risk areas, S indicates Sicily and I indicates Italy.
Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

Fig. 9. Petrochemical employees in the three industrial high-risk areas, 1951–2001



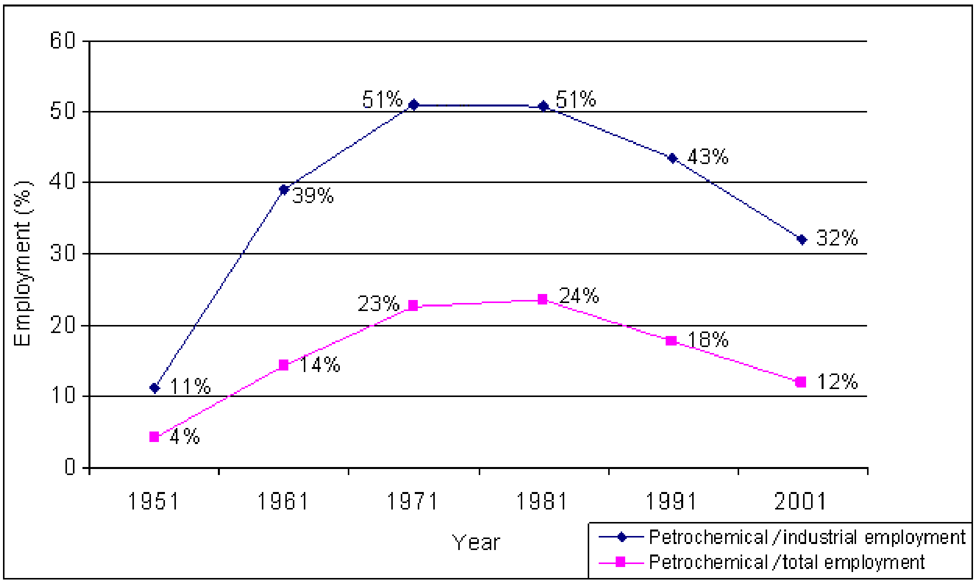
Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

Fig. 10. Total and sectoral employment in the high-risk petrochemical areas of Sicily, 1951–2001



Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

Fig. 11. Petrochemical employment expressed as a per cent of industrial employment and total employment



Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

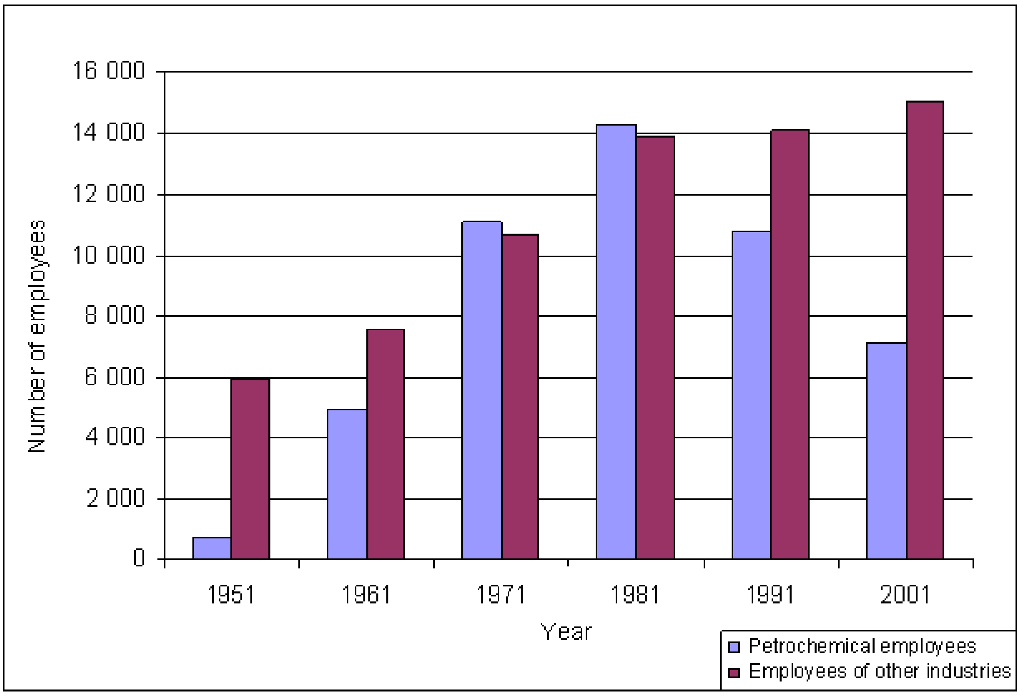
Fig. 12 and 13 show that, after 1981, no substitution effect – that is, the transfer of the workforce expelled from the petrochemical sector to other industrial sectors – took place. This means that, even though other manufacturing activities maintained on the whole about the same level (Fig. 13), showing a small increase in the latest period, total industrial employment decreased because of its reduction in the petrochemical sector (Fig. 12). During the period 1981–2001, employment in the petrochemical industry decreased by 7137 individuals, while employment in other industries increased by 1145 individuals; this implies that the adoption of labour saving technologies in the transformation of the oil processing cycle caused a net destruction of about 6000 jobs in the total manufacturing sector during this period: a loss of 21.2%.

As a result, the sign of correlation between petrochemical employment and employment in other industries changed (from positive to negative). In the scatter diagram (Fig. 13), the positive slope for the period 1951–1981 becomes negative in the following period, 1981–2001, because of the decrease in the number of employees in the petrochemical industry; this decrease is associated with a slight increase in the number of employees in other parts of the manufacturing sector. In conclusion, jobs lost in the petrochemical industry have not been absorbed by the local productive sector, giving rise to new unemployment.

The transformation of the local productive sectors is evident when considering the impressive reduction in the share of cultivated land compared with total land in the three areas (see Table 50). This is a characteristic that the three high-risk areas share with the whole region.

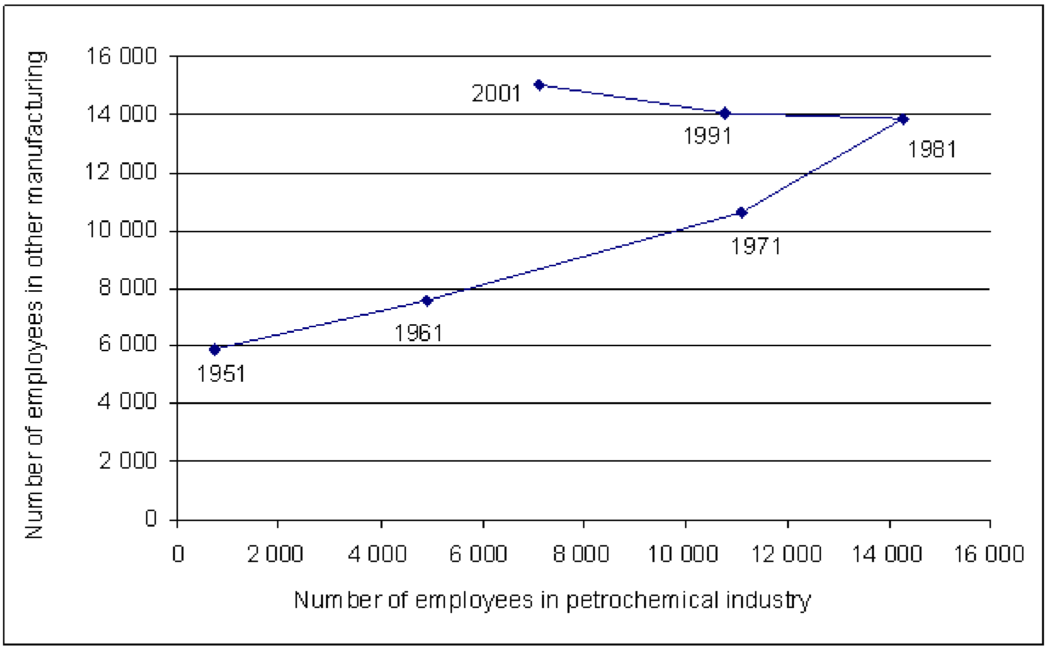
It is worth noting that the composition of the manufacturing sector underwent a dramatic change, with a huge increase in the metallurgy, manufacture of machinery and equipment and plastics industries (apart from the petrochemical industry) and an important decrease in the most traditional activities. As Table 51 shows, the decrease in traditional activities was particularly severe in the expansionary phase of petrochemical activities (1951–1981), while in the period 1981–2001 a slight increase (in terms of both firms and workers) followed. On the other hand, the expansion of the manufacture of machinery and equipment and plastics production sectors accompanied the growth of the petrochemical sector and outlived its following shrinkage.

Fig. 12. Petrochemical employment versus employment in other industries, 1951–2001



Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

Fig. 13. Number of employees in petrochemical and other industries, 1951–2001



Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

Table 50. Share of cultivated land

Area	Share of cultivated land, by year			
	1970	1980	1990	2000
Augusta–Priolo	0.77	0.68	0.58	0.48
Gela	0.62	0.63	0.55	0.47
Milazzo–Valle del Mela	0.70	0.63	0.52	0.37
Sicily	0.75	0.66	0.62	0.50

Source: Adapted from Istat data: agriculture census.

Table 51. Employees and firms (manufacturing activities), for select years 1951–2001

Productive activity	Number of firms and workers, for select years					
	1951		1981		2001	
	Firms	Workers	Firms	Workers	Firms	Workers
Manufacturing sector	2 559	6 640	2 595	28 160	3 060	22 168
Food and beverages	465	2 098	302	1 148	424	1 357
Textiles, clothing, footwear and leather goods	935	1 459	244	453	111	255
Wood products, paper products and printing	588	1 122	486	1 052	487	1 180
Metallurgy, machinery and equipment, petrochemical and rubber	571	1 961	1 534	25 042	1 959	18 486
Metallurgy	–	–	10	529	9	233
Machinery and equipment	429	805	1 315	8 542	1 705	10 242
Petrochemical	23	737	50	14 267	70	7 130
Plastics industry and other manufacturing activities	–	–	29	465	79	890
Plastics	–	–	20	216	30	463

Source: Adapted from Istat census data (1951, 1981 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

By using the relative firms' dimension index (*RFD*), which is the ratio between the average dimension (workers per business) of local firms and the corresponding regional average, it is possible to compare the structural characterization of the industrialization processes that took place in the three high-risk petrochemical areas with that of Sicily for each industrial activity. Letting *RFD* indicate the number of workers in the petrochemical industry versus all Sicilian manufacturing sectors, W indicate the number of workers, *F* indicate the number of firms and poles indicate the high-risk contaminated areas, the following expression is obtained:

$$RFD = (W/F)_{\text{Petrochemical poles}}/(W/F)_{\text{Sicily}}$$

where *RFD* greater than one implies a larger average number of workers for local enterprises than for regional enterprises.

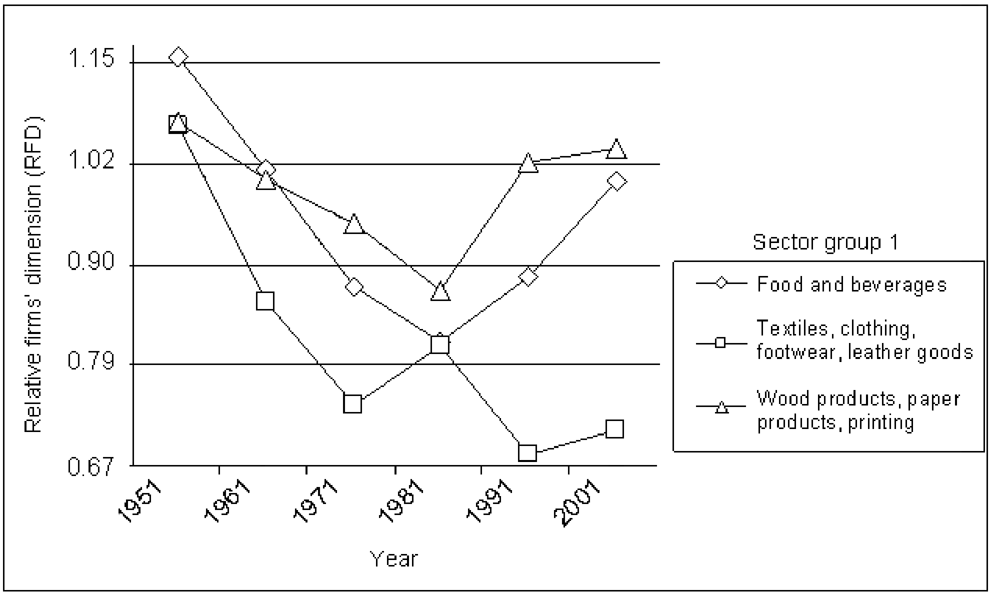
Table 52, Fig. 14 and Fig. 15 show that traditional activities had a larger average number of workers per business in the Sicilian high-risk areas than they did in Sicily as a whole in 1951. During the expansion of the petrochemical industry, *RFD* was lower than one, witnessing a relative reduction in the size of a firm's workforce within these activities; in 1991–2001, parallel to a decline in petrochemical employment, employment in the food and beverage, wood products, paper products, and printing sectors increased in terms of the average size of firms (Fig. 14). The increase in the workforce in the metallurgy, manufacture of machinery and equipment, and plastics industries, covering the whole period 1971–2001 (Fig. 15), similar to the pattern of the petrochemical industry, marks the structural change in local economies.

Table 52. *RFD*, by manufacturing activity

Productive activity	$(W/F)_{\text{Petrochemical poles}}/(W/F)_{\text{Sicily}}$					
	1951	1961	1971	1981	1991	2001
Manufacturing sector	1.14	1.75	2.76	2.82	2.14	2.15
Food and beverages	1.14	1.01	0.88	0.81	0.89	1.00
Textile, clothing, footwear and leather goods	1.06	0.86	0.74	0.81	0.68	0.71
Wood products, paper products and printing	1.06	1.00	0.95	0.87	1.02	1.03
Metallurgy, machinery and equipment, petrochemical and rubber	1.19	2.75	3.88	3.45	2.83	2.56
Metallurgy	0.00	0.00	3.33	2.04	2.19	1.85
Machinery and equipment	0.82	1.08	2.04	1.85	1.70	1.93
Petrochemical	3.54	8.56	7.39	5.00	4.91	4.66
Plastics industry and other manufacturing activities	0.00	0.63	3.29	1.98	1.49	1.90
Plastics	0.00	0.00	1.96	1.29	1.56	1.70

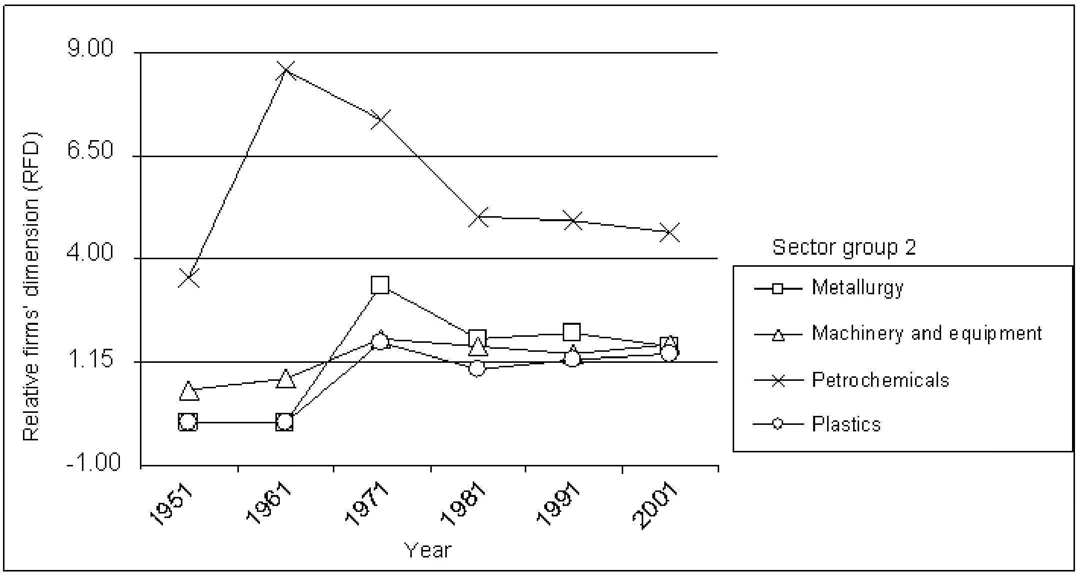
Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

Fig. 14. Average number of workers per business, by manufacturing sector in the high-risk petrochemical areas relative to Sicily: sector group 1



Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

Fig. 15. Average number of workers per business, by manufacturing sector in the high-risk petrochemical areas relative to Sicily: sector group 2



Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

As a general conclusion to this section on the effects of industrialization on employment, the most important point made is that the implementation of petrochemical plants within the three high-risk areas had important effects on the local economies. This implementation induced in the industrial sector a dramatic despecialization of labour in traditional activities and an increasing specialization in so-called heavy activities, particularly in the petrochemical growth period (1951–1981). Then, the following reduction (or relative stabilization) of the petrochemical industry has been matched by a renewal of specialization in traditional activities and a stabilization of metallurgy and mechanical and plastic industry specialization patterns.

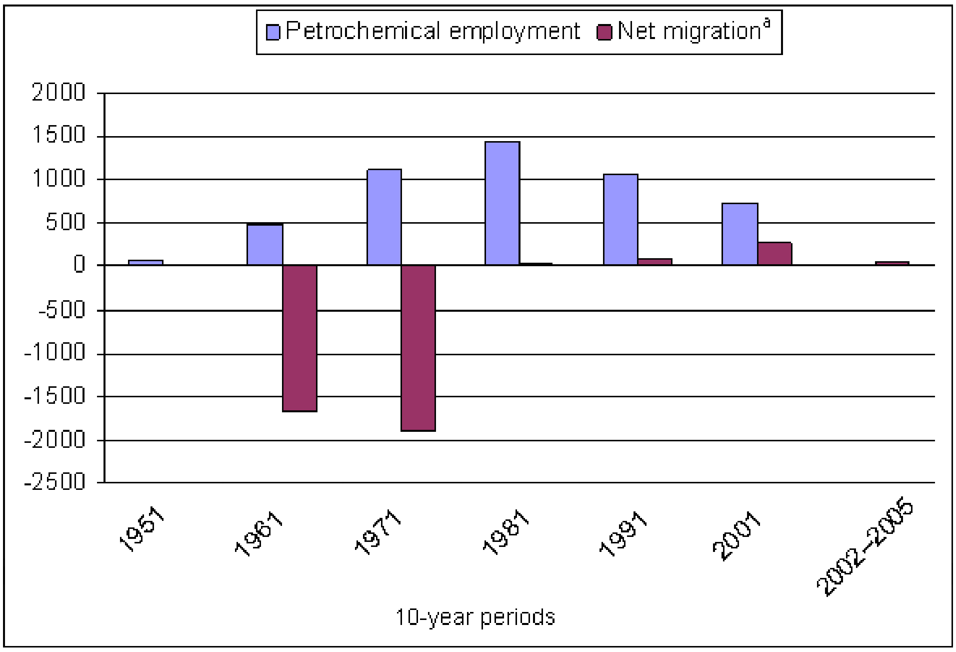
Effects of the petrochemical industrialization model on migration

In Sicily, since the end of the Second World War, people have left agriculture to find work in the more industrialized regions of Northern Italy and Europe. Investment in petrochemicals was expected to promote employment and stem emigration. A comparison of official data on the local demographic balance (1958–2005) with data from petrochemical employment shows that this expectation has not been realized. Excluding data for the City of Syracuse (the capital of the Province, which is not a petrochemical site and where migration is influenced by the concentrated administrative functions of the city), no clear correlation appears between employment levels and average 10-year migration patterns.

As Fig. 16 shows, until 1971 the increase of petrochemical employment did not effectively counteract local net emigration. For the period 1971–1981, the expansion of the petrochemical industry was associated with modest immigration, which continued (slightly rising) in the following 10-year periods, despite the decrease in employment in the petrochemical industry.

The delinking of petrochemical dynamics and migration is not completely surprising. On the one hand, the strength of the expulsive pressure coming from an overcrowded and underproductive agricultural sector needs to be considered: the expansion of local industry may have been insufficient to compensate for labourers abandoning the land, thus forcing emigration. This explains why migration remained negative during the expansion phase of the petrochemical industry.

Fig. 16. Petrochemical employment and net migration: high-risk petrochemical areas of Sicily, 1958–2005



[a] Ten-year averages (first data is for the period 1958–1961).
Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

On the other hand, it is well known that interregional migration in a dual (rural–industrial) economy often responds to real income differentials and to different employment opportunities in the regions of destination and origin (Todaro, 1969; Harris & Todaro, 1970). Because of this, the persistence of higher wages and almost full employment in the northern regions attracted Sicilian labour, until 1971. In the 1970s, intrasector territorial wage differentials (the so-called *gabbie salariali* or wage cages – a system of calculating wages in relation to certain variables, such as the cost of living in particular place) were abrogated by law, accomplishing an important transition in the economic structure of Sicily (from rural to service activities), as data on industrial employment reported in the preceding section show.

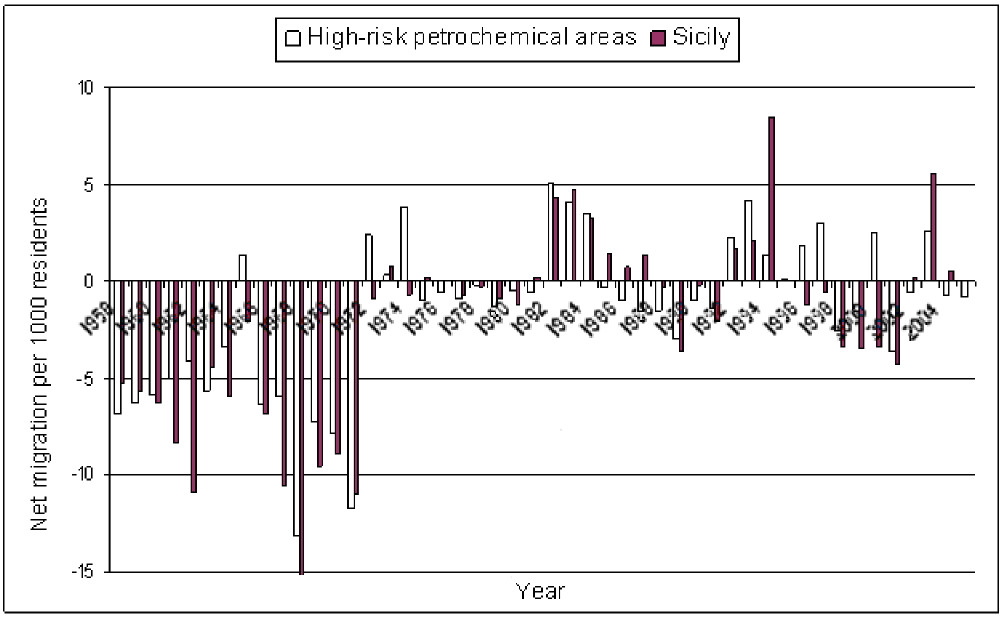
In response to the subsequent first oil crisis, firms adopted cost-reduction strategies and labour-saving techniques, so that unemployment in Northern Italy increased and emigration from Sicily decreased (Salvatore, 1981). More recently, the difference in unemployment between Sicily and the northern and central regions of Italy has not reactivated migration, due to various distortions of the regional labour market (Centorrino & Signorino, 2000; Signorino, 2003, 2005).

What is indeed surprising is that the installation of petrochemical plants in the three high-risk petrochemical areas did not differentiate these areas from the whole of Sicily. One might expect that, in the industrializing high-risk petrochemical areas, emigration would be mitigated in the period 1951–1981, compared with the regional migration pattern, and that overall migration dynamics would differ from that of the rest of the island.

Fig. 17 shows that, particularly in the first period (1958–1972), emigration was important both in Sicily and in its three high-risk petrochemical areas, while in the following period (1973–1981) net migration was more persistently negative within the petrochemical areas than in the whole region.

To test the existence of a systematic relationship between petrochemical sector evolution and migration, a correlation analysis was performed. The correlation values show various patterns. The correlation between local migration (10-year average) and petrochemical employment (10-year census data) is quite poor ($r = 0.31$), providing evidence that the two variables do not follow a common pattern over time. On the other hand, the important correlation detected by estimating the correlation coefficient of local versus regional migration for the period 1958–2005 (r = 0.86) shows that industrialization policies in the high-risk areas did not significantly differentiate the local and regional migration dynamics. Also, the correlation was higher (r = 0.88) during the phase of expansion in petrochemical employment, supporting the conclusion that the installation of petrochemical plants had no significant effect on local migration patterns.

Fig. 17. Net migration per 1000 residents in the high-risk petrochemical areas and in Sicily



Source: Adapted from Istat census data (1951, 1961, 1971, 1981, 1991 and 2001) collected and harmonized for changing classifications by the Chamber of Commerce, Industry, Agriculture and Crafts of Messina.

Conclusions

In conclusion, our evaluation of the economic sustainability of the petrochemical industry in Sicily showed that this large and environmentally harmful investment produced no long-term economically sustainable result.

The initial increase in employment was insufficient to absorb the workforce that abandoned the agricultural sector and to restrain emigration. The high expectations of rapid, self-sustained industrialization spontaneously induced by the presence of petrochemical plants did not materialize and, since the 1980s (especially in the chemical subsector, though with different dynamics and results in the three areas), employment in the petrochemical industry has been halved. Also, a moderate renewal of emigration now characterizes the complex of the three high-risk petrochemical areas of Sicily. Far from differentiating the local economic history of the three high-risk areas from that of the rest of the island, the petrochemical industry has created new unemployment and emigration, leaving these three areas with environmental damage and at increased risk to human health.

Also, environmental damage is much wider, and social effects are even worse than those of occupational fragility. The *unnatural* vocational specialization of these three areas in the petrochemical industry prevents both the possibility of a different perspective – producing an almost *exclusive relationship* with all aspects of the three areas (environment, economy, society) – and any viable economic alternative for development. In this context, new generations seem to face few choices and no available resources to build their future. Under these conditions, health should be considered the end-point of a complex set of factors (and events) that adversely affect population well-being, in general, and that are the real benchmark of sustainability (McMichael, 2006).

DESIGNING AND CONDUCTING SPECIFIC STUDIES

9. OCCUPATIONAL AND RESIDENTIAL COHORTS

Pietro Comba, Caterina Bruno, Lucia Fazzo, Roberto Pasetto and Amerigo Zona

Introduction

The scientific community widely views the notion of an epidemiological framework as a group of related studies – ranging from the ecological realm to the clinical or biomolecular realm – that can progressively attain an increasingly valid characterization of a specific context or issue. Even if no individual study provides a definitive answer, summing up the findings of different investigations may shed light on the issues of interest. The integration of observations performed at the population level and individual level has been also recommended, to investigate the causal links between environmental exposure and adverse effects on health (Pearce, 1996; Susser & Susser, 1996; Susser, 1998). An example of an epidemiological framework is the integration of geographical and analytical epidemiological studies of residents of polluted Italian sites (Pasetto et al., 2007a).

The European Environment Agency estimates that, throughout Europe, soil contamination affects almost 250 000 sites – a number expected to grow – and that industries are the main source of this pollution (EEA, 2010). To study the adverse effects of industries on the health of populations residing in the neighbourhood of industrial plants, both the occupational and residential contexts should be taken into account.

To study these effects, cohort studies may be the most useful tools (Pasetto & Pirastu, 2006). The cohort study design is a common approach to evaluating occupational risk, though it has not been applied as frequently to estimate residential risk. The best known example of the cohort approach to evaluating residential risk is the cohort of residents in the area of the Seveso (Italy) accident (Pesatori et al., 2003), which resulted in the highest known exposure to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in residential populations.

The definition and size of a cohort can be based on environmental monitoring results or on modelling the spatial distribution of emissions, which implies exposure categorization of the study area; the distance of a residence from a point source may also be employed as a proxy for exposure (Armstrong, White & Saracci, 1992; Steenland & Savitz, 1997; MacIntosh & Spengler, 2000; Williams & Ogston, 2002). The lack of exposure data, however, hampers the possibility of formulating a priori etiological hypotheses; Moreover, together with exposure data, residential cohort studies in polluted sites should include information on time-related variables, to fully understand the potential role of duration of residence, latency time, and the relationship to time of the exposure–effect relationship.

The present chapter describes the contribution of cohort studies to the local epidemiological framework of polluted sites and presents three case studies.

Occupational risk and health surveillance programmes: case study of workers exposed to asbestos in San Filippo del Mela

Background and objectives

In Europe, the prevalent use of asbestos (85–90%) is attributed to the asbestos-cement industry. Italy was the first European producer of asbestos, and the presence of a widespread asbestos-cement industry led to epidemics of asbestos-related diseases (Amendola et al., 2003; Luberto et al., 2004; Magnani et al., 2008; Musti et al., 2009; Mirabelli et al., 2010).

Epidemiological studies of asbestos-polluted sites help characterize the population health profile, while occupational cohort studies may help assess the occupational risk that affects the general population.

Health authorities in many countries have planned initiatives for the health surveillance of workers formerly exposed to asbestos (Zona & Bruno, 2009). Medical surveillance of these subjects is a public health issue particularly relevant in areas where major asbestos facilities operated in the past.

Among other things, the joint WHO and Italian National Institute of Health research project Cohort Studies in Areas of High Environmental Risk in Sicily investigated former workers of an asbestos-cement plant (Sacelit) located in San Filippo del Mela, near Messina, in the Milazzo–Valle del Mela area. The project's two goals were to: (a) estimate the asbestos-related disease burden in the area; and (b) study the feasibility of a medical surveillance programme for former asbestos workers (Fazzo et al., 2010a; Zona et al., 2010).

The Sacelit plant operated from 1954 to 1993, manufacturing various asbestos-cement products. Initially, asbestos was transported by train; subsequently it was transported by road haulage. The asbestos bags delivered were carried to the warehouse. If the bags tore, employees removed asbestos with a shovel or swept it away. About 2000 tonnes of asbestos and 16 000 tonnes of cement were used every year. Before mixing, crocidolite (considered the most hazardous asbestos fibre) was milled by an extremely dusty process. Some major modifications of the plant occurred in the mid-1970s: the grinder mill was renovated and an air filtration system was added. Different asbestos mixtures stored in silos were put into plastic bags by shovel, weighed and unloaded in a mixer that contained cement and water. Cleaning machinery and pipes to process the small amount of asbestos that remained also created dust. Until the mid-1970s, protection devices were not available and working clothes were cleaned at home. No information about the disposal of the jute bags used to carry asbestos was available before 1986, when it was decided to add empty bags to the mixture.

Mortality and incidence studies: methods

Since the company register was not available, the cohort was enumerated by the Workers Formerly Exposed to Asbestos Permanent Committee, which personally knew each subject who had worked in the industry. The list was validated using the information available at the Italian National Institute of Health and Local Health Unit No. 5 of Messina.

All subjects with complete personal data were enrolled in the cohort. Since no information was available on the duration of each subject's activity at the plant, person-years at risk could not be calculated.

Incidence study. Cases of mesothelioma in cohort subjects were obtained from the regional centre of the National Mesothelioma Registry (INAIL, 2010), which includes mesothelioma cases in Sicily since 1998. The study follow-up period was from 1998 to 2008. To calculate the occurrence of mesothelioma in the cohort and to compare it with the corresponding incidence in the population of Sicily, person-years were computed, assuming that each subject contributes for the whole follow-up period. The reference rates, stratified by gender and age, were then applied to the person-years, and SIRs were calculated for ascertained and suspected mesothelioma diagnoses. Regional incidence rates included pleural, peritoneal and pericardial mesothelioma; in the cohort, only cases of pleural mesothelioma were found.

Mortality study. In the database of Local Health Unit No. 5 of Messina, vital status information and cause of death of cohort members were available only from 1 January 1986 to 31 March 2009 (end of the study). Proportional mortality ratios for three major causes of interest – malignant neoplasm of the pleura, of the trachea, bronchus and lung, and pneumoconiosis (ICD-9 codes 163, 162 and 500–505, respectively) – were calculated. To avoid missing possible misclassified cases of asbestosis, pneumoconiosis (and not the more specific asbestosis cause of death) was used. Standardized proportional mortality ratios (SPMRs) were calculated, using the rates for Sicily as reference values. Due to incomplete information on the duration of employment, it was impossible to calculate person-years at risk; this was one of the factors in favour of the use of proportionate mortality; for an exhaustive discussion about this indicator, the reader is referred to Rothman & Greenland (1998) and Checkoway, Pearce & Kriebel (2004).

Incidence study: results

The follow-up of cases of mesothelioma ranged from 1 January 1998 (when recording of mesothelioma cases started in Sicily) to 26 September 2008 (the end of the present study). All workers registered in the Committee list with complete personal records (199 of 231 people: 175 men and 24 women) were included in the study. The average age of the cohort at the end of the follow-up period was 74.8 years. Table 53 shows the SIRs of mesothelioma by gender for the study period.

Table 53. Incidence of mesothelioma, by gender, and SIR

Gender	Number of cases		SIR	95% CI
	Observed	Expected		
Men	3	0.02	193	39.8–565.0
Women	1	0.00	–	–
Total	4	0.02	251	68.4–643.0

Mortality study: results

In the mortality study, 4 cohort members were lost to follow-up, and 13 workers who died before 1 January 1986 and 5 subjects with an unknown cause of death were excluded from the analysis. Eventually, of 199 cohort members, 176 (152 men and 24 women) were included in the analysis. Because three women died from causes not related to exposure to asbestos, statistical analysis was carried out on men only. Standardized statistical mortality ratios were significantly increased for all causes of interest, as shown in Table 54.

In particular, all cases of pneumoconiosis ($n = 5$) in the cohort were asbestosis. Because of the study design, SPMRs were calculated for the ICD pneumoconiosis group code and not for the single asbestosis code. Also, according to Mesothelioma Register records, two cases of pleural malignant tumour were mesothelioma.

Table 54. Mortality by causes (men): 1 January 1986 to 31 March 2009, SPMR

Cause of mortality	ICD-9 diagnosis code(s)	Number of cases		SPMR (95% CI)
		Observed	Expected	
Malignant neoplasm of the pleura	163	2	0.10	19.40 (2.35–70.20)
Malignant neoplasm of the trachea, bronchus and lung	162	10	3.56	2.81 (1.35–5.16)
Pneumoconiosis	500–505	5	0.06	80.10 (26.00–187.00)

Surveillance

Background

In 2004, Local Health Unit No. 5 of Messina started medical checks for Sacelit asbestos-cement factory (San Filippo del Mela) workers and their families, who were identified from the Workers Formerly Exposed to Asbestos Permanent Committee list. The Unit provided medical examinations, blood tests and urine analyses, respiratory function tests, chest X-rays and chest computer tomography scans. The participants underwent a health examination and received test results and diagnostic conclusions. For their questions or needs, they were also given contact details for physicians. Suspected cases of occupational disease were reported to the Italian Workers' Compensation Authority. Within the framework of this project, Italian National Institute of Health researchers and Local Health Unit health personnel cooperated to examine the activity taking place, to set up an official, evidence-based follow-up protocol. Some general observations were made on the requirements of the programme described here (Zona et al., 2010).

Key points

This subsection covers general recommendations for the approach to be taken. First, a medical surveillance programme should be based on evidence and should comply with international standards and guidelines. Also, a careful feasibility study – and the identification of technical needs (staffing, expertise, equipment, and proper organization of work) – can be helpful.

Among the things to be determined in advance are: the criteria for recruiting subjects, diseases to study, timing and types of medical examinations, health care facilities, methods of communication, and legal and other aspects of the plan. Also, the programme's main aims should be clearly stated, and the content and procedures of the whole activity defined. Moreover, the programme should be presented and discussed with the participants, and an official protocol should eventually be written.

For lung cancer and mesothelioma, no type of screening has yet to be proven effective (Manser et al., 2008; NCI, 2011a,b), and early cancer diagnosis should not be considered. Also, suspected cases of lung cancer and mesothelioma should be referred to appropriate facilities identified previously.

Pulmonologists, radiologists, pathologists, surgeons, oncologists, and technical personnel for the investigations planned are essential figures that should be part of the medical team. The personnel involved should be familiar with the issues related to the health effects of exposure to asbestos, should be appropriately skilled in performing and interpreting health checks, and should provide any information requested by surveillance programme. Also, all activities, test results and diagnostic conclusions should be computerized, to facilitate access to them and future comparisons.

A permanent relationship with each participant's family doctor is of the utmost importance. Therefore, family doctors should be in direct contact with the programme participants, even during the time that elapses between medical check-ups. These doctors might evaluate whether suspected symptoms are related to previous exposure to asbestos and, if necessary, refer the patient to the health care facility provided in the programme.

The minimum set of a medical surveillance activities should include a clinical examination, respiratory function tests (such as flow-volume curve and lung diffusion for carbon monoxide), a chest X-ray, a programme for smoking cessation, and influenza and pneumococcal vaccination (American Thoracic Society, 2004). Reasonably, the first three points should be repeated at five-year intervals.

Cessation of smoking can help reduce an individual's risk of lung cancer and slow pulmonary function deterioration. Centres offering anti-smoking courses should be identified, and appropriate counselling proposed.

International guidelines for respiratory function tests and chest radiographs for the detection of pneumoconiosis should be adopted. To guarantee data quality, the equipment supplied to operators should be maintained in good condition and should satisfy the requirements of existing guidelines (ILO, 2003; Miller et al., 2005). Also, all the examinations included in the programme should be offered free of charge.

Subjects with negative tests for asbestos-related diseases and a sufficiently long time since they were first exposed should leave the programme. In case of negative tests and a period of time that is not long enough since first being exposed, a worker should repeat the checks at planned intervals. Workers suffering from asbestosis (American Thoracic Society, 2004) should be vaccinated against seasonal flu annually, receive pneumococcal vaccination, and undergo medical checks every five years. Medical surveillance should be suspended for the elderly (for example, older than 75 years). Workers leaving the programme should definitely remain in contact with their family doctors, who know their past exposure to asbestos.

All programme activities should be periodically reviewed, taking into consideration the characteristics of the population studied and the trends in scientific knowledge. Any significant change should be communicated and explained to participants.

Comments and concluding remarks

Cohort enumeration was based on information about single workers, available from the Workers Formerly Exposed to Asbestos Permanent Committee, and on the validation of the lists of workers, obtained by integrating information from the Italian National Institute of Health and Local Health Unit No. 5 of Messina. The same process was also the foundation for the health surveillance programme (Zona et al., 2010).

The exclusion of 33 subjects with incomplete personnel records (14% of the total cohort) resulted in a loss of precision, but not in any bias. Lack of official sources for working histories led to the use of proportional mortality analysis, instead of SMR analysis. This can be considered appropriate, since the SPMR retains a valid estimate of SMR when the exposure studied is associated with specific outcomes, in the absence of an increase in mortality from all causes (Rothman & Greenland, 1998; Checkoway, Pearce & Kriebel, 2004).

The presence in Sicily of the regional centre of the National Mesothelioma Registry allowed mortality analysis to be associated with the study of mesothelioma incidence in the cohort. This created a narrower time window and improved the data quality. The results of the two studies were consistent. At the end of the clinical surveillance programme, the asbestosis prevalence among Sacelit workers will be assessed.

Increased mortality from lung cancer emphasizes the relevance of previous exposure to asbestos, since rather high levels of exposure are required to determine a threefold or fourfold increased risk (Hodgson & Darnton, 2000). Also, the cohort study showed a significant increase in the occurrence of asbestos-related diseases in the Sacelit cohort (Fazzo et al., 2010a); this finding confirms the usefulness of the surveillance programme Local Health Unit No. 5 of Messina (Zona et al., 2010) is currently implementing.

Occupational and residential risks in the same population: case study of petrochemical employees in the Gela area

Background and objectives

In the early 1960s, in the Gela area, a large petrochemical complex began operation. It included an oil refinery, a thermoelectric power plant and petrochemical plants for the production of organic (ethylene, acrylonitrile) and inorganic (sulfuric acid, ammonia, chlorine, urea) chemicals. Data collected in the middle of the first decade of the 21st century documented contamination of groundwater, soil and air (see Chapters 6 and 7). Also, ecological mortality and morbidity studies of Gela residents showed health risks that may be associated with occupational and environmental exposures (see Chapter 6). In this context, a cohort study of workers in the Gela petrochemical complex aimed to disentangle the occupational and residential health risk in the same population.

Methods

Details about the Gela petrochemical cohort study, as well as information about the contamination from the petrochemical complex of the Gela area, have already been described elsewhere (Pasetto et al., 2007b; Pasetto, Comba & Pirastu, 2008; Pasetto, Saitta & Bracci, 2008; Signorino et al., 2011). Briefly, the mortality of a cohort of Gela petrochemical plant workers was studied and included people employed from 1 January 1960 (when the plant began operation) to 31 January 2002. Twenty employment rosters of eight different companies were used to collect workers' personal and employment data. The cohort was made up of 7147 workers (6961 men, 186 women). Most of them were employed in different companies within the complex. The duration of employment could not be determined. Ascertaining their vital status (alive or dead) was completed for the years 1960–2002. The analysis was restricted to men hired from 1 January 1960 to 31 December 1993. This restriction was adopted to take into account a minimum 10-year latency period for the delayed effects of exposure.

The origins of workers differed. As documented by some local sociological studies, most workers came from Gela, but they also came from other provinces within Sicily or other regions of Italy. Also, a number of them – mainly until the late 1990s – commuted daily to Gela from other Sicilian locations. Table 55 describes the origins of workers, by birthplace. In the cohort, 26% of workers were born in Gela, and most of them were born in other Sicilian municipalities.

Table 55. Number and proportion of men hired in the period 1960–1993, by birthplace

Birthplace or total	Number (%) of men hired		
	1960–1970	1971–1993	Total
Gela	684 (18.4)	1000 (36.5)	1684 (26.1)
Other Sicilian municipalities	2416 (65.0)	1527 (55.8)	3943 (61.1)
Municipalities outside Sicily	548 (14.7)	184 (6.7)	732 (11.3)
Missing data	69 (1.9)	26 (0.9)	95 (1.5)
Column total (%) and % of overall total	3717 (100.0) (57.6)	2737 (100.0) (42.4)	6454 (100.0) (100.0)

On the basis of international (mainly epidemiological) peer-reviewed literature, occupational risk was studied by selecting cancer causes of a priori interest. Neoplasms of the liver, bronchus, lung, pleura, skin, kidney and central nervous system were selected, as was leukaemia. Mortality analysis in terms of SMRs was performed for the cohort of 6454 men chosen on the basis of the criteria described above. Mortality rates of the regional population of Sicily were adopted as reference values. Also, the unknown causes of death contributed to the SMRs calculated, under the assumption of a distribution equal to the known causes – that is, adding the number of unknown deaths to each group on a proportional basis (Checkoway, Pearce & Kriebel, 2004).

The literature assessment that evaluated both occupational and residential risk (see Chapter 3) showed that cancer sites of major a priori interest were the lymphohaematopoietic system and lung. An internal analysis that compared workers with different job titles and residential categories was performed for these neoplasms. The internal analysis was restricted to 5627 workers born in Sicily (in Gela and other Sicilian municipalities). The only occupational information available to define the work experience came from job titles in rosters; using job title data, workers were classified in three categories, as: white collar (office and professional workers whose work generally does not involve manual labour), blue collar (typically manual labourers) and both white and blue collar (workers who changed their job title over time).

Residential classification was based on assumptions about birthplace and the use of a mobility model (Signorino et al., 2011). Workers were classified according to the following categories:

1. *residents in Gela:* workers born in Gela;
2. *moved to Gela when hired:* workers born in Sicilian municipalities with the probability of commuting defined by the model as $P < 0.5$; and
3. *commuters:* workers born in Sicilian municipalities with the probability of commuting defined by the model as $P \geq 0.5$.

The internal analysis calculated mortality rate ratios,[11] by using a Poisson regression model and the time-related predictive variables age and calendar period.

11 In epidemiology, a rate ratio is calculated to compare the rate of events (such as incidence) occurring at any given point in time.

A morbidity study was also performed to analyse chronic or low-mortality diseases, using hospital discharge records. All such records for the period 2001–2006 were searched at the Sicilian Epidemiological Observatory. For each record, the fiscal code was calculated. Hospital discharge records without relevant personal data were not considered. Day admissions to a hospital, rehabilitation, long stays and duplicate hospital discharge records were excluded. Hospital discharge record data were linked to cohort participants, using the fiscal code as a key, and information on the main diagnosis was used in the analysis. Finally, the first hospitalization for any given cause of a priori interest for each subject was selected.

Results

At the end of the follow-up period, the median age of the workers was about 59 years, and 78% of them were younger than 65 years. The median value of the period from being hired to the end of the follow-up period was about 31.5 years.

The results of SMR analysis show that, for most causes, the observed deaths were below those expected. Slight and imprecise increases were observed for primary liver cancer, pleural cancer and malignant kidney neoplasms.

The main results of the internal analysis are shown in Table 56. Mortality for all causes was similar in the categories compared, except for blue collar, where the rate ratio is higher relative to the white collar reference. Rate ratios were also higher for malignant neoplasms and for cancer causes of major interest in blue collar workers and in both white and blue collar workers when white collar workers were used as the reference. Moreover, an excess in trachea, bronchus and lung neoplasms in the residents and in the moved to Gela category was observed. Also, lymphohaematopoietic tissue neoplasms were in excess in the category moved to Gela. Finally, preliminary results of the cohort morbidity study show a higher prevalence of chronic obstructive pulmonary disease among residents than among commuters.

Table 56. Mortality rate ratio for a cohort of men hired in the period 1960–1993

Causes (ICD-9 code)	Number of cases	Rate ratio by job title (reference: white collar) [a]		Rate ratio by residence (reference: commuters) [b]	
		Both white and blue collar (90% CI) [c]	Blue collar (90% CI)	Moved to Gela (90% CI)	Residents (90% CI)
All (001–999)	562	0.94 (0.72–1.21)	1.30 (1.06–1.59)	0.90 (0.73–1.11)	0.88 (0.75–1.03)
Malignant neoplasms (140–208)	176	1.57 (0.99–2.49)	1.83 (1.23–2.71)	0.94 (0.64–1.37)	1.09 (0.82–1.44)
Trachea, bronchus and lung neoplasms (162)	54	2.17 (0.89–5.28)	2.24 (1.01–4.96)	1.71 (0.92–3.17)	1.70 (1.03–2.81)
Lymphohaematopoietic tissue neoplasms (200–208)	15	1.91 (0.46–7.0)	1.43 (0.39–5.27)	3.0 (1.14–7.9)	0.87 (0.28–2.72)

[a] Rate ratio by job title, adjusted for age, calendar period and residence.
[b] Rate ratio by likelihood of residence, adjusted for age, calendar period and job title.
[c] The category *both blue and white collar* includes workers who had both titles in their work history in Gela petrochemical plants. The men in the cohort were all born in Sicily.

Comments and concluding remarks

A lack of information on individual occupational and residential exposure limited the study. Only data about job title were available to define occupational history, while the residential history was indirectly evaluated by a qualitative approach.

The decreases observed in the mortality analysis (in terms of SMRs) are probably due to the *healthy worker effect*. This effect is a common drawback in analyses with external references in occupational cohorts, and it is typically characterized by lower relative mortality for all causes combined, for cardiovascular diseases and for nonmalignant respiratory diseases. The healthy worker effect may be explained by selective processes at two points in time: (a) upon hiring, when relatively healthy individuals are likely to gain employment and to remain employed; and (b) at the time of termination, when individuals in poor health are selected to leave the workforce (Checkoway, Pearce & Kriebel, 2004).

The present cohort provides a small contribution to the evaluation of occupational risks in Gela petrochemical workers: excess risk was seen in the comparison of blue collar workers with white collar workers. However, an additional benefit was obtained during the focus group inquiry (Krueger, 1994) conducted among some former workers in the chlor-alkali unit, to assess the commuting phenomenon. Besides confirming the relevance of commuting, it was possible to inform these former workers (operating in the period 1970–1994) about health risks and legal compensation procedures.

Because of the lack of information about smoking habits, the internal analysis for lung cancer was not controlled for smoking. The lack of data about possible confounders is a common problem in occupational retrospective studies, though examples of substantial confounding are rare in occupational epidemiology (Blair et al., 2007). Another important limitation on the interpretation of results is the absence of information about the duration of work in the petrochemical plant and residence in Gela.

Some ecological mortality studies of the resident population of Gela showed excess risk for lung cancer among men (Martuzzi et al., 2002; Fano et al., 2006; Cernigliaro et al., 2008) and, in recent years, also among women (Fano et al., 2006; Cernigliaro et al., 2008). Ecological studies also showed excess risk of morbidity for acute and chronic diseases of the respiratory system among Gela residents (Fano et al., 2006; Cernigliaro et al., 2008). Martuzzi et al. (2002) proposed that these excesses could be due to the evidence – at a general population level – that the risk arises from the occupational setting. The results of the cohort study, however, suggest that the explanation should be different. The analysis of overall cohort mortality with an external reference showed – for lung cancer and other respiratory diseases – a defect in risk estimates, while the internal analysis showed an excess of mortality for lung cancer and morbidity for chronic obstructive pulmonary disease in workers more likely to have resided in Gela (estimates of residential risk were adjusted for occupational experience – that is, job title).

A recent biomonitoring study of several heavy metals in a group of Gela residents showed a high level of total arsenic in the urine of some subjects; this observation is deemed valuable for further investigation (see Chapter 10). Biomonitoring results, although relevant for recent exposures (Hughes, 2006), are of interest because inorganic arsenic or its metabolites (above typical environmental levels) can result in a variety of adverse effects on health, including lung cancer (Straif et al., 2009).

In conclusion, study results on respiratory diseases in Gela residents corroborate the urgent need for an adequate air pollution monitoring programme, as recommended since 1995 (Settimo, Mudu & Viviano, 2009; also see Chapter 7). A complete air quality assessment should incorporate the available data on land contamination, thus contributing to identifying the main sources of exposure to toxic substances like arsenic. Results of the present study also suggest the need to implement an epidemiological surveillance programme of acute and chronic respiratory diseases.

Residential risk in populations in the neighbourhood of industrial sites: case study of the Gabbia District

Background and objectives

The municipality of Pace del Mela (in the Milazzo–Valle del Mela area) and the municipalities of Milazzo, San Filippo del Mela, Merì and Condrò have been recognized as areas with a high risk of environmental contamination". In previous reports, the area as a whole showed mortality and morbidity excesses for particular diseases (Fano et al., 2005; Cernigliaro et al., 2008).

Cause-specific mortality and hospital admissions in the population residing in the Gabbia District of Pace del Mela municipality, located south-east of Milazzo, were studied. The motivation for studying the Gabbia District is its proximity to the Milazzo–Valle del Mela industrial area. Also, the District has an industrial facility for reprocessing exhausted batteries, factories for constructing resin boats, food industries and a facility for manufacturing bricks. Even though, no satisfactory environmental monitoring programme has been implemented in the Milazzo–Valle del Mela area (see Chapters 6 and 7), the residential cohort study was regarded as appropriate – in part, because of the elevated risk perception in the area. A detailed presentation of this study was published recently (Fazzo et al., 2010b). Studies of mortality and hospital discharge records at the municipality level in this area have been discussed previously (see Chapter 5).

Methods

The study design followed the methods for cohort enumeration, follow-up procedures, and mortality and morbidity analyses currently adopted for residential cohort studies in Italy (Fazzo et al., 2009).

The boundaries enclosing the District are the coastline to the north, Muto Creek to the east, the railway to the south, and the highway to the west. All street names and house numbers included in this area were listed and checked with the Registrar Office of the municipality of Pace del Mela, to enumerate the resident population from 1 September 1984 (the date that corresponds to the availability of Registrar Office records on electronic files) through 31 December 2007 (the date of enumeration of the cohort). For every subject residing in the study area for any period of time, personal identifying data were retrieved and coded. The database thus generated was then transferred both to Local Health Unit No. 5 of Messina, to ascertain vital status and causes of death, and to the Sicilian Epidemiological Observatory , for the search of hospital discharge files.

For the follow-up period (1984–2007), SMRs and their corresponding 95% CIs were computed by indirect standardization, using the cause-, age-, gender- and calendar-year-specific mortality rates of the Sicilian population. Morbidity analysis was based on the contrast between the cause-specific number of hospital discharges observed among cohort members and the corresponding expected figures computed by indirect standardization, using the Sicilian population cause-, age- and gender-specific rates as a reference. The follow-up period was from 2001 to 2007 – that is, the time frame covered by hospital discharge records. Only the first hospital admission (for each nosological code), subsequent to the start of residence in the study area, was considered. Standardized hospitalization ratios (SHRs) and their corresponding 95% CIs were thus computed.

Results

The cohort included 457 subjects, 230 men and 227 women. Vital status could not be ascertained for 39 subjects (8.5%) of the cohort. Subjects lost to follow-up were excluded from the analysis, which was restricted to 418 subjects (208 men and 210 women). The mean age at the end of the follow-up period was 38 years for men and 43 years for women. At the end of the follow-up period (2001–2007), 62 subjects (36 men and 26 women) were dead and 356 were alive.

SMRs for the causes of death with at least one observed case are shown in Table 57. No departure was detected either for mortality from all causes or all cancers. Increases in mortality from all causes and all cancers were observed in men, but they were not statistically significant. In particular, two cases of cancer of the rectum were detected; among men, one case of cancer of the larynx and one case of Hodgkin's disease were observed.

Mortality from noncancerous causes detected showed compliance with expected figures. Also, non-significant excesses were found among men for ischaemic heart disease and respiratory diseases. The latter showed a non-significant increase among women as well.

Table 57. Findings of mortality analysis: Gabbia District, 1984–2007

Causes (ICD-9 diagnosis codes)	Men				Women				Overall			
	Observed cases	Expected cases	SMR	95% CI	Observed cases	Expected cases	SMR	95% CI	Observed cases	Expected cases	SMR	95% CI
All causes (0–999)	36	29.50	1.22	0.88–1.69	26	33.60	0.77	0.53–1.14	62	63.10	0.98	0.77–1.26
All cancers (140–208)	9	6.81	1.33	0.69–2.54	5	8.24	0.61	0.25–1.46	14	15.05	0.93	0.55–1.57
Malignant neoplasm of digestive organs and peritoneum (150–159)	3	2.30	1.30	0.42–4.04	2	2.82	0.71	0.17–2.83	5	5.12	0.98	0.41–2.34
Malignant neoplasm of rectum (154)	1	0.19	5.23	0.74–37.10	1	0.23	4.28	0.60–30.40	2	0.42	4.71	1.18–18.90
Malignant neoplasm of liver (155)	1	0.52	1.91	0.27–13.50	0	0.65	0	–	1	1.17	0.85	0.12–6.03
Malignant neoplasm of pancreas (157)	0	0.30	0	–	1	0.37	2.70	0.38–19.25	1	0.67	1.50	0.21–10.60
Malignant neoplasm of larynx (161)	1	0.11	9.50	1.34–67.4	0	0.13	0	–	1	0.24	4.25	0.60–30.20
Malignant neoplasm of trachea, bronchus and lung (162)	1	1.44	0.69	0.10–4.93	0	1.75	0	–	1	3.19	0.31	0.04–2.22
Malignant neoplasm of bladder (188)	1	0.29	3.40	0.48–24.10	0	0.36	0	–	1	0.65	1.52	0.21–10.80
Hodgkin's disease (201)	1	0.03	32.4	4.56–229.70	0	0.04	0	–	1	0.07	14.9	2.10–105.70
Cardiovascular diseases (390–459)	12	12.50	0.96	0.54–1.69	9	14.10	0.64	0.33–1.23	21	26.60	0.79	0.51–1.21
Ischaemic heart disease (410–414)	5	3.39	1.48	0.61–3.55	3	4.02	0.75	0.24–2.31	8	7.41	1.08	0.54–2.16
Respiratory diseases (460–519)	4	1.98	2.02	0.76–5.39	4	2.30	1.74	0.65–4.64	8	4.28	1.87	0.94–3.74

Note. SMRs in bold type have a lower limit of 95% CI > 1.

In the morbidity study, subjects who died before 1 January 2001 and those who had left Sicily that same date were excluded. The cohort was thus restricted to 393 subjects. Fifty-six subjects (28 men and 28 women) had at least one hospital admission for the diseases shown in Table 58. The total number of hospital admissions was 67 (35 men and 32 women).

Table 58. Findings of hospital discharge analysis: Gabbia District, 2001–2007

Causes (ICD-9 codes)	Men				Women				Overall			
	Observed cases	Expected cases	SHR	95% CI	Observed cases	Expected cases	SHR	95% CI	Observed cases	Expected cases	SHR	95% CI
All cancers (140–239)	9	16.60	0.54	0.28–1.04	8	17.80	0.45	0.22–0.90	17	34.40	0.49	0.31–0.79
Malignant neoplasms of colon and rectum (153–154)	1	0.77	1.29	0.18–9.16	0	0.96	0	–	1	1.73	0.58	0.08–4.10
Malignant neoplasm of larynx (161)	1	0.09	10.60	1.50–75.50	0	0.10	0	–	1	0.19	5.26	0.74–37.40
Malignant neoplasms of trachea, bronchus and lung (162)	1	0.64	1.57	0.22–11.13	0	0.71	0	–	1	1.35	0.74	0.10–5.27
Malignant neoplasm of bladder (188)	0	0.69	0	–	1	0.80	1.25	0.18–8.89	1	1.49	0.67	0.09–4.77
Neoplasms of brain and nervous system (191–192; 225)	0	0.30	0	–	1	0.33	3.03	0.43–21.50	1	0.63	1.59	0.22–11.30
Cardiovascular disease (390–459)	14	21.30	0.66	0.39–1.11	16	25.30	0.63	0.39–1.03	30	46.60	0.64	0.45–0.92
Ischaemic heart disease (410–414)	4	4.62	0.87	0.32–2.31	6	5.37	1.12	0.50–2.49	10	9.99	1.00	0.54–1.86
Respiratory diseases (460–519)	8	10.30	0.77	0.39–1.55	7	11.50	0.61	0.29–1.28	15	21.80	0.69	0.41–1.14
Acute respiratory infections (460–466; 480–487)	3	2.76	1.09	0.35–3.37	0	3.07	0	–	3	5.83	0.51	0.17–1.60
Chronic obstructive pulmonary disease (490–496)	4	3.19	1.25	0.47–3.34	1	3.73	0.40	0.27–1.90	5	6.92	0.72	0.30–1.74
Asthma (493)	1	0.72	1.38	0.19–9.83	0	0.71	0	–	1	1.43	0.70	0.10–4.95
Renal diseases (580–589)	2	1.60	1.25	0.31–4.99	0	2.02	0	–	2	3.62	0.55	0.14–2.21

[a] The SHR in bold type has a lower limit of 95% CI >1.

The hospital admission rate for all cancers was significantly lower than expected. Among men, single cases of cancer of the colon and rectum, larynx and lung were observed. Among women single cases of cancer of the bladder and of the brain and nervous system were detected. Non-significant excesses were detected for ischaemic heart disease among women and for respiratory and renal diseases among men.

Comments and concluding remarks

The study findings deserve some comments. Thanks to the cooperation of the municipality of Pace del Mela, the cohort's enumeration was exhaustive. Since electronic files were available only from 1984 onwards, a time-based analysis, taking into account the length of residence and latency times, was not possible. The proportion of people lost to follow-up (8.5%) was (to some extent) higher in this residential cohort than in most occupational cohorts, but there is no reason to hypothesize a differential loss to follow-up of health status and, consequently, no selection bias may have occurred.

Three major limitations should be considered when examining the study results. First, the lack of adequate monitoring of emissions from the Milazzo–Valle del Mela industrial site hampered the possibility of formulating a priori etiological hypotheses about the possible increasing occurrence of diseases in the Gabbia District. Second, the low average age of cohort members precluded the possibility of observing an environmentally-induced burden of disease in the sub-cohort characterized by the longest duration of latency. Finally, the modest sample size of the cohort predisposes the study to low statistical power, which may result in an increased risk of misleading negative results.

Notwithstanding these limitations, it can be observed that, with respect to the regional population, no mortality excess was found for the population of the Gabbia District. With respect to morbidity data, however, a decreased hospital admission rate for all cancers was detected. Also, the occurrence of non-lethal diseases that do not require hospitalization remains unknown.

Mortality and morbidity surveillance in this area should be continued, to detect possible long-term effects. Moreover, data available from an appropriate environmental monitoring programme would be valuable, to focus on the sub-areas most affected by industrial emissions.

Conclusions

The cohort investigations in two polluted sites in Sicily have produced scientific information that may help improve the retrospective assessment of the health impact of the sites being studied. The detection of an increased risk of lung cancer and chronic obstructive pulmonary disease among petrochemical workers resident in Gela when compared with workers of the same industrial facility, but resident elsewhere, confirms the evidence of the adverse effects on health of local air pollution. These findings provide the rationale for requesting effective reduction of emissions of hazardous air pollutants and comprehensive environmental monitoring programmes. The detection of a significantly increased occurrence of asbestos-related diseases among former asbestos-cement workers in the Milazzo–Valle del Mela industrial area has fostered the implementation of overly delayed environmental remediation and has also provided the correct scientific background for health surveillance of formerly exposed subjects. The Gabbia District cohort study has detected no increase in mortality and hospitalization rates, in comparison with reference rates for Sicily. The finding may be due to a real absence of any adverse effect on health of local industrial emissions or be due to inadequate statistical power and duration of observation. In either case, an extension of the follow-up is warranted, to improve the precision of estimated parameters.

When investigating contaminated sites, different study designs can be adopted. Case-control and cross-sectional studies have been used, for instance, to assess, respectively, chronic and acute health risks in the neighbourhood of petrochemical sites (see Chapter 4). Cohort studies have been performed extensively in occupational settings, but their use in the general environment is not well assessed yet, even if remarkable examples are available, especially in case of accidental events, like the one that occurred in Seveso.

Within this framework, the objective of the Gela occupational cohort study was to detect the additional environmental risks due to residence in a polluted site, while the objective of the Gabbia District residential cohort was to test the hypothesis that a localized health risk could be detected at the level of a small area. The latter took into account some findings of a previous geographical study that showed increases in mortality and morbidity from selected causes (see Chapter 6), the results of an asthma study in children (see Chapter 11), and the commonly held perception of health problems in the area. The combination of these elements led to the decision to perform an ad hoc study. The Municipality of Pace del Mela's support, the quality of its Registrar Office's work, and the support of general practitioners and citizen's organizations also weighed strongly in the decision.

A critical aspect of these studies is their weak statistical power, which hampers the possibility of appreciating moderate increases in risk. Under some circumstances, this limitation can be overcome by extension of the observation period. Uncertainty in the estimation of the parameters of interest, however, should always be taken into account (Terracini, 2005).

Each of the cohort studies presented had some weaknesses – in data, exposure assessment, completeness of cohort enumeration and sample size requirements; these limitations hampered a fully satisfactory testing of the etiological hypotheses of interest. These problems notwithstanding, each investigation was implemented using all the environmental and health information available at the local level through routinely collected data. The results of these studies should, therefore, be viewed as "precautionary research" (Grandjean, 2004), a notion that implies addressing issues of possible relevance to public health even if the setting of the investigation is not suitable for the optimal study design, because of limitations in quantity and in quality of available data. Conducting studies in polluted areas where local communities may suffer from both specific environmental risks and unfavourable socioeconomic conditions may speed up clean-up activities, thus contributing (to some extent) to the pursuit of equity (Pagliarani & Botti, 2011).

Cohort studies, in the context of polluted sites in Sicily, confirm their traditional role as the most appropriate epidemiological tools for assessing a range of health outcomes in a population that was identified a priori, according to suitable admissibility criteria. The integration of analytical studies based on individual data and ecological studies based on aggregate data is a core issue widely recognized by researchers engaged in studies of environmental epidemiology.

The sparseness or lack of information on exposure, due to a substantial absence of proper environmental monitoring, is the major problem that hampers the interpretation of the findings of these cohorts. The implementation of environmental control programmes appears to be the main priority for Sicily's polluted sites. From a public health perspective, the importance of this priority – in linking environmental remediation and epidemiological surveillance – cannot be overlooked.

Also, the process of communicating with the communities observed in environmental epidemiological studies deserves attention at all stages of an investigation. The targets of communication include the general population, public health authorities, industry, labour organizations, environmental associations, the media, local experts, scientists and the judicial system (Terracini, 2005). A valid communication process with the population exposed and local authorities can foster mutual confidence (Fazzo, 2007). Such communication can make it easier to conduct an investigation and, subsequently, to endorse the study findings, so that environmental remediation and, if appropriate, health surveillance can proceed.

The present project has devoted special care to set up a collaborative approach with all stakeholders. This approach promoted participation and provided exhaustive information on both the procedures adopted during the study and the findings of the investigation at the end of the project.

10. BIOMONITORING STUDIES: BIOACCUMULATION OF POLYCHLORINATED BIPHENYLS AND HEAVY METALS

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Introduction

In 1990, the Italian Ministry of the Environment declared a 276-km^2 area – which includes the municipalities of Gela, Niscemi and Butera – a high-risk area (see Chapter 1). Gela, a coastal city located in the south of Sicily, had a population of 77 145 people in 2008 (54 774 in 1961). In 2008, the municipalities of Niscemi (332 m above sea level) and Butera (402 m above sea level) had 26 541 and 5063 inhabitants, respectively. In 2000, on the basis of the documented presence of soil contamination or hazardous waste, 51 km^2 of Gela (corresponding to private, industrial, public and marine areas) were designated a site of national concern (see "Introduction" in Chapter 6). In this area, extremely high levels of toxic, persistent and bioaccumulating chemical pollutants have been detected in soil, surface and groundwater, as well as in marine water and sediments (Musmeci et al., 2009). In the last decade, descriptive epidemiological studies have provided evidence of highly significant adverse health outcomes (see Chapter 5). Prior to the analytical epidemiological study described in the present chapter, the data produced by industry, to characterize chemical substances measured in soil, surface water and groundwater in the national sites of concern, were evaluated by an ad hoc multidisciplinary group (Musmeci et al., 2009).

Although data on environmental matrices and health outcomes are available for the area of national concern, these data are scattered and lack organization. Considering the data available on polluting chemicals, and taking into account their toxic properties, the multidisciplinary group produced a list of chemicals defined as *index substances*. This list represents a priority set for environment and health assessments (Musmeci et al., 2009). The human biomonitoring study described in the present chapter aims to improve the knowledge of exposure of the residents of the municipalities of Gela, Niscemi and Butera to selected pollutants. The study surveyed the development of a communication plan: dissemination of information, contacts with local communities, meetings, training activities and the involvement of stakeholders. The study started in 2008, and its results were presented publicly in July 2009.

This chapter will show the results of a human biomonitoring study, called *Studio Epidemiologico Biomonitoraggio Area Gela* (SEBIOMAG), in the Gela area. The chapter contains four sections:

1. background information on environment and health data;
2. material and methods for investigating several metals and organochlorinated compounds;
3. results of metals detected in urine and blood and organochlorinated compounds detected in plasma; and
4. discussion.

Background

Environmental data

Since 1962, the Gela area has included chemical production plants, a power station and an oil refinery plant (one of the largest in Europe, refining 5 million tonnes of crude oil a year) (see the section on "Areas under investigation in Sicily" in Chapter 7 and the section on "Emission data quality issues" in Chapter 14). The prevailing winds in the area blow from the south-west and north-east. Under different conditions – when the wind blows from the south-east or there is a wind inversion or the wind is calm – the City of Gela is exposed to industrial emissions (Settimo, Mudu & Viviano, 2009; also see the section on

"Air quality in the Gela area" in Chapter 7). Under these conditions, high concentrations of metals and organic compounds have been detected in the soil and groundwater of the Gela area of national concern (Table 59). For example, in the sea sediments of this area, mixtures of polychlorinated biphenyl congeners (138, 153 and 169) were detected in quantities that exceeded legal limits (Musmeci et al., 2009). Also, an ecotoxicological analysis detected marine area sediments contaminated by copper, arsenic, mercury and polychlorinated biphenyls. Moreover, fish and benthic organisms were contaminated by heavy metals. Concentrations higher than the predicted no-effect concentrations proposed by a European Commission study (EC, 1999b) for copper (21 μg/l), chromium (6 μg/l) and zinc (32 μg/l) were detected in the Gela River (north of a reclamation site) (Musmeci et al., 2009). Also, high levels of copper (15 μg/l) and zinc (58 μg/l) were detected in the Dirillo River (south of the same reclamation site), and total mercury showed concentration of 2 μg/l – a value about 30–40 times higher than the limits of protection defined by the European Commission for acute (0.07 μg/l) and chronic (0.05 μg/l) toxicity (Musmeci et al., 2009).

Table 59. Mean concentrations of selected pollutants detected in soil and groundwater at the Gela site of national concern

Pollutant	Matrix					
	Soil			Groundwater		
	Value detected (mg/kg)	Reference value (mg/kg)	Ratio of value detected to reference value	Value detected (μg/l)	Reference value (μg/l)	Ratio of value detected to reference value
Arsenic	34.2	20.0	1.7	250	10.0	25
Mercury	118.1	1.0	118.1	2.3	1.0	2.3
Copper	203.0	120.0	1.7	--	--	--
1,2-Dichloroethane	1 000.0	0.2	5 000	3 252 000	3.0	1 084 000
Benzene	190.0	0.1	1 900	160	1.0	160
Benzo[*a*]pyrene	--	--	--	0.14	0.01	14
Xylene/paraxylene	771.0	0.5	1 542	1 580	10.0	158
Vinyl chloride	35.0	0.01	3.5	--	--	--

Source: Musmeci et al. (2009).

For the period 2000–2007, data on air pollution in Gela (collected only by two monitoring stations) showed several pollutants (sulfur dioxide, PM_{10}, nitrogen dioxide and ozone) exceeding the limits established by Ministerial Degree 60/2002 (Ministry of the Environment and Territory & Ministry of Health, 2002). For the same period, data on metals, polychlorinated dibenzo-*p*-dioxins and dibenzofurans, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons were not available. Hourly peak values for sulfur dioxide of 500 μg/m^3 in the monitoring station located in the south-east part of the city and 800 μg/m^3 in the other monitoring station (located closer to the industrial site) were detected, with annual average values of 12 μg/m^3 and 21 μg/m^3, respectively. Higher values were registered during summer months. The annual mean PM_{10} concentration values collected from 2000 to 2007 by a monitoring station located near Gela Hospital were found to be lower than 40 μg/m^3, but hourly peak values greater than 400 μg/m^3 were registered for the period 2006–2007 (Settimo, Mudu & Viviano, 2009; also see the section on "Air quality in the Gela area" in Chapter 7).

Also, monitoring campaigns (53 samplings), conducted between 2002 and 2005, detected abnormal n-butane concentrations in air (about 238 μg/m^3 or 100 ppm), and levels of benzene, toluene and benzo[*a*]pyrene reached peak values of 151.02 μg/m^3, 25.21 μg/m^3 and 264 ng/m^3, respectively. Moreover, concentrations that ranged from a few hundred nanograms per cubic metre to over 2000 ng/m^3 were measured for nickel and vanadium, both contained in the coke produced by the refinery. In addition, peak values of 1000–15 816 ng/m^3 were found for chromium (Cortina & Toscano, 2009), and high concentrations of heavy metals were detected in pine needles (Bosco, Varrica & Dongarrà, 2005; Manno, Varrica & Dongarrà, 2006).

Epidemiological data

Mortality data for 1994–2002 and hospital discharge records for 2001–2007 were surveyed (Cernigliaro et al., 2008; also see Chapter 5). In the Gela area, for both genders, the most impressive finding is an excess of overall mortality compared either with the rest of Sicily or with the neighbouring municipalities in a 40-km radius around Gela. Mortality from lung cancer increased in both genders. Pleural cancer also accounted for a sizable number of deaths. Analyses of hospital discharge records detected excesses of hospitalizations for acute respiratory diseases and (limited to children) asthma.

Also, a cohort study of mortality in male petrochemical workers detected a marked healthy-worker effect. Within the cohort, the risk of lung cancer was higher in residents in Gela than in workers living elsewhere and commuting to work in Gela (Pasetto, Comba & Pirastu, 2008; see also Chapter 9). Despite the absence of an adequate registry of malformations, a survey of cases diagnosed in 1991–2002 showed excesses in the prevalence rates of several birth defects, mainly urinary tract anomalies and hypospadias, when compared with Italian and European figures (Bianchi et al., 2006).

The SEBIOMAG study: material and methods

SEBIOMAG, a cross-sectional biomonitoring study, aimed to assess the levels of population exposure through measurements of the concentration of pollutants in biological systems. The study contributes to defining an environment and health surveillance system at the local level.

Taking into consideration the list of index substances, the study focused on several metals and organochlorinated compounds in biological samples from study subjects living in the Gela area. The data on substances presented and discussed included: antimony, arsenic, copper, mercury, selenium and thallium detected in urine; antimony, arsenic, beryllium, cadmium, copper, lead, mercury, selenium, thallium and vanadium detected in blood; and organochlorinated compounds (59 polychlorinated biphenyl congeners and 12 pesticides) detected in plasma. Blood and urine samples from randomly selected resident subjects and from volunteers living in the risk area were collected and analysed. Individual information on medical history, occupational and environmental exposure, lifestyle and dietary habits was obtained through interviews that used a detailed questionnaire.

Study timetable

Preparation for the study started at the end of 2007. In March 2008, the population began to be increasingly involved. The protocol was finalized in May 2008, and the Ethical Committee of Local Health Unit No. 2 of Caltanissetta approved it in July 2008. During this period, population subjects were selected. The recruitment of subjects started in September 2008, and the collection of biological materials was carried out between October and December 2008. Laboratory analyses and the subsequent statistical analysis were carried out in the first six months of 2009. The first report was presented to the WHO Scientific Committee in June 2009, and its public presentation was held in Gela on 16 July 2009. In the second half of 2009, the report was finalized and recommendations for further research were issued.

Population sampling and sample collection

At the end of 2007, the number of residents 20–44 years of age in the cities of Gela, Niscemi and Butera was 42 545, as obtained by the municipal registry offices (Table 60).

Table 60. Population 20–44 years of age residing in the Gela area, 2007

Municipality	Age group (years)	Number			Percentage[a]		
		Men	Women	Total	Men	Women	Total
Gela	20–24	2 663	2 641	5 304	9.3	9.2	18.5
	25–29	2 761	2 863	5 624	9.6	10.0	19.6
	30–34	2 989	2 958	5 947	10.4	10.3	20.8
	35–39	2 870	3 063	5 933	10.0	10.7	20.7
	40–44	2 854	3 007	5 861	10.0	10.5	20.4
	20–44	14 137	14 532	28 669	49.3	50.7	100.0
Niscemi	20–24	1 141	1 061	2 202	9.4	8.8	18.2
	25–29	1 112	1 156	2 268	9.2	9.5	18.7
	30–34	1 259	1 314	2 573	10.4	10.9	21.2
	35–39	1 332	1 275	2 607	11.0	10.5	21.5
	40–44	1 240	1 223	2 463	10.2	10.1	20.3
	20–44	6 084	6 029	12 113	50.2	49.8	100.0
Butera	20–24	154	163	317	8.7	9.3	18.0
	25–29	175	157	332	9.9	8.9	18.8
	30–34	181	171	352	10.3	9.7	20.0
	35–39	182	187	369	10.3	10.6	20.9
	40–44	185	208	393	10.5	11.8	22.3
	20–44	877	886	1 763	49.7	50.3	100.0
Total	20–24	3 958	3 865	7 823	9.3	9.1	18.4
	25–29	4 048	4 176	8 224	9.5	9.8	19.3
	30–34	4 429	4 443	8 872	10.4	10.4	20.9
	35–39	4 384	4 525	8 909	10.3	10.7	20.9
	40–44	4 279	4 438	8 717	10.1	10.4	20.5
	20–44	21 098	21 447	42 545	49.6	50.4	100.0

[a] The percentage is calculated from total men and women 20–44 years of age.
Source: Municipal office registries of Gela, Niscemi and Butera, 31 December 2007.

The decision to concentrate on the age group of 20- to 44-year-olds was based on the following criteria: (a) the concern of local communities about adverse reproductive health outcomes; (b) the difficulty of involving younger subjects in this type of study (biological samples plus interviews); and (c) the avoidance of the well-known higher body burden of selected pollutants in older people, due to lifelong bioaccumulation.

Subjects were randomly selected and classified by gender and age, using the list of residents from the municipal office registries of Butera, Gela and Niscemi, and the assistance of the local health unit.[12]

A moderate or poor response rate was expected, given such social difficulties as high deprivation index, low income and low level of education (Cernigliaro et al., 2008), and also a poorly functioning mail service. Therefore, subjects were classified according to gender (men/women) and age groups (20–24, 25–29, 30–34, 35–39 and 40–44) and proportionally sampled. The subjects selected were contacted first by letter and then by telephone. Those who accepted to participate went to the district health service, to provide

12 To estimate the sampling error (SE) of a proportion, if the sampling fraction is lower than 5%, the following formula was used: $SE = 1.96 \cdot \sqrt{[p(1\text{-}p)/n]}$, where 1.96 is the zeta value that corresponds to a confidence level of 95%, n is the sample size and p is the sample population proportion to be estimated.

urine and blood samples. Also, all subjects were given an information sheet, outlining the study, and were asked for formal written consent. Trained health officers administered a detailed questionnaire to each study subject who donated a blood or urine sample, or both.

The number of blood donors and subjects interviewed in the three municipalities is shown in Table 61, and the distribution by gender and age group of the subjects recruited is shown in Table 62. A group of volunteers 20–44 years of age was also included, to meet the request of a sensitive part of the community very responsive to social problems, but their results are reported and discussed separately.

Table 61. Number of blood donors and subjects interviewed in sample targeted

Municipality	Number targeted	Number interviewed	Number of donors	Ratio of interviewed to targeted (%)	Ratio of donors to targeted (%)
Gela	140	141	118	100.7	84.3
Niscemi	40	52	39	130.0	97.5
Butera	20	30	29	150.0	145.0
Total	200	223	186	111.5	93.0

Table 62. Distribution of subjects recruited, by gender and age group

Municipality	Gender	Age group (years)					Total	Probability[a]
		20–24	25–29	30–34	35–39	40–44		
Gela	Male	8	11	13	12	13	57	0.106
	Female	6	13	16	14	12	61	
Niscemi	Male	3	5	4	2	3	17	0.517
	Female	4	3	4	5	6	22	
Butera	Male	1	1	5	3	4	14	0.009
	Female	2	5	3	3	2	15	
Total (for all municipalities)[b]	Male	12	17	22	17	20	88	0.401
	%	13.6	19.3	25.0	19.3	22.7	100.0	
	Female	12	21	23	22	20	98	0.528
	%	12.2	21.4	23.5	22.4	20.4	100.0	
	Total	24	38	45	39	40	186	0.223
	%	12.9	20.4	24.2	21.0	21.5	100.0	

[a] The chi-squared *P* value was calculated to test the hypothesis that the age and gender distribution of the subjects recruited is the same as that of the general population (data reported in Table 60).
[b] The percentage is calculated for each age group over the total number of men and women 20–44 years of age.

Questionnaire

A detailed questionnaire was administered to each subject, to collect information about lifestyle, diet, health conditions and potential occupational exposure. Some study variables received specific attention: water consumption (from civic aqueducts or private wells); food consumption (fish, shellfish, meat, milk products, rice, fruit and vegetables produced and/or purchased at the local level); exposure to dust, chemical substances, gases or ionizing radiation; smoking and alcohol habits; and diseases and symptoms in the course of a lifetime. Also, a section that explores risk perception, sources of information on environmental risks and trust was included in the questionnaire, to provide qualitative insights for framing results and supporting their dissemination.

Sample collection and storage

Immediately after collection, urine and blood plasma samples were stored at –20°C, while whole blood was stored at +5°C. Frozen (dry ice) samples were transported by a courier service in a temperature-controlled vehicle to the Laboratory for Environmental and Toxicological Testing at Salvatore Maugeri Foundation, in Pavia, Lombardy, where they were properly stored at the same temperatures until they were analysed.

Overall, 262 whole blood and blood plasma samples and 139 urine samples were processed. For three samples (two from Gela and one from a volunteer), analysis of organochlorinated compounds in plasma was not possible. Also, for 27 samples (10 from Gela, 1 from Niscemi, 4 from Butera and 12 from volunteers), analysis of trace elements was not possible, because the amount of blood was insufficient or the red blood cells disintegrated and released haemoglobin (haemolysed).

Determination of trace elements

An inductively coupled plasma mass spectrometer equipped with a dynamic reaction cell (Perkin Elmer Sciex Elan DRC II ICP–MS) was used to measure trace elements in biological fluids (urine, blood plasma and whole blood). Prior to analysis, the urine samples were properly homogenized, while blood and blood plasma samples underwent microwave pretreatment to reduce matrix interference – that is, sample characteristics that interfere with the ability to detect the presence or amount of a chemical substance in the sample. Certified standard reference materials were used to demonstrate the validity of the method and the reliability of the results. This was demonstrated through the evaluation of all performance parameters, including sensitivity, specificity, applicability and feasibility.

Determination of selected organochlorinated compounds

A fast and reliable method was developed and validated for the simultaneous detection of 12 organochlorine pesticides and up to 59 polychlorinated biphenyl congeners, their selection being based on their environmental occurrence, abundance and potential toxicity. Target analytes included dichlorodiphenyltrichloroethane (DDT) isomers and its metabolites, hexachlorocyclohexane (HCH) isomers (α-, β- and γ-HCH), hexachlorobenzene (HCB), aldrin and dieldrin (Turci et al., 2010).

A selected ion monitoring program was constructed for gas chromatography–mass spectrometry acquisition and quantification of ions. Two molecular ions (M+ and [M+2]+ ions) were monitored for each level of chlorination,[13] to quantify the concentration of the compounds considered in the samples. Retention time, mass, and the relative abundance of the ion measured (compared with that of the standard ion) were used as criteria for identifying these ions and the associated compound levels.

To validate the performance of the method, accuracy, precision and trueness (the hypothetical ability of a measurement procedure to yield results close to expected reference quantity values) were assessed according to the EURACHEM guidelines (EURACHEM Working Group, 1998; Ellison, Rosslein & Williams, 2000). The method was found to be reliable and therefore suitable for establishing reference values (background levels) and can be considered to be suitable for exposure assessment in this field.

Statistical methods for trace elements

To simplify the presentation of the findings, the concentrations of all analytes were log-transformed to normalize their distribution, and geometric means were calculated. All levels below the limit of detection were set to the limit of detection divided by the square root of 2,[14] for calculating geometric means.

13 The presence of a chlorine atom in a compound causes two spectrometric peaks in the molecular ion region – the M+ peak and the M+2 peak – depending on the particular molecular ion: chlorine-35 or chlorine-37 isotope.

14 The limit of detection is the limit of quantification, which is the limit at which one can reasonably tell the difference between two different values.

The limit of detection for all trace elements was 0.01 μg/l. If the proportion of results below the limit of detection was greater than 40%, geometric means were not calculated. For each element, the number of subjects with valid values for the statistics – geometric mean, 95% CI, median, 75th and 95th percentile (for each municipality sample or their sum and for the group of volunteers) – are shown in Tables 63 and 64 for, respectively, urine and blood of participants who provided samples for the SEBIOMAG study.[15]

Table 63. Trace elements in the urine of the 139 participants who provided samples

Trace element	Sample[a]	Limit of detection (%)[b]	Geometric mean (μg/l)	95% CI (μg/l)	75th percentile (μg/l)	95th percentile (μg/l)	Probability[c]
Antimony	Gela	98.6	0.03	0.02–0.03	0.05	0.09	< 0.05
	Niscemi	82.6	0.02	0.01–0.02	0.03	0.04	
	Butera	84.6	0.03	0.02–0.06	0.04	0.35	
	Volunteers	96.8	0.03	0.02–0.03	0.05	0.07	
Arsenic	Gela	100.0	16.43	10.79–25.01	48.02	352.00	< 0.001
	Niscemi	100.0	5.13	2.78–9.47	14.11	44.34	
	Butera	100.0	2.78	0.76–10.14	7.19	89.50	
	Volunteers	100.0	15.21	6.30–36.72	41.38	634.80	
Copper	Gela	100.0	6.09	5.34–6.95	9.11	13.98	< 0.05
	Niscemi	100.0	5.03	3.91–6.47	7.87	11.63	
	Butera	100.0	3.65	1.93–6.88	9.50	18.48	
	Volunteers	100.0	5.24	3.84–7.14	8.69	13.10	
Mercury	Gela	100.0	0.45	0.36–0.57	0.79	3.12	< 0.05
	Niscemi	100.0	0.24	0.17–0.32	0.45	0.71	
	Butera	100.0	0.39	0.22–0.70	0.60	1.54	
	Volunteers	100.0	0.26	0.15–0.43	0.39	2.62	
Selenium	Gela	100.0	16.88	14.07–20.24	30.47	49.41	< 0.01
	Niscemi	100.0	11.15	7.92–15.70	20.74	35.75	
	Butera	100.0	7.64	3.90–14.97	21.46	38.43	
	Volunteers	100.0	15.17	10.72–21.49	32.92	43.29	
Thallium	Gela	98.6	0.15	0.12–0.18	0.26	0.41	< 0.01
	Niscemi	100.0	0.12	0.08–0.18	0.26	0.38	
	Butera	100.0	0.07	0.03–0.13	0.22	0.29	
	Volunteers	100.0	0.14	0.20–0.20	0.24	0.41	

[a] Sample size: Gela (*n* = 72); Niscemi (*n* = 23); Butera (*n* = 13); volunteers (*n* = 31).
[b] Proportion of samples with values greater than the limit of detection (< 0.01 μg/l).
[c] An analysis of variance (Anova) test among three population subsamples.

15 The geometric mean is not affected by the presence of anomalous values that may affect the interpretation of the analysis. In addition, the geometric mean is very similar to the arithmetic mean in the case of symmetric distributions with few extreme values. The 95% CI means that 95% of all possible samples would contain the population parameter of interest. The width of the CI offers information about the uncertainty of the estimates for the unknown parameter. Percentiles give the values below which a certain percent of observations fall. The median is the 50th percentile.

Table 64. Trace elements in the blood of the 232 participants who provided samples

Trace element	Sample [a]	Limit of detection (%) [b]	Geometric mean (µg/l)	95% CI (µg/l)	75th percentile (µg/l)	95th percentile (µg/l)	Probability [c]
Arsenic	Gela	100.0	18.93	17.35–20.64	23.00	44.97	<0.05
	Niscemi	100.0	15.33	13.43–17.49	17.10	48.95	
	Butera	100.0	17.55	15.08–20.43	22.42	26.29	
	Volunteers	100.0	21.91	18.49–25.97	26.27	54.82	--
Beryllium	3 municipalities	38.5	0.02	0.02–0.03	0.16	0.33	--
	Volunteers	51.6	0.04	0.02–0.06	0.16	0.33	--
Cadmium	Gela	91.5	0.31	0.24–0.39	0.57	1.14	<0.05
	Niscemi	100.0	0.57	0.42–0.76	1.23	1.91	
	Butera	100.0	0.41	0.31–0.53	0.60	1.01	
	Volunteers	96.9	0.38	0.29–0.51	0.58	1.41	--
Lead	3 municipalities	99.4	30.48	27.35–33.97	40.79	64.21	--
	Volunteers	100.0	33.09	28.64–38.23	46.13	64.41	--
Mercury	Gela	96.2	0.09	0.06–0.15	0.83	2.76	<0.05
	Niscemi	65.8	0.03	0.02–0.06	0.33	0.72	
	Butera	60.0	0.13	0.05–0.38	1.10	3.31	
	Volunteers	56.2	0.12	0.05–0.24	1.07	6.27	--
Vanadium	3 municipalities	37.8	0.02	0.01–0.03	0.09	0.62	--
	Volunteers	35.1	0.03	0.01–0.04	0.13	0.42	--

[a] Sample size: Gela (*n* = 106); Niscemi (*n* = 38); Butera (*n* = 25); volunteers (*n* = 63).
[b] Proportion of samples with values greater than the limit of detection (< 0.01 µg/l).
[c] An Anova test among three population subsamples.

Geometric means were compared with reference data obtained for Pavia, Lombardy, by selecting a subsample of 162 subjects aged 20–44 years (Turci et al., 2006a,b). In Pavia, there are no industrial plants and relevant accidental pollution has not been documented. Other comparisons with existing threshold limit values and with data from the European Human Biomonitoring study and studies by the United States National Health and Nutrition Examination Survey are presented in the section on "Results" in this chapter.

Student *t*-tests were carried out to detect significant differences in the geometric means between genders. Also, Anova tests, with comparisons (using Tukey's honestly significant difference post-hoc test), were carried out to compare the geometric means among age groups and among the three population samples. A probability value (*P*) less than 0.05 was regarded as significant, for a two-tailed test. When the Student *t*-test or Anova *F*-test was not statistically significant, only the average value is presented. Non-parametric methods (Kruskal–Wallis test) did not yield different results and, therefore, they are not presented. Moreover, a statistical analysis of concentration values, using variables detected through the questionnaire, was performed. Furthermore, for those subjects with higher concentration values than the reference values, the characteristics of demography, socioeconomic status, lifestyle, and occupational and environmental exposure are presented in the subsections on "Trace elements in urine" and "Trace elements in blood" and the "Discussion" section in this chapter.

All statistical analyses were performed using STATA 10/SE (STATA, 2007). Afterwards, to identify possible spatial clusters of cases with high arsenic concentration, a spatial analysis of geocoded residences in the Gela area was performed according to Kulldorff' Spatial Scan Statistics (Kulldorff, 1997), using SaTScan version 6.1 software (Kulldorff, 2002).

Statistical methods for organochlorinated compounds

The concentrations of all analytes were log-transformed to normalize their distribution, and geometric means were calculated. Also, all levels below the limit of detection were set to the limit of detection divided by the square root of 2 for the calculation of geometric means.

The limit of detection for each compound was:

- 0.02 µg/l for: β-HCH, HCB, o,p'-DDE (dichlorodiphenyldichloroethylene), p,p'-DDE, o,p'-DDD (dichlorodiphenyldichloroethane), p,p'-DDD, o,p'-DDT, and polychlorinated biphenyl congeners 18, 21, 28, 31, 37, 44, 47, 49, 52, 61, 66, 70, 74, 87, 97, 99, 101, 105, 110, 118, 119, 123, 128, 138, 146, 149, 151, 153, 158, 167, 168, 170, 171, 172, 177, 178, 180, 183 and 187;
- 0.03 µg/l for: p,p'-DDT and polychlorinated biphenyl congeners 189, 190, 193, 194, 195, 196, 199, 201 and 202;
- 0.05 µg/l for: α-HCH, γ–HCH (lindane), and polychlorinated biphenyl congeners 77, 81, 114, 126, 156, 157, 169, 206, 207, 208 and 209;
- 0.10 µg/l for: aldrin; and
- 0.50 µg/l for: dieldrin.

If the proportion of results below the limit of detection was greater than 40%, geometric means were not calculated. Geometric means were compared with reference data obtained for two Italian areas (Pavia, Lombardy, and Novafeltria, Emilia-Romagna), where no accidental events were registered (Turci et al., 2010). For the comparison, a subsample aged 20–44 years was used (Table 65). All statistical analyses were performed using STATA 10/SE software (STATA, 2007).

Table 65. Comparison of organochlorinated compound values

Organochlorinated compounds	Per cent greater than the limit of detection[a]	SEBIOMAG study: sampled[b] (ng/ml)	SEBIOMAG study: volunteers (ng/ml)	Italian reference: Novafeltria (ng/ml)	Italian reference: Pavia (ng/ml)
Pesticides	--	*n* = 116	*n* = 75	*n* = 36	*n* = 59
HCB	100	0.097^	0.085	0.233	0.147
p,p'-DDE	100	0.716^	0.615	0.539	0.297
p,p'-DDD	18	0.019^	0.021	0.082	0.119
p,p'-DDT	16	0.030^	0.032	0.051	0.026
Polychlorinated biphenyl congeners	--	*n* = 116	*n* = 75	*n* = 94	*n* = 103
52	16	0.018§	0.019	0.015	0.083
138	100	0.106^	0.104	0.269	0.483
153	100	0.140^	0.138	0.381	0.630
180	100	0.121^	0.122	0.282	0.385

[a] Percentage of values greater than the limit of detection level in subjects sampled and volunteers.
[b] Higher value measured in Gela (^) or in Butera (§) (*n* = 29).

Communication and participation activities

Communication activities are a crucial part of human biomonitoring studies (NRC Committee on Human Biomonitoring for Environmental Toxicants, 2006). Keune, Morrens and Loots (2008) have recommended devoting specific attention to identifying suitable tools to be proposed and applied in the research setting.

Planning communication activities requires proper attention, based on knowledge of social and historical features of the communities involved in human biomonitoring research. Also, communication is particularly important where an environmental hazard is present, a public alarm is raised, a clear understanding of the risk is lacking and controversies arise among the stakeholders. This is the case in the study area (Bianchi, 2007).

In planning communication activities, the multidisciplinary working group collected documents and available data. Also, exploratory field work and meetings and exchanges of information with nongovernmental organizations provided the essential input to draft a communication plan for the SEBIOMAG study.

The communication tools identified as being suitable were:

- information materials for the general public, which included leaflets and posters for public dissemination and a television advertisement;
- an informed consent document (legally required), in which the blood donor specified the intention to receive or not receive their own results, either separately or together with the family doctor; and
- a section of the questionnaire that explored risk perception, information sources and trust.

The need for transparency, confidentiality and publicity was considered relevant. To reach the best possible comprehension of the texts of leaflets and posters for public dissemination, the group's interviewers checked all documents.

Interaction with the various media received special attention, and personal relationships were created with the relevant and more influential local media people. Also, to support the research, physicians were targeted specifically: two seminars, legally recognized as a professional training course, were organized. Among other things, the course covered the issues of human biomonitoring, pollution prevention and exposure of community members in high-risk areas – all relevant to the SEBIOMAG research. In the Gela area, 54 general practitioners participated in the training activities.

Careful planning went into communicating the results of analyses of biological samples to the study subjects. During three days, the SEBIOMAG research team and the local staff delivered the results to each donor and replied to their general and specific questions. This was done just prior to a public meeting where the SEBIOMAG results were presented to the prefect – that is, the representative of the central government at the provincial level – and to the regional authority for the environment. Results were presented to the general public and authorities in a public meeting and were summarized in a report, which was distributed to the appropriate institutions and the public. The report included recommendations and suggestions for immediate actions to be taken in the areas of monitoring, remediation and prevention.

Results

Population sampling

As shown in Table 61, the sample contained 200 subjects: 70% in Gela, 20% in Niscemi and 10% in Butera. The sample was stratified by gender and age group, according to the relative proportions in the general population. Thus, 560 in Gela, 160 in Niscemi and 80 in Butera (800 in all) were selected originally. However, the proportion of those tracked by letter or by intermediate general practitioners and responding was higher in Niscemi (155 (96.9%)) and Butera (75 (93.8%)) than in Gela (347 (62.0%)) – for a total of 577 (72.1%).

Among the subjects contacted and not found (mainly students or workers employed outside the area), 87 were in Gela (25.1%), 54 in Niscemi (34.1%), and 37 in Butera (49.3%) – for a total of 178 (30.8%). Among the subjects successfully contacted who accepted being interviewed, 141 of 260 people contacted (54.2%) were in Gela, 52 of 101 (51.5%) were in Niscemi and 30 of 38 (78.9%) were in Butera – in all, 223 of 399 people (55.9%). Among the subjects interviewed who accepted giving blood samples, 118 (83.7%)

were in Gela, 39 (75.0%) in Niscemi and 29 (96.7%) in Butera – for a total of 186 (83.4%). A 108-subject subgroup (72 from Gela, 23 from Niscemi and 13 from Butera) also provided urine samples.

For each municipality and for the whole area, the distribution by gender and age group of the subjects who accepted biosampling is shown in Table 62. Also, the mean age in the SEBIOMAG sample (32.9 years, *n* = 186) was younger than that in the Pavia (34.0 years, *n* = 103) and Novafeltria (35.2 years, *n* = 94) samples; and the proportion of subjects 35–44 years of age was 42.5%, 48.5% and 60.6%, respectively. Moreover, among the 76 volunteers, 66 lived in Gela (36 men and 30 women), 9 in Niscemi (6 men and 3 women) and 1 woman in Butera. All age groups were represented for both genders (5–9 subjects) with a peak of 14 men aged 30–34 years. All volunteers provided a blood sample, and 31 of them provided a urine sample.

The distribution by gender and age group of the individual samples with insufficient volume of blood was quite homogeneous. The data on arsenic concentrations, according to the answers provided for selected categorical variables obtained by SEBIOMAG questionnaires, are shown in Table 66.

Table 66. Arsenic in urine and blood

Variable	Category	Urine			Blood		
		n	Geometric mean (µg/l)	Probability[a]	*n*	Geometric mean (µg/l)	Probability[a]
Gender	Male	51	14.04	NS	79	19.19	
	Female	56	7.94		89	16.80	< 0.05
Age group	20–24	15	3.95	< 0.001	24	16.09	< 0.1
	25–29	23	5.17		34	16.36	
	30–34	27	6.78		39	16.61	
	35–39	19	25.99		38	19.88	
	40–44	24	28.87		35	20.05	
Drank tap water	No	103	10.21	NS	162	17.66	< 0.01
	Yes	4	17.34		6	25.46	
Consumed fish (times per week)	No	28	6.85	NS	44	16.67	< 0.01
	1–2	65	11.73		102	17.24	
	3–4	12	9.08		18	24.04	
	>4	3	40.66		5	22.60	
Exposed to metals	No	55	8.32	< 0.05	79	17.43	< 0.05
	Yes	18	25.08		31	21.51	
Exposed to petrol or its derivatives	No	55	8.32	< 0.1	79	17.43	< 0.05
	Yes	19	22.35		26	21.36	
Exposed to fumes	No	55	8.32	< 0.01	79	17.43	< 0.05
	Yes	17	33.72		27	20.74	
Exposed to wood/ coal ashes	No	55	8.32	< 0.05	79	17.43	NS
	Yes	18	28.79		28	19.21	
Kidney disease	No	101	9.92	NS	158	17.44	
	Yes	7	23.37		11	24.86	< 0.01

[a] NS: not statistically significant.

Trace elements in urine

As shown in Table 63, urinary concentrations in the SEBIOMAG study were above the limit of detection for all the elements, except antimony. Copper concentrations in urine showed a statistically significant heterogeneity among the three population subsamples ($P < 0.05$), with values for the volunteers being in the same range as the values for the three population subsamples (see Table 63). SEBIOMAG study copper concentrations in urine also showed slightly lower geometric mean and similar 95th percentile values when compared with corresponding values in the Pavia sample (geometric mean: 7.70 μg/l; 95th percentile: 13.80 μg/l) (Turci et al., 2006a,b), and slightly lower geometric mean and 95th percentile values when compared with data collected in an industrial area and in capital cities of Andalusia, Spain (geometric means: 7.70 μg/l and 8.12 μg/l, respectively; 95th percentiles: 29.12 μg/l and 27.45 μg/l, respectively) (Aguilera et al., 2008). Median and 95th percentile values reported in France for copper concentrations in urine (Goullé et al., 2005) (6.9 μg/l and 12.1 μg/l, respectively) were similar to those in the SEBIOMAG study, and the latter values were also within the wide range proposed by the Italian Society for Reference Values (Minoia & Apostoli, 2003).

Antimony concentrations in urine were statistically different in the three population subsamples in the SEBIOMAG study ($P < 0.05$), with values for the volunteers being in the same range as the values for the three population subsamples (see Table 63). Mean values of antimony concentrations in urine in the SEBIOMAG study were slightly lower than values collected in Pavia (geometric mean: 0.08 μg/l; 95th percentile: 0.14 μg/l), in the United States National Health and Nutrition Examination Survey (CDC, 2009) (geometric mean: 0.08 μg/l; 95th percentile: 0.28 μg/l;), and in Germany (Schulz et al. 2007) (geometric mean: 0.11 μg/l; 95th percentile: 0.31 μg/l), while the 95th percentile values were somewhat different. The range proposed by the Italian Society for Reference Values (0.2–0.5 μg/l) was also slightly broader than that shown in Table 63, with the exception of Butera (Minoia & Apostoli, 2003). French data showed a similar median value but a lower 95th percentile value (median: 0.04 μg/l and 0.08 μg/l, respectively) compared with SEBIOMAG data for antimony concentrations in urine (Goullé et al., 2005).

Selenium concentrations in urine were statistically different in the three population subsamples in the SEBIOMAG study ($P < 0.01$), with Gela having the highest values and the values for the volunteers being in the range of values for the three subsamples. Also, these concentration levels in urine were higher than those in the Pavia sample (geometric mean: 4.65 μg/l; 95th percentile: 8.15 μg/l) and slightly lower than the value reported in France (median: 20 μg/l; 95th percentile: 45.5 μg/l) (Goullé et al., 2005). The SEBIOMAG study mean values fell in the wide range of 1–25 μg/l reported by Italian Society of Reference Values (Minoia & Apostoli, 2003). A statistically significant trend of increasing mean values with age group ($P < 0.05$) – from 10.4 μg/l in 20- to 24-year-olds to 19.3 μg/l in 40- to 44-year-olds – occurred in the Gela population sample.

Thallium concentrations in urine were statistically different among the three population subsamples in the SEBIOMAG study ($P < 0.01$), with the Gela sample having the highest values and the values for the volunteers falling in the range of the three population subsamples. The SEBIOMAG study thallium concentration values in urine were similar to the values from the Pavia sample (geometric mean: 0.08 μg/l; 95th percentile: 0.14 μg/l) and those from the United States National Health and Nutrition Examination Survey (geometric mean: 0.15 μg/l; 95th percentile: 0.42 μg/l) (CDC, 2009). French data showed a similar mean, but a twofold upper value (median: 0.15 μg/l; 95th percentile: 0.84 μg/l) (Goullé et al., 2005). Also, the SEBIOMAG data had lower values than the upper value of 1.00 μg/l reported by the Italian Society for Reference Values (Minoia & Apostoli, 2003).

Mercury concentrations in urine were statistically different in the three population subsamples in the SEBIOMAG study ($P < 0.05$), and the values for the volunteers were in the range of the three population subsamples. The SEBIOMAG study mercury concentration values in urine were higher than the low level reported for Pavia (geometric mean: 0.09 μg/l; 95th percentile: 0.20 μg/l) and similar to the reference values in Germany (geometric mean: 0.40 μg/l; 95th percentile: 3.00 μg/l) (Schulz et al., 2007) and in the United States National Health and Nutrition Examination Survey (geometric mean: 0.49 μg/l; 95th percentile: 3.33 μg/l) (CDC, 2009). Also, the SEBIOMAG study values for the mercury concentration in urine were slightly lower than those in France (median: 0.59 µg/l; 95th percentile: 2.21 µg/l) (Goullé et al., 2005) and lower than the upper limit of 9.0 µg/l proposed by the Italian Society for Reference Values (Minoia & Apostoli, 2003). Moreover, not one value for the concentration of mercury in urine was over 5.00 µg/l in the SEBIOMAG study.

Arsenic concentrations in urine showed statistically significant heterogeneity among the three population subsamples in the SEBIOMAG study ($P < 0.001$); and values for the volunteers were in the range of the three population subsamples. The mean values for Gela and the volunteers, and all the upper percentile values (Table 63), were higher than the values for Pavia (geometric mean: 5.15 µg/l; 95th percentile: 9.98 µg/l) and Germany (geometric mean: 3.87 µg/l; 95th percentile: 19 3 µg/l) (Schulz et al., 2007) and much higher than the upper levels collected in Spain (geometric mean: 1.27 µg/l; 95th percentile: 5.53 µg/) (Aguilera et al., 2008). The values for the Gela and volunteer geometric mean data were twofold that of the United States National Health and Nutrition Examination Survey data (geometric mean: 8.40 µg/l) and about fivefold and tenfold higher, respectively, than the 95th percentile (66.2 µg/l), while the other two SEBIOMAG study population subsamples (Butera and Niscemi) had lower geometric mean and comparable upper limit values (CDC, 2009). Also, the median value reported in France (19 µg/l) was similar to the higher values of the SEBIOMAG study, while the 95th percentile (161 µg/l) was lower (Goullé et al., 2005). The SEBIOMAG study average fell in the wide range of 5–35 µg/l proposed by the Italian Society for Reference Values (Minoia & Apostoli, 2003).

Arsenic concentrations in urine higher than 100 µg/l were found in 12 samples in Gela (16.7%): 3 women and 9 men. In this group of 12 people, 2 women and 1 man had arsenic concentrations in urine higher than 300 µg/l, 1 man in the age group of 30- to 34-year-olds had a concentration of 774 µg/l, and 1 man in the age group of 40- to 44-year-olds had a concentration of 1197 µg/l. Among the volunteers, arsenic concentrations in urine higher than 100 µg/l were found in 6 of 31 individual samples (19.4%): 4 men and 2 women. In this group of six people, one man and one woman had values higher than 300 µg/l, and one man had a value higher than 600 µg/l.

Statistically significant results of the analysis of individual arsenic concentrations in urine and questionnaire responses of the population sample (see Table 66) showed the following.

- The geometric mean concentration in men was almost two times that in women, even if not statistically significant.
- A marked statistical difference between age groups was found, with a trend of increasing values from the youngest group to the oldest.
- The geometric mean in consumers of tap water was higher than that in non-consumers, without statistical significance, due to the low number of consumers, since the majority of people drank bottled water.
- The geometric mean in stronger consumers of fish (more than four times a week) was fourfold that of non-consumers or weaker consumers and sixfold that of non-consumers; although due to reduced numbers, the difference was not statistically significant.
- The geometric mean in study participants exposed to metal ashes, to petrol or its derivatives, to fumes, ot to wood/coal ashes was threefold to fourfold that of participants not exposed. Also, a similar statistical difference between people exposed to asbestos and people not exposed was found (27.39 µg/l versus 8.32 µg/l).
- In seven subjects with kidney disease, the geometric mean for arsenic concentrations in urine was more than twofold that among the other subjects, though it was not statistically significant.

Trace elements in blood

As shown in Table 64, the percentage of concentration values in blood below the limit of detection in the SEBIOMAG study was high for beryllium and vanadium and for mercury in two of three population subsamples (Niscemi and Butera) and in the volunteer sample, while it was low in the Gela subsample, a result worthy of discussion. For lead, cadmium and arsenic, the percentage of concentration values below the limit of detection was low or null.

Beryllium concentrations in blood were homogeneous among the three subsamples in the SEBIOMAG study (see Table 64). The concentrations measured in Pavia were lower (geometric mean: 0.005 µg/l; 95th percentile: 0.011 µg/l) than those in the SEBIOMAG study. The levels reported in France (median: 0.02 µg/l; 95th percentile: 0.09 µg/l) (Goullé et al., 2005) were similar to values in the SEBIOMAG study, and they were lower than the limit of detection (0.13 g/l). The United States National Health and Nutrition Examination Survey data for beryllium were lower than the limit of detection (< 0.13 µg/l) (CDC, 2009).

Cadmium concentrations in blood in the SEBIOMAG study were higher than the very low values collected in Pavia (geometric mean: 0.09 µg/l; 95th percentile: 0.21 µg/l) and were similar to the values reported in: France (median: 0.31 µg/l; 95th percentile: 2.04 µg/l) (Goullé et al., 2005), Germany (geometric mean: 0.43 µg/l; 95th percentile: 2.20 µg/l) (Schulz et al., 2007), the Czech Republic (geometric mean: 0.6 µg/l; 95th percentile: 3.0 µg/l) (Batáriová et al., 2006) and the United States National Health and Nutrition Examination Survey (geometric mean: 0.38 µg/l; 95th percentile: 1.80 µg/l) (CDC, 2009). The cadmium concentrations in blood in the SEBIOMAG study were also within the range 0.1–3.0 µg/l reported by the Italian Society for Reference Values (Minoia & Apostoli, 2003). Also, only one value was higher than 5 µg/l (7.06 µg/l, female, age group 30- to 34-year-olds, volunteer), and in 11 subjects a concentration higher than 1 µg/l was detected. Moreover, a statistically significant heterogeneity was found for the age groups, with a trend showing an increase from 0.23 µg/l in 20- to 24-year-olds to 0.51 µg/l in 35- to 39-year-olds. Furthermore, SEBIOMAG study cadmium concentrations in blood were higher for previous smokers (geometric mean: 0.52 µg/l; *n*: 56) than for those who never smoked (geometric mean: 0.25 µg/l; *n*: 26) and were higher for smokers (geometric mean: 0.68 µg/l; *n*: 57) than for non-smokers (geometric mean: 0.37 µg/l; *n*: 26).

Lead concentrations in blood were similar in the three population subsamples and in the volunteers in the SEBIOMAG study (see Table 64). SEBIOMAG lead concentration levels in blood were similar to data reported in: Pavia (geometric mean: 2.74 µg/dl; 95th percentile: 7.15 µg/dl); Germany ((geometric mean: 3.16 µg/dl; 95th percentile: 7.20 µg/dl) (Becker et al., 2002) and (geometric mean: 3.07 µg/dl: 95th percentile: unavailable) (Schulz et al., 2007)); the Czech Republic (geometric mean: 3.3 µg/dl; 95th percentile: 7.2 µg/dl) (Batáriová et al., 2006); and France (median: 2.6 µg/dl; 95th percentile: 6.3 µg/dl) (Goullé et al. 2005); and they were about twofold higher than the United States National Health and Nutrition Examination Survey data (geometric mean: 1.52 µg/dl; 95th percentile: 4.30 µg/dl) (CDC, 2009). Slightly higher lead concentration levels in blood were reported in a survey of adults conducted in Italy in 2000 (arithmetic mean: 3.7 µg/dl) (Apostoli et al., 2002), while the range suggested by the Italian Society for Reference Values was very broad (0.5–16.0 µg/dl) (Minoia & Apostoli, 2003).

Also, lead concentrations in blood in the SEBIOMAG study were significantly higher for men than for women, both in a randomly selected sample (geometric mean: 3.82 µg/dl (men) versus 2.49 µg/dl (women)) and for the volunteers (geometric mean: 3.89 µg/dl (men) versus 2.62 µg/dl (women)). This gender difference was in agreement with other data – for example, 3.72 µg/dl (men) versus 2.69 µg/dl (women) in Germany (Schulz et al., 2007), 3.7 µg/dl (men) versus 2.6 µg/dl (women) in the Czech Republic (Batáriová et al., 2006), and 1.69 µg/dl (men) versus 1.22 µg/dl (women) in the United States National Health and Nutrition Examination Survey (CDC, 2009).

Considering the possible reference action level of 10 µg/dl for lead concentrations in blood, established by the CDC for children in 1991, and considering different health effects reported at lower levels of exposure by subsequent studies (CDC, 2009), three outlier data in the SEBIOMAG study are worth noting for their magnitude: 28.7 µg/dl for a volunteer man in the age group 30–34 years (with elevated blood concentration of arsenic, cadmium and mercury); 13.3 µg/dl for a man in the age group 30–34 years; and 11.9 µg/dl for a man in the age group 40–44 years (with a high blood concentration of vanadium: 13.63 µg/l). Moreover, geometric mean concentrations in those exposed to metal ashes (geometric mean: 3.90 µg/dl; *n*: 31) or wood/coal ashes (geometric mean: 3.74 µg/dl; *n*: 28) were significantly higher than in those not exposed (geometric mean: 2.89 µg/dl; *n*: 79; $P < 0.05$).

Vanadium concentrations in blood were homogeneous in the three population subsamples and in the volunteers in the SEBIOMAG study (see Table 64). These vanadium concentration levels in blood, however, were lower than those of Pavia (geometric mean: 0.06 µg/l; 95th percentile: 0.10 µg/l) and similar to those reported by different studies (geometric mean: 0.032–0.095 μg/l) (ATSDR, 2009). In the Niscemi subsample, two men and one woman had high concentration values (5.5 μg/l, 13.6 μg/l and 8.1 μg/l, respectively), as well as one woman among the volunteers (5.6 μg/l). These data are similar to blood concentrations of individuals exposed occupationally, for which a mean of 33.2 μg/l and a range of 3.1–217 μg/l have been reported (ATSDR, 2009).

Mercury concentrations in blood were statistically different in the three population subsamples in the SEBIOMAG study, while in the study's volunteers the geometric mean was comparable and the 95th percentile value was almost twofold higher than the upper range level (see Table 64). The SEBIOMAG study mercury concentration levels in blood were lower than those reported in Pavia (geometric mean: 0.27 μg/l; 95th percentile: 0.78 μg/l) if the average was considered, while upper percentile values were similar or higher. Also, the SEBIOMAG study geometric mean values for mercury concentration levels in blood were lower than those in data reported for Germany (geometric mean: 0.61 μg/l; 95th percentile: 2.40 μg/l) (Schulz et al., 2007), the Czech Republic (geometric mean: 0.82 μg/l; 95th percentile: 3.45 μg/l) (Batáriová et al., 2006) and the United States National Health and Nutrition Examination Survey (geometric mean: 0.98 μg/l; 95th percentile: 5.4 μg/l) (CDC, 2009); and they were quite lower than the data in the French study (median: 3.0 μg/l; 95th percentile: 8.13 μg/l) (Goullé et al., 2005). The SEBIOMAG study geometric means fell in the 1–5 μg/l range proposed by the Italian Society of Reference Values (Minoia & Apostoli, 2003). Moreover, for three subjects in the SEBIOMAG study, a mercury concentration in blood higher than 10 μg/l was found: 12.55 μg/l for a man in the 30–34-year age group; 19.30 μg/l for a woman in the 35–39-year age group; and 10.75 μg/l for a woman (volunteer) in the 40–44-year age group. Furthermore, values of mercury concentration levels in blood were significantly higher for SEBIOMAG study volunteers with occupational exposures than for volunteers not exposed.

Arsenic concentrations in blood differed statistically among the three population subsamples in the SEBIOMAG study, while among the volunteers higher values were observed (see Table 64). The SEBIOMAG study values for arsenic concentrations in blood were much higher than those reported both in Pavia (geometric mean: 4.90 μg/l; 95th percentile: 6.87 μg/l), and France (median: 5.0 μg/l; 95th percentile: 17.8 μg/l) (Goullé et al., 2005). Also, the geometric mean values of the SEBIOMAG study exceeded the range limits proposed by the Italian Society for Reference Values (1–12 μg/l) (Minoia & Apostoli, 2003). Moreover, in the SEBIOMAG study, arsenic concentration levels in blood higher than 40 μg/l were found in:

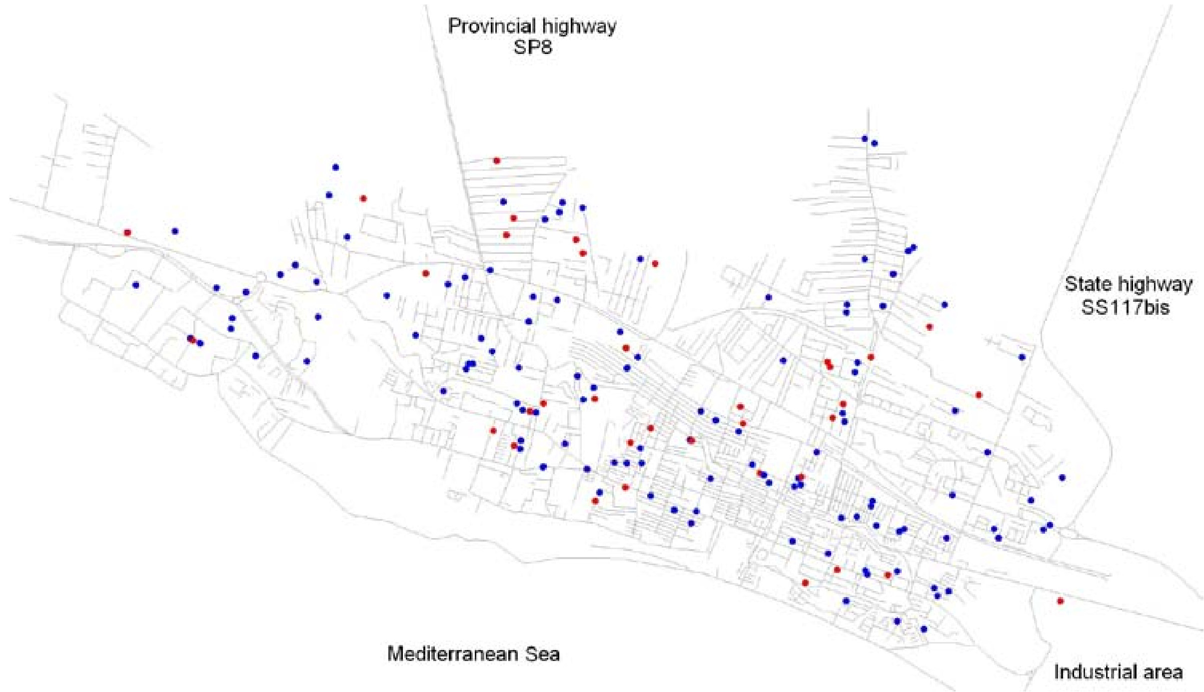
- five samples in Gela (4.7%): four men (one in the 30–34-year age group, three more than 40 years of age); one woman (in the 35–39-year age group);
- two women in Niscemi (5.3%), (one in the 20–24-year age group and the other in the 25–29-year age group);
- one man in Butera (4%) (in the 40–44-year age group); and
- three volunteers (4.7%): one man (with 210.8 μg/l, already reported as an outlier), one woman in the 30–34-year age group (with 271.8 μg/l) and one woman in the 40–44-year age group (with 210.8 μg/l), both women having an outlier value of urinary arsenic concentration.

Statistically significant results of the analysis of individual arsenic concentrations in blood and questionnaire responses of the population sample in the SEBIOMAG study (see Table 66) showed the following.

- The geometric mean concentrations for men were slightly (but significantly) higher than those for women.
- A difference between age groups was found, with a trend of increasing values, from 16.19 μg/l for the youngest age group to 20.05 μg/l for the oldest ($P < 0.1$).
- The geometric mean for consumers of tap water (n = 6) was significantly higher ($P < 0.05$) than that for the non-consumers (25.46 μg/l versus 17.66 μg/l), although the sample size was small;
- The geometric mean for consumers of fish at least three times a week was significantly higher than that for non-consumers or weaker consumers (24.04–22.60 μg/l versus 16.67–17.24 μg/l; $P < 0.01$).
- The geometric mean for study participants exposed to metals, to petrol or its derivatives, to fumes, or to wood/coal ashes was significantly higher than that for study participants not exposed ($P < 0.05$).
- For 11 subjects with kidney disease, the geometric mean for arsenic concentrations in blood was 24.86 μg/l, compared with 17.44 μg/l for other study subjects without kidney disease ($P < 0.01$).

Neither spatial clusters nor the pattern of cases with higher urinary or blood concentrations of arsenic emerged from spatial scan analysis (Fig. 18).

Fig. 18. Spatial distribution of the subjects sampled in Gela, according to arsenic concentration in their urine and blood [a]



[a] Red dots indicate the subjects with an arsenic level in urine greater than 40 μg/l and/or with an arsenic level in blood greater than 20 μg/l; blue dots indicate all other study subjects.

Organochlorinated compounds in serum

The results show that α-HCH, γ-HCH, aldrin, dieldrin and 45 of 59 polychlorinated biphenyl congeners were below the limit of quantification in all SEBIOMAG study samples. Other results include the following.

- Four organochlorine pesticides and ten polychlorinated biphenyls were found to be above the limit of detection in less than 10% of the samples.
- Two organochlorine pesticides and one polychlorinated biphenyl were found to be above the limit of detection in 10–20% of the samples.
- Two organochlorine pesticides and three polychlorinated biphenyls were found to be above the limit of detection in all samples.

The organochlorinated compounds with at least 10% of values greater than the limit of detection and the comparison reference values of Pavia and Novafeltria (Turci et al., 2006a,b) (shown in Table 65) showed the following.

- Among the pesticide metabolites, HCB and p,p'-DDD in the SEBIOMAG study had lower levels than those of the two reference studies; the level for p,p'-DDE was similar to that of one reference study and twofold higher than that of the other; and the level for p,p'-DDT was similar to that of one reference study and slightly lower than that of the other.
- The levels of polychlorinated biphenyl congeners 52, 138, 153 and 180 were similar in population and volunteer samples and were lower than those of both reference studies.

Dioxin-like congeners 77, 126 and 169 were represented more proportionally in population samples in the SEBIOMAG study (5 of 116 subjects in Gela, 2 of 39 in Niscemi and 1 of 29 in Butera) than they were in the reference studies.

Furthermore, three outliers, with measured values clearly higher than the others and higher than those in the reference studies (Turci et al., 2010), were found within the Gela samples (including two volunteers): a Gela man in the 35–39-year age group, a male volunteer in the 30–34-year age group and a female volunteer in the 35–39-year age group (Table 67). The first and the last subjects had high values of β-HCH, all the DDT isomers, and polychlorinated biphenyl congeners 101, 138, 153, 180, with polychlorinated biphenyl congener 52 appearing only in the male volunteer. The other male subject had abnormal values of β-HCH, p,p'-DDT and polychlorinated biphenyl congener 180.

Table 67. Concentration of selected organochlorinated compounds in three outliers

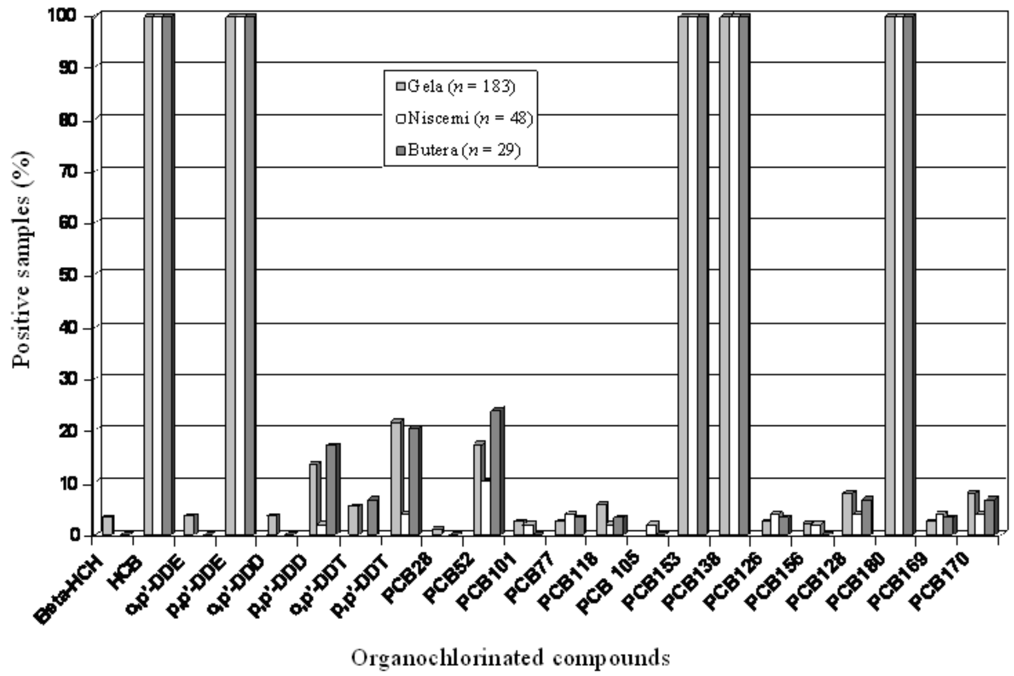
Organochlorinated compounds	SEBIOMAG subject (code) concentration values		
	1M428[a] (μg/l)	V1M31[b] (μg/l)	V1F44[c] (μg/l)
β–HCH	14.4	51.0	19.7
HCB	0.088	0.077	0.082
o,p′-DDE	13.6	0.62	76.9
p,p′-DDE	85.0	1.68	106
o,p′-DDD	93.2	0.98	95.0
p,p′-DDD	117	2.28	92.8
o,p'-DDT	130	0.65	123
p,p'-DDT	180	5.1	141
Polychlorinated biphenyl congener 28	< 0.02	< 0.02	0.89
Polychlorinated biphenyl congener 52	< 0.02	< 0.02	10.5
Polychlorinated biphenyl congener 101	17.6	< 0.02	76.4
Polychlorinated biphenyl congener 138	133	2.1	117
Polychlorinated biphenyl congener 153	126	0.90	120
Polychlorinated biphenyl congener 180	134	14.2	106

[a] 1M428: Gela man in the 35–39-year age group.
[b] V1M31: male volunteer in the 30–34-year age group.
[c] V1F44: female volunteer in the 35–39-year age group.

No dioxin-like congeners were found in the outlier subjects, while some of them were measured in eight subjects (five in Gela, two in Niscemi, one in Butera), but all with concentrations lower than 0.5 ng/ml, with the exception of a woman volunteer in the 35–39-year age group (with polychlorinated biphenyl congener 77 = 1.08 ng/ml, polychlorinated biphenyl congener 126 = 3.80 ng/ml and polychlorinated biphenyl congener 169 = 5.01 ng/ml).

In Fig. 19, the percentage of positive samples is shown for the three municipalities monitored. It should be noted that HCB, p,p'-DDE, and polychlorinated biphenyl congeners 153, 138 and 180 were detected in all samples, in accordance with the literature (McFarland & Clarke, 1989; Ritter et al., 1995; ATSDR, 2000, 2002, 2005).

Fig. 19. Percentage of positive samples in the three municipalities



PCB: polychlorinated biphenyl.

Risk perception: questionnaire analysis

The questionnaire administered to the blood donors included a section on risk awareness and perception: the questions had been selected from the questionnaire used in the Milazzo–Valle del Mela and Augusta–Priolo areas (see Chapter 15 and the fourth section in the Annex on "Questionnaire: multipurpose investigation on a population in an area at risk").

Among the hazards believed to be very dangerous or dangerous, those more frequently mentioned by residents in the Gela area were air pollution (88%), dangerous industrial plants (87%) and water pollution (82%). Of the respondents, 64% stated they were insufficiently informed about the hazards in the area, while 33% stated they were informed. Of the people interviewed, 30% believed the environmental situation was *serious and irreversible*, 61% believed it was *serious and soluble* or *possible to improve*, only 7% believed it was *acceptable*, and nobody believed it was *very good* (2% of the answers were missing). Almost everybody was aware of the environmental problems (95%) and health problems (97%) that existed in the area.[16] Among the sources of information on environmental hazards, 85% of respondents mentioned national television as their major or exclusive source of information.

One of the questions concerned the perception of health problems among residents in a polluted area. Of the people believing that the onset of an illness is certain or highly probable, 93% asserted that such problems could cause cancer, 92% asserted they could cause congenital malformations, 86% asserted they could cause acute respiratory effects and 78% asserted they could cause leukaemia.

16 Some comparisons with the other two areas deserve attention. In the Augusta–Priolo and Milazzo–Valle del Mela areas, the survey results also showed a high concern for air pollution, dangerous industrial plants and water pollution. In the Augusta–Priolo area, the results were 92%, 93% and 87%, respectively, while in the Milazzo–Valle del Mela area they were 93%, 91% and 76% respectively for air pollution, dangerous industrial plants and water pollution. Of respondents not sufficiently informed about the hazards in the area, 88% were in the Augusta–Priolo area and 92% were in the Milazzo–Valle del Mela area. The environmental situation was considered to be *serious and irreversible* by 19% of respondents in the Augusta–Priolo area and by 13% of respondents in the Milazzo–Valle del Mela area. Also, 26% of respondents in the Augusta–Priolo area considered the situation *acceptable*, as did 25% of respondents in the Milazzo–Valle del Mela area. Among the sources of information on environmental hazards, 70% of respondents mentioned national television as the major or exclusive source in the Augusta–Priolo area, as did 72% of respondents in the Milazzo–Valle del Mela area. Of respondents thinking that the onset of an illness is *certain* or *highly probable* in the Augusta–Priolo area (Milazzo–Valle del Mela area), 97% (93%) thought so for cancer; 95% (75%) thought so for congenital malformations; 93% (94%) thought so for acute respiratory effects; and 86% (77%) thought so for leukaemia.

Discussion

The final distribution of the subjects recruited was not significantly different from that of the original random sample. However, 30% of subjects from the original sample were not found, and only 56% of the people contacted accepted to participate. Thus, a selection bias cannot be ruled out. Compared with Niscemi and Butera, Gela had a higher proportion of subjects that could be traced, but at a lower acceptance rate. Also, younger subjects had less representation among those targeted, mainly due to the high number of commuting students and workers that resided outside the area. The difficulty in finding, contacting and recruiting subjects is, in our opinion, further evidence of the critical social and economical situation in the area. Moreover, the high deprivation index requires further consideration (see Chapter 5).

We cannot exclude the possibility that the exposure profile of participants differed from those who were not traced or did not respond. Due to logistic difficulties, we could not analyse in depth the characteristics of non-respondents.

However, some further considerations should be included here. First, among the subjects not traced, a considerable number of them resided only formally in Gela (workers, university students, convicts). Also, refusals included a high proportion of public employees (about 1 in 3). Moreover, industrial workers comprised about 15% of volunteers, compared with 5% of sampled subjects. Nevertheless, no relevant differences emerged between groups, especially when volunteer and Gela groups were compared. As stated above, the spatial distribution of subjects studied was not associated with exposure to arsenic (Fig. 18).

All the above considered, although the weight of non-responses and refusals cannot be fully assessed, we can reasonably assume that these shortcomings do not impair the robustness of the findings, notably for arsenic. In general, a case for a selection bias could have made for the exclusion of a few highly exposed subjects, with a consequent small decrease in the geometric mean values. Overall, exposure and concentration vary according to different factors (Table 68).

Table 68. SEBIOMAG survey in the Gela area: synthesis of results and comments[a]

Trace element concentrations	Results	General comments
Antimony in urine	Concentrations were lower than both those in the reference studies and data reported for other areas (Minoia et al., 1990; Hamilton, Sabbioni & Van der Venne, 1994; Paschal et al., 1998).	Results are probably due to actual differences in exposure profile and in methods.
Arsenic in urine and blood	Arsenic mean concentrations in the urine of the residents of Gela and in the urine of volunteers were consistently higher than those in the other SEBIOMAG subpopulations and in the Italian and other reference studies. Although the mean concentration reported for a Korean community exposed to arsenic and living in the United States was fourfold that of the SEBIOMAG higher value, the 95th percentile values were similar (Cleland et al., 2009). SEBIOMAG values were similar to those reported among people exposed to elevated levels of arsenic in drinking-water in Taiwan Province of China (Chiou et al., 1997); they were lower than levels reported for highly exposed communities in Argentina (Vahter et al., 1995), in some districts of Bangladesh (Ahsan et al., 2000; Chowdhury et al., 2003), and in Mongolia, China (Pi et al., 2002; Sun et al., 2007). Urinary arsenic concentrations higher than 300 µg/l were detected in 3 women and 2 men, while values over 100 µg/l were found in 12 of 72 samples in Gela (16.7%) and in 6 volunteers (19.4%), prevalently men (9 of 12 and 4 of 6, respectively). Values of blood arsenic concentrations higher than 40 µg/l were found for four men and one woman in Gela, two women in Niscemi, one man in Butera, and two women and one man among the volunteers.	The lack of data on arsenic species found in biological samples of residents in Gela and in tap water impairs a full comparison with the data from polluted countries, where high concentrations of inorganic arsenic are documented. A speciation study could contribute to clarifying this point.
Beryllium in blood (upper limit of detection)	Concentrations were homogeneous in the SEBIOMAG sample, higher than those in the Italian reference study and similar to those in the other reference studies.	The high proportion of values lower than the limit of detection must be considered.

Table 68 (concluded)

Trace element concentrations	Results	General comments
Cadmium in blood	Concentrations were similar to those of the foreign reference studies and higher than those in the Pavia study (where they were very low).	Only one sample was higher than the 95th percentile of 5 μg/l proposed by the United States Occupational Safety and Health Administration (OSHA, 2009), and few samples were higher than 1 μg/l that is, a low level, but previously associated with subtle increases in markers of renal tubular effects (Ezaki et al., 2003; Åkesson et al., 2005). The significant association with smoking habits was in agreement with data reported in the literature (Becker et al., 2002; Olsson et al., 2002; Batáriová et al., 2006).
Copper in urine	Concentrations were lower or similar to those of the reference population.	None
Lead in blood	Concentrations were similar to those of the Pavia and European reference studies, and higher than those in the United States National Health and Nutrition Examination Survey data. Concentrations were significantly higher in men than in women, in agreement with other studies (Batáriová et al., 2006; Schulz et al., 2007; CDC, 2009).	None
Mercury in blood and urine	The proportions of values for mercury in blood lower than the limit of detection were quite high in Niscemi, Butera and in the volunteers and very low in Gela. While the average of the SEBIOMAG data was lower than that of the reference studies, the 95th percentile levels were comparable. Only three outlier values were observed. The levels of mercury in urine were higher in residents in Gela than in residents in Niscemi and Butera. As a whole, the SEBIOMAG results were similar or slightly lower than those for the other reference studies, with the exception of the comparison with the Pavia study. No SEBIOMAG values were higher than 5 μg/l.	No statistically significant associations with fish consumption or with teeth amalgam were detected. However, associations with some occupational exposures, especially among volunteers, were found. The concentrations of mercury in blood were lower than those of the reference studies, and the concentrations of mercury in urine were similar to the reference study values and point towards a weak role for diet. Also, anomalies of sample storage cannot be ruled out to explain the low concentration values detected for mercury in blood. For a comprehensive assessment, data on different species of mercury in the immediate surroundings and in the total diet would be needed.
Selenium in urine	Concentrations were higher than those of the Italian reference studies and similar to those of the other reference studies.	None
Thallium in urine	Concentrations were similar to those detected in the reference study populations.	None
Vanadium in blood	SEBIOMAG concentration levels for vanadium in blood were lower than those of the Pavia study and similar to those reported by a number of different studies (ATSDR, 2009).	The results are worth attention, although two thirds of the individual samples had values below the limit of detection. Given that only four subjects from Niscemi showed concentration values similar to individuals occupationally exposed (ATSDR, 2009), the hypothesis of environmental exposure is not supported.

[a] The table contains a summary of both findings mentioned in this chapter and results and comments from other articles not mentioned earlier.

In addition to the general comments made in Table 68 for trace elements in urine and blood, more specific comments follow for selenium, lead, vanadium, mercury and arsenic, in particular.

With regard to urinary selenium levels, a significant trend of concentration increasing with age was found. Although selenium is a very rare element in the natural environment and the International Agency for Research on Cancer evaluated it as Group 3 (not classifiable as to its carcinogenicity in humans) (IARC, 1999), possible exposure to selenium is a significant issue. The health effects of selenium can vary from brittle hair and deformed nails at low levels of exposure, to rashes, the sensation of heat, swelling of the skin and severe pain, and different respiratory diseases at high levels of exposure. Exposure can occur through ingestion of food (it is naturally present in meat, grains and cereals) and water, contact with soil, and inhalation of air. In the Gela area, the main documented sources of exposure are hazardous waste landfill sites, farmland, and coal and oil combustion – mainly through breathing.

With regard to the levels of lead in blood, only three outliers were identified: all men with altered values of other metals and with some occupational exposure. However, 5% of individuals measured over 6 μg/dl and 25% over 4 μg/dl, which is indicative of environmental exposure.

Because it is a constituent of nearly all coal and petroleum crude oils, vanadium deserves particular consideration. Compared with other elements, it is highly enriched in heavy fuel oils due to vanadium porphyrins: for this reason, it is used as a marker of emissions from fuel oil combustion (Mamane & Pirrone, 1998). Vanadium is present in food, particularly in grains, sweeteners, meat, fish, and poultry. The International Agency for Research on Cancer recognizes vanadium pentoxide as possibly being carcinogenic to humans (Group 2B) (IARC, 2006b).

In human biomonitoring studies, to properly interpret the presence of mercury, the different significances of haematic and urinary mercury must be considered. The total mercury concentration in blood is due predominantly to the dietary intake of organic forms, mostly methylmercury, while the concentration of urinary mercury consists mostly of inorganic forms (Cianciola et al., 1997; Kingman, Albertini & Brown, 1998). Also, it is well accepted that total urinary mercury levels increase with fish consumption (Dewailly et al., 2001; Sanzo et al., 2001; Schober et al., 2003; Mahaffey, Clickner & Bodurow, 2004) and are associated with teeth filled with amalgams that contain mercury (Becker et al., 2003). Moreover, in an area with industrial pollution, where subjects had no amalgam in their teeth, concentrations of urinary mercury were still higher than that in a reference group (Jarosinska et al., 2006).

The concentration of arsenic also deserves additional comment. A sampling error of 4.4% can be estimated for 16.7% (12 of 72 subjects) of the Gela sample (the population size is shown in Table 60 and the formula for the sampling error appears in a footnote in this chapter in the subsection on "Population sampling and sample collection"), corresponding to an interval estimate of 12.3% to 21.1% around the figure estimated. These estimates, if applied to the group of 20- to 44-year-olds in the Gela population (Table 60), predict 4788 (between 3528 and 6048) residents in Gela with urinary arsenic concentrations greater than 100 μg/l. Also, arsenic concentrations in blood were higher in Gela and volunteer samples, which exceeded those of the Italian (Pavia) and the French reference studies.

The arsenic findings, particularly those for urine, are of concern when considering that arsenic concentration levels up to 60 μg/l in blood and 274 μg/l in urine were previously reported during chronic arsenic intoxication (NRC Subcommittee on Arsenic in Drinking Water, 1999; Benbrahim-Tallaa & Waalkes, 2008). In 7 and 11 subjects with kidney disease, the urinary and blood arsenic levels were, respectively, 2 and almost 1.5 times greater than those in subjects without kidney disease. These findings are consistent with the evidence that chronic exposure to low levels of arsenic and/or cadmium can produce renal injuries in people and with suggestions that injury can be produced by tubular damage in the kidney through oxidative stress in people (Huang et al., 2009). The higher level of arsenic detected in men and older subjects – as well as the higher values found among people exposed to metals, petrol or its derivatives, fumes or wood/coal ashes – may give weight to the contribution made by the occupational component of exposure to the burden of exposure.

On the other hand, the suggestion of an environmental component of exposure comes from the higher arsenic levels in the urine and blood of people: (a) who drink tap water, than in those who drink bottled water; and (b) who are strong consumers of fish, than in those who are non-consumers or weaker consumers. The lack of data about the arsenic concentration in tap water impairs the understanding of this particular cause–effect relationship.

The higher arsenic concentrations observed in Gela and volunteer subjects may reflect both environmental and occupational causes. The homogeneous distribution of subjects with high urinary and/or blood arsenic levels in the Gela area suggests diffuse exposure (for example, due to the ingestion of contaminated food or water) rather than concentrated exposure (for example, due to the proximity of an industrial plant). Also, recently reported contamination – by lead, cadmium and copper in artichokes and tomatoes cultivated in the Gela area – was associated mainly with the use of polluted groundwater and was interpreted as corroborating the scenario of the local community being exposed through the food-chain (Granata et al., 2011).

Moreover, relevant, diffuse environmental pollution is indicated by the high concentrations of total arsenic in soil and, particularly, groundwater (Table 59), and in marine and river sediments (Musmeci et al., 2009), as well as in pine needles (Bosco, Varrica & Dongarrà, 2005; Manno, Varrica & Dongarrà, 2006). Concern about exposure to arsenic is understandable, not only because it is recognized and well known as a cause of lung, skin and bladder cancer (IARC, 2004; NRC Committee on Human Biomonitoring for Environmental Toxicants, 2006), but also because of the recently strengthened knowledge about levels of exposure similar to those of the SEBIOMAG study.

Further concern about early exposure to arsenic is enhanced by reports that indicate that the prenatal period and childhood are sensitive windows in the development of lung cancer (Smith et al., 2006) and that indicate lower respiratory tract infections during infancy, following large environmental exposures to arsenic (Rahman et al., 2010a). In addition, increased risks of spontaneous abortion and infant mortality among the offspring of women with urinary arsenic concentrations of 249 µg/l to 2019 µg/l, compared with women having less than 38 µg/l, were recently reported (Rahman et al., 2010b). Furthermore, non-cancerous outcomes, such as dermal lesions, vasospasm and peripheral neuropathy, were associated with low urinary levels of 50–100 µg/l, due to chronic exposure (WHO, 2001; Tseng et al., 2005; Valenzuela et al., 2005).

With regard to exposure to organic compounds, their levels in SEBIOMAG study subjects were in general either lower than the limit of detection or lower than the values collected in Pavia and Novafeltria. Nevertheless, since some dioxin-like congeners (77, 126 and 169) were found in eight subjects distributed throughout the sampling area, a characteristic exposure footprint can be postulated. Another three subjects – with values of β-HCH, DDT isomers and some non-dioxin-like polychlorinated biphenyl congeners clearly higher than the reference values (Turci et al., 2006a,b, 2010) and with positive questionnaire responses on environmental and occupational exposures – were enrolled in a follow-up surveillance study.

Overall, the data on organic compounds is not alarming. However, further monitoring is recommended – in particular, to explain the values found for the three outliers (Table 67) and to investigate the long-term health effects of human exposure to polychlorinated biphenyls and organochlorinated compounds.

Compared with the findings for Pavia and Novafeltria, the findings for Gela showed low values for some organic pollutants. Although the findings noted in the preceding two paragraphs are unlikely to reflect a selection bias, the distribution of subjects among different age groups could have played a role in bioaccumulation levels, considering the mechanisms of bioaccumulation of organic compounds. Lending itself to the case of a possible selection bias is the circumstance that the subjects sampled in Gela were younger than those sampled in Pavia and Novafeltria. Nevertheless, because of the lack of information about the environmental background levels in the area and about the time trend of concentration in the human body, interpretation of the observed differences is difficult.

Finally, the replies to the questionnaire on risk perception and sources of information depict a community where the perception of risk to health is very high and where residents perceive themselves as living under conditions that endanger their personal safety. Together with the environmental and health data, described in other chapters of this book, the SEBIOMAG study results provide evidence that healthy conditions are not guaranteed for this community. Since most people in the Gela area live with the awareness of being exposed to a wide range of toxic pollutants and believe that this will produce several illnesses, this situation is in conflict with the broad WHO definition of health.

Conclusions

The SEBIOMAG study provides a composite picture of the environmental situation and of human exposure to pollutants in the Gela area. A local system that assesses the relationship between environmental pollution and population health is urgently needed, to provide risk managers with specific tools for improving environmental protection and preventing further risks to local communities. Also, the SEBIOMAG study represents an additional step towards establishing an environment and health surveillance system and addressing primary prevention measures in the Gela area.

The SEBIOMAG study brought to light a specific finding – that is, diffuse exposure to arsenic, as indicated by its concentration in urine and blood. The mean values for these concentrations were higher than those detected in non-occupationally exposed populations and in those exposed because of accidental events; the study observed a large number of subjects with abnormally high concentration values. The geographical distribution of the residence of subjects sampled was not associated with arsenic exposure. These two observations suggest wide geographical and diffuse exposure for which a relationship to health risks, in the absence of advanced analytical epidemiological studies, cannot be assessed.

In the Gela area, thousands of people could have abnormal arsenic concentration values, a consideration that has contributed to the growth of public concern about the health consequences of pollution. As a priority action, a study of different forms of arsenic, by repeating a targeted sampling of subjects, was promptly recommended and begun in late 2010, in a project funded by the Ministry of Health.

For the other trace elements, the results do not show a profile of diffuse exposure, although a number of subjects with high concentration values were identified. Also, for the subjects with high values, a repetition of the analysis was suggested, including characterization of chemical species, to understand the time frame and cause of exposure.

For organochlorinated compounds, the results indicate a low exposure profile; however, further monitoring was recommended, both to explain the values found for the three outliers and to investigate long-term effects on health of exposing people to polychlorinated biphenyls and organochlorinated compounds.

As a whole, the SEBIOMAG study contributes to enhancing scientific knowledge of human exposure to pollutants in the Gela area. Until recently, such knowledge was limited to and based on environmental data models. Studies of bioaccumulation of pollutants are relevant to better understanding the public health continuum, from pollution to health impacts via exposure. Such studies may also clarify the role of the environment in the etiology of the adverse health outcomes reported to be in excess in the Gela area. To enhance the comprehension of exposure pathways, reliable monitoring of contaminants in cultivated food and in the whole diet of the local population is also a priority.

The perception of risk to personal health presented by the environment, obtained from the interviews, deserves careful consideration and suggests the need for a discussion of the causes of risk. It also suggests the need to undertake action to reconstruct public trust in authorities and to jointly identify positive solutions.

In summary, the authors of the SEBIOMAG study believe that its results are useful for:

- further examining donors with values above the baseline reported for non-exposed populations;
- monitoring the environment, to identify exposure sources and time trends;
- building an epidemiological environment and health surveillance system dedicated to reliably measuring risk and monitoring population health;
- focusing remediation and rehabilitation activities, with the objective of eliminating dangerous sources of exposure; and
- planning further research activities on the interaction between the environment and the health of the citizens of Gela, Niscemi and Butera.

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11. EPIDEMIOLOGICAL INVESTIGATIONS OF AIR POLLUTION AND ASTHMA SYMPTOMS IN CHILDREN LIVING IN THE MILAZZO–VALLE DEL MELA HIGH-RISK AREA

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Introduction

Respiratory disorders in childhood are frequent and taken seriously. If not properly diagnosed and treated, respiratory disorders represent an important determinant of future chronic respiratory diseases (Gauderman et al., 2004). The role air pollutants (such as sulfur dioxide, nitrogen dioxide and particulate matter) play in the mechanism that leads to future diseases has been established in the literature (Timonen et al., 2002; Lewis et al., 2005; Delfino et al., 2006; Morshammer et al., 2006).

The occurrence of respiratory disorders and asthma among children has increased in the last 25 years in all high- and middle-income countries. In Sicily, among children (6–7 years old) who attend primary schools in Palermo, the Italian Studies on Respiratory Disorders in Children and the Environment (SIDRIA-2) reported a prevalence of wheezing during the last 12 months of 8.4% (versus 8.3% over all areas investigated by the SIDRIA-2 project), a prevalence of persistent cough or phlegm of 3.0% (versus 2.9%), and a prevalence of 8.8% of lifetime asthma (versus 9.2%) (Galassi, Battista & Forastiere, 2005).

Little information has been available about population health profiles and environmental pollution in the Milazzo–Valle del Mela area. Published ARPA Sicily data on air pollution show a yearly average for sulfur dioxide of 40 μg/m^3 during the period 1996–1999 and a decrease to 10–20 μg/m^3 in 2007, with nine hourly maxima that year above the EU-legislated alarm threshold of 500 μg/m^3. Also, descriptive epidemiological data from the Sicilian Epidemiological Observatory documented a higher than expected occurrence of respiratory diseases (Fano et al., 2005). The Milazzo–Valle del Mela area contains an oil refinery, a petrochemical plant, a large oil-powered energy plant and several minor industries (among them ferrous and non-ferrous foundries) that may contribute to respiratory disorders in childhood.

Between April 2007 and April 2008, an epidemiological investigation of air pollution and asthma symptoms was carried out on children attending primary schools in the following municipalities: Condrò, Gualtieri Sicaminò, Milazzo, Pace del Mela, San Filippo del Mela, San Pier Niceto and Santa Lucia del Mela. This chapter presents this investigation.

Objectives and study design

The present epidemiological investigation aims to clarify the role of air pollution in creating and exacerbating asthma symptoms. Its specific objectives are:

- to quantify the prevalence of childhood respiratory disorders among the paediatric population residing in the Milazzo–Valle del Mela area;
- to characterize the air pollution level in the area; and
- to evaluate respiratory function among resident children affected by obstructive pulmonary diseases and evaluate its relationship to air pollution levels.

The investigation consisted of cross-sectional and panel studies and a monitoring campaign. The first study was a cross-sectional survey of the prevalence of respiratory disorders among all children (6–10 years old) who attended the primary schools in the area. It surveyed 2506 children. The study took place from April to May 2007, and a questionnaire was administered to the parents of the children.

Two panel studies – PANEL 120 and PANEL 50 – were then conducted on a subsample of children. The first panel study, PANEL 120, enrolled 154 children that scored positive for any asthmatic symptoms on the questionnaire completed by their parents. The panel was followed up from November 2007 to April 2008. Every two weeks, respiratory function and bronchial inflammation were assessed, while parents recorded (in a diary) symptoms and drugs taken by their children during the follow-up.

The second panel study, PANEL 50, enrolled 50 children. The subjects were followed up for a week with daily measurements of health status, respiratory function, bronchial inflammation and air pollutant level, performed with personal monitors. Epigenetic markers – that is, the study of pathways that develop heritable patterns of gene expression without changing the underlying DNA – were evaluated twice using samples of nasal cells. The 50 children were divided into small groups of 5 children each. Each group was followed up for a week; after that another group was followed up, and so on from December 2007 to April 2008. Groups were matched by residence and the school the children attended. Within each group, a so-called witness was chosen to wear the personal monitoring device. During the day, parents compiled an hourly diary of the children's activities.

Ambient air quality was assessed by monitoring campaigns. Dosimeters measured gaseous pollutants, and a gravimetric device measured $PM_{2.5}$.

A communication plan was developed, and the parents of the children attending the schools enrolled in the study participated in all investigatory phases through a series of public meetings and initiatives. The dates of release of the results of each study were communicated to the parents.

The epidemiological investigation was launched on 27 March 2007. The first study results were presented during a meeting on 6 October 2007. From November 2007 to February 2008, several meetings with the parents of the population groups accompanied the subsequent studies. The data on air quality recorded by the monitoring campaign were presented on 30 May 2008. Final results were reported during a scientific meeting at the University of Messina on 28 February 2009 and at public meetings in the Municipality of Milazzo on 30 April 2009, in the Municipality of San Filippo del Mela on 24 April 2010 and in the Municipality of Santa Lucia del Mela on 5 June 2010.

Material and methods

Exposure assessment

Ambient air quality was assessed by monitoring campaigns. Passive dosimeters were located at 21 sites in each schoolyard, measuring continuously for a week each month during the study period, from November 2007 to April 2008. These dosimeters measured gaseous pollutants (sulfur dioxide, nitrogen dioxide, and benzene, toluene and xylene).[17] Also, a gravimetric device located at the secondary school of Pace del Mela measured $PM_{2.5}$, and ARPA Tuscany analysed the particle filters collected. From December 2007 to April 2008, we obtained a series of daily $PM_{2.5}$ averages.[18] Personal passive dosimeters were also used for personal monitoring of exposure to gaseous air pollutants. Personal monitoring was completed with $PM_{2.5}$ laser-based personal monitors.[19] Every day, at the witness's home, at 18:00, a nurse collected and replaced the daily personal passive dosimeters and checked the $PM_{2.5}$ instrument.

17 The sampling was in accordance with European Committee for Standardization practices. The analysis was performed by Passam AG Laboratory for Environmental Analysis (technical standards EN 45001 1996 and ISO/IEC 17025 2001).

18 The sampler used was AirFlow HS Avantech (technical standards UNI–EN 12341:2001 and UNI EN 14907:2005).

19 Personal monitoring of exposure to $PM_{2.5}$ was done using a laser-based Sidepack AM510 (technical standards: EN61326-1:1997 A11998 Clause 6 and EN61326:1997 + A1:1998; and ATEX Equipment Directive 94/9/EC). Calibration with gravimetric standards was done by ARPA Tuscany.

Outcome evaluation

For the first panel study, PANEL 120, a team of two nurses and one or two pneumologists examined (every two weeks) the children enrolled, at each primary school of the study area. They performed a spirometric examination, collecting:

- forced vital capacity (FVC), which determines the vital capacity from a maximally forced expiratory effort;
- forced expiratory volume in 1 second (FEV1);
- the ratio of FEV1 to FVC;
- forced expiratory flow between 25% and 75% of vital capacity ($FEF_{25–75}$); and
- measurements of fractional exhaled nitric oxide (FeNO), a reproducible marker of airway inflammation.

Children enrolled in the PANEL 50 study performed self-administered FEV1 measurements at home, using a pocket-size pulmonary function electronic monitoring device (Piko-1) twice a day – in the morning, when they got up for school, and in the evening (at 18:00), under the supervision of a nurse; on that occasion, the nurse measured the child's FeNO. On Tuesday and Friday afternoons, each child went to a dedicated outpatient clinic to undergo nasal brushing, to collect nasal cells for DNA methylation analysis. Nasal brushing was performed on Tuesdays in the right nostril and on Fridays in the left nostril by a trained nurse. The highly quantitative polymerase chain reaction–pyrosequencing analysis on bisulfite-treated DNA was used to measure DNA methylation in the promoter regions of interleukin-6 and nitric oxide synthase gene promoters and of Alu and LINE-1 repetitive elements (Baccarelli et al., 2012).[20]

The studies were conducted in accordance with the Declaration of Helsinki and a Ministry of Health Circular from 2 September 2002 (Ministry of Health, 2002). The Ethics Committee of Local Health Service Unit No. 7, Cagliari, Italy, and the Research Ethics Committee of the University of Milan approved the study; the parents of the study participants gave their informed written consent. The local health authority was informed, and general practitioners and paediatricians with practices in the study area were informed and worked with the study researchers.

Statistical methods

Standard descriptive statistics were used to summarize data. To evaluate the association of FEV1, FeNO and DNA methylation with pollutant concentration, we fitted the data with a generalized estimating equation population average model, specifying a gamma family with a log link and a robust estimator of standard error. We chose a gamma-distributed response because one of the dependent variables (FEV1) had a slightly asymmetrical distribution. The association of wheezing symptoms (yes/no) with pollutants concentration was quantified by fitting the data with a multivariable generalized estimating equation regression model for binary data. The generalized estimating equation models were used to take into account the presence of correlated data in the panel studies – that is, repeated measurements for each child during the follow-up period.

All observations of FeNO levels below the limit of detection of 6.25 $\mu g/m^3$ (5 ppb; 5 measurements) were excluded from the analysis. In addition, to avoid ambient nitric oxide interfering with FeNO readings, readings taken when the ambient nitric oxide level was greater than 6.25 $\mu g/m^3$ (5 ppb) were excluded.

20 DNA methylation, performed by enzymes called DNA methyltransferases, is an epigenetic mechanism that regulates gene expression. DNA methylation is established in utero or during early life and subsequently varies in response to environmental stressors. There is growing evidence that several inflammatory mediators are programmed through epigenetic mechanisms, such as DNA methylation. Among those mediators relevant to asthma are: fractional exhaled nitric oxide production – which is predominantly due to overexpression in the airway epithelium of the inducible nitric oxide synthase (iNOS) associated with lower DNA methylation in its specific gene promoter – and also interleukin-6, the overexpression of which is associated with reduced DNA methylation in its specific gene promoter. However, a large part of DNA methylation in the human genome is located in intergenic DNA – that is, DNA sequences located between gene clusters. In particular, Alu and LINE-1 repetitive elements, which are sequences of intergenic DNA repeated in up to one million copies per haploid genome, represent about 30% of the human genome and are heavily methylated. Alu and LINE-1 methylation has been shown to correlate with the global amount of DNA methylation and has been shown to decrease in response to inflammation and oxidative stress.

Multivariate models for statistical analysis of FEV1, FeNO and DNA methylation data were used as continuous variables, and results were expressed as a per cent variation for a 10 µg/m^3 increase in pollutant concentration. These models included independent variables for: age; gender; subject's height and weight; day of the week; parental education; exposure to environmental tobacco smoke and to mould or dampness in the child's room; symptoms of rhinoconjunctivitis (as a proxy for atopy); traffic intensity in the street of residence; recent respiratory infections; use of a steroid inhalator for asthma; outdoor temperature; and relative humidity.

Results

Cross-sectional study

The target population consisted of 2506 children who attended the primary schools of the municipalities of Condrò, Gualtieri Sicaminò, Milazzo, Pace del Mela, San Filippo del Mela, San Pier Niceto and Santa Lucia del Mela. Parents were asked to fill out the Italian version of the International Study of Asthma and Allergies in Childhood questionnaire (Galassi, Battista & Forastiere, 2005), and 2242 valid questionnaires (89.5% of those completed) were analysed.

The number (and prevalence) of respiratory disorders among children participating in the Milazzo–Valle del Mela area 2007 cross-sectional study included: 168 (7.5%) with lifetime asthma; 239 (10.7%) with wheezing during the last 12 months; 84 (3.7%) with persistent cough or phlegm during the last 12 months; and 193 and 133 (19.6% and 15.6%) with allergic rhinitis or eczema, respectively (Table 69).

Table 69. Respiratory disorders and allergic symptoms in primary school children

Respiratory disorder or allergic symptom	Gender	Children 6–7 years old		Children older than 8 years	
		Number	Per cent	Number	Per cent
Wheezing ever	Boys	117	29.1	204	27.3
	Girls	85	21.7	154	21.9
Wheezing last 12 months	Boys	47	11.7	94	12.6
	Girls	38	9.7	60	8.5
Asthma ever	Boys	33	8.2	81	10.9
	Girls	11	2.8	43	6.1
Allergic rhinitis ever	Boys	86	21.4	168	22.5
	Girls	58	14.8	127	18.1
Allergic rhinitis last 12 months	Boys	103	25.6	205	27.5
	Girls	65	16.6	139	19.8
Rhinoconjunctivitis last 12 months	Boys	43	10.7	106	14.2
	Girls	32	8.2	73	10.4
Eczema ever	Boys	51	12.7	121	16.2
	Girls	59	15.1	120	17.1
Eczema last 12 months	Boys	46	11.4	90	12.1
	Girls	49	12.5	72	10.2
Persistent cough or phlegm last 12 months	Boys	19	4.7	28	3.8
	Girls	15	3.8	22	3.1

The socioeconomic characteristics for education and employment of the parents and other characteristics are described in Table 70.

Table 70. Prevalence of risk factors and predictors of childhood respiratory disorders

Category	Subcategory	Children 6–7 years old		Children older than 8 years old	
		Number	Per cent	Number	Per cent
Gender	Boys	402	50.7	746	51.5
	Girls	391	49.3	703	48.5
	Total	793	100.0	1449	100.0
Mother	Education ≥ 14years	488	61.5	806	55.6
	Employed	325	41.0	582	40.2
	Housewife	324	40.9	607	41.9
Father	Education ≥ 14 years	422	53.2	716	49.4
	Employed	700	88.3	1278	88.2
Mean age of mother at delivery (years)	–	29.8	–	29.3	–
Child's current weight (kg)	–	26.1	–	36.1	–
Child's habits	Sedentary	61	7.7	137	9.5
	Intense physical activity more than once a week	338	42.6	688	47.5
Parents' and others' habits	Mother current smoker	149	18.8	295	20.4
	Mother smoker during pregnancy	55	6.9	76	5.2
	Father current smoker	244	30.8	440	30.4
	Mother and father current smokers	92	11.6	176	12.1
	At least one parent current smoker	301	38.0	559	38.6
	At least one smoker at home	205	25.9	438	30.2
	At least one smoker at home or one parent smoker	322	40.6	621	42.9
Traffic intensity in the area of residence	Absent	115	14.5	185	12.8
	Small to moderate	569	71.8	1078	74.4
	Intense	99	12.5	175	12.1
Highly frequent traffic of cars and trucks in the street of residence	Cars	489	38.8	908	41.4
	Trucks	154	12.2	332	15.1
	During the first year of life	121	9.6	217	17.2
Mould or dampness in child's room	Current	127	10.1	240	19.0
	Both	39	3.1	77	6.1

Tables 71–77 show the data on prevalence and their corresponding ORs for the 2007 Milazzo–Valle del Mela cross-sectional study. The estimated effects (prevalence ORs) of the main risk factors showed that, in children exposed to passive smoke, the prevalence of asthmatic symptoms and persistent cough or phlegm increased consistently (Table 71). For example, having mother as a current smoker versus never smoker showed an OR for wheezing during the last 12 months of 1.4 (95% CI: 1.0–2.0); for current asthma, it was 1.6 (95% CI: 1.0–2.5); and for persistent cough or phlegm, it was 2.1 (95% CI: 1.3–3.6(Table 71). Exposure to intense car traffic or living in areas with the highly frequent passage of trucks increases the prevalence of inflammatory symptoms (Table 72). For example, for children exposed to intense car traffic, in contrast to its absence, the OR for wheezing during the last 12 months was 0.8 (95% CI: 0.5–1.4); for asthma ever, it was 1.5 (95% CI: 1.0–2.2); and for persistent cough or phlegm, it was 2.3 (95% CI: 1.0–5.3). Exposure to mould or dampness (currently and in the first year of life), versus never being exposed, increases the risk of asthmatic symptoms (Table 73). The OR for wheezing during the last 12 months was 1.8 (95% CI: 1.1–3.0); for current asthma, it was 1.5 (95% CI: 1.0–2.2); and for persistent cough or phlegm, it was 0.2 (95% CI: 0.0–1.5).

Table 71. Prevalence and OR of childhood respiratory disorders: passive smoking

Respiratory disorders and passive smoking	Number of children	Per cent[a]	OR	95% CI
Wheezing last 12 months				
Parents smoking				
Non-smokers	62	8.0	1.0	–
Ex-smokers	12	11.2	1.4	0.7–2.7
At least one smoker	87	10.6	1.4	1.0–1.9
Mother smoking				
Non-smoker	109	8.1	1.0	–
Ex-smoker	32	11.0	1.4	0.9–2.1
Current smoker	45	10.8	1.4	1.0–2.0
Father smoking				
Non-smoker	78	8.5	1.0	–
Ex-smoker	39	7.9	0.9	0.6–1.3
Current smoker	74	11.3	1.4	1.0–1.9
Current asthma				
Parents smoking				
Non-smokers	36	4.6	1.0	–
Ex-smokers	3	2.8	0.6	0.2–2.0
At-least one smoker	39	4.7	1.1	0.7–1.8
Mother smoking				
Non-smoker	55	4.1	1.0	–
Ex-smoker	11	3.8	0.8	0.4–1.7
Current smoker	27	6.5	1.6	1.0–2.5
Father smoking				
Non-smoker	40	4.4	1.0	–
Ex-smoker	25	5.1	1.3	0.8–2.1
Current smoker	32	4.9	1.2	0.7–1.9
Persistent cough or phlegm				
Parents smoking				
Non-smokers	26	3.3	1.0	–
Ex-smokers	5	4.7	1.4	0.5–3.7
At least one smoker	36	4.4	1.3	0.8–2.2
Mother smoking				
Non-smoker	38	2.8	1.0	–
Ex-smoker	13	4.5	1.7	0.9–3.2
Current smoker	24	5.8	2.1	1.3–3.6
Father smoking				
Non-smoker	31	3.4	1.0	–
Ex-smoker	15	3.1	0.9	0.5–1.6
Current smoker	28	4.3	1.2	0.7–2.1

[a] Per cent of children with respiratory disorders (by disorder indicated), which indicates prevalence.

Table 72. Prevalence and OR of childhood respiratory disorders: traffic pollution

Respiratory disorders and traffic	Number of children	Per cent [a]	OR	95% CI
Wheezing last 12 months				
Traffic intensity				
Absent	34	11.3	1.0	–
Low	92	10.5	0.9	0.6–1.4
Moderate	86	11.1	1.0	0.7–1.6
Intense	27	9.9	0.8	0.5–1.4
Regularity of trucks				
Never	73	10.2	1.0	–
Seldom	113	11.1	1.1	0.8–1.5
Frequently	45	11.4	1.1	0.8–1.7
Continuously	8	8.9	0.9	0.4–1.9
Asthma ever				
Traffic intensity				
Absent	25	8.3	1.0	–
Low	68	7.8	0.9	0.6–1.5
Moderate	55	7.1	0.9	0.5–1.4
Intense	19	6.9	0.8	0.4–1.6
Regularity of trucks				
Never	59	8.3	1.00	–
Seldom	73	7.2	0.9	0.6–1.2
Frequently	27	6.8	0.8	0.5–1.3
Continuously	8	8.9	1.1	0.5–2.4
Persistent cough or phlegm				
Traffic intensity				
Absent	9	3.0	1.0	–
Low	36	4.1	1.5	0.7–3.1
Moderate	18	2.3	0.9	0.4–2.0
Intense	17	6.2	2.3	1.0–5.3
Regularity of trucks				
Never	27	3.8	1.0	–
Seldom	34	3.3	0.8	0.5–1.4
Frequently	11	2.8	0.8	0.4–1.6
Continuously	10	11.1	3.1	1.4–6.7

[a] Per cent of children with respiratory disorders (by disorder indicated), which indicates prevalence.

Table 73. Prevalence and OR of childhood respiratory disorders: mould or dampness

Respiratory disorders and mould or dampness	Number of children	Per cent[a]	OR	95% CI
Wheezing last 12 months				
Never	160	9.9	1.0	–
Only current	36	14.3	1.5	1.0–2.3
In the first year of life	23	10.4	1.0	0.6–1.6
Always	19	11.4	1.8	1.1–3.0
Current asthma				
Never	465	28.8	1.0	–
Only current	111	44.2	1.9	1.4–2.5
In the first year of life	72	32.4	1.2	0.8–1.6
Always	44	26.5	1.5	1.0–2.2
Persistent cough or phlegm				
Never	56	3.5	1.0	–
Only current	14	5.6	1.5	0.8–2.9
In the first year of life	12	5.4	1.5	0.8–3.0
Always	1	0.6	0.2	0.0–1.5

[a] Per cent of children with respiratory disorders (by disorder indicated), which indicates prevalence.

Social inequalities clearly emerged from the survey. The prevalence of persistent cough or phlegm was higher among children whose parents were blue collar workers or had a lower level of education (Tables 74 and 75). The percentage of asthma hospital admissions for children with a father who was a blue collar worker was 3.5%, in contrast to 1.9% among children with no blue collar father. This did not correspond to a greater severity of the disease: 74% of asthmatic children with their father classified as executive for his job were diagnosed as having severe asthma, in contrast to 50% among other asthmatic children.

Table 74. Prevalence and OR of childhood respiratory disorders: parents' work

Respiratory disorders and parents' occupational category	Number of parents	Per cent[a]	OR	95% CI
Wheezing last 12 months				
Executive	35	13.6	1.0	–
High-ranking white collar	50	9.6	0.7	0.4–1.1
Low-ranking white collar	11	7.9	0.6	0.3–1.1
Blue collar	90	11.2	0.8	0.5–1.2
Asthma ever				
Executive	19	7.4	1.0	–
High-ranking white collar	38	7.3	1.0	0.6–1.9
Low-ranking white collar	9	6.4	0.9	0.4–2.0
Blue collar	75	9.4	1.3	0.8–2.2
Persistent cough or phlegm				
Executive	5	1.9	1.00	–
High-ranking white collar	14	2.7	1.4	0.5–3.9
Low-ranking white collar	5	3.6	1.8	0.5–6.5
Blue collar	40	5.0	2.6	1.0–6.7

[a] Per cent of children with respiratory disorders (by disorder indicated), which indicates prevalence.

Table 75. Prevalence and OR of childhood respiratory disorders: parents' education

Respiratory disorders and number of years of parents' education	Number of parents	Per cent[a]	OR	95% CI
Wheezing last 12 months				
>14	52	13.3	1.0	–
14	120	10.2	0.7	0.5–1.0
9	62	10.3	0.8	0.5–1.1
6	5	9.3	0.8	0.3–2.0
Asthma ever				
>14	31	7.9	1.0	–
14	91	7.8	0.9	0.6–1.4
9	42	7.0	0.8	0.5–1.3
6	3	5.6	0.7	0.2–2.5
Persistent cough or phlegm				
>14	7	1.8	1.0	–
14	47	4.0	2.3	1.0–5.0
9	27	4.5	2.4	1.0–5.6
6	2	3.7	2.2	0.4–11.2

[a] Per cent of children with respiratory disorders (by disorder indicated), which indicates prevalence.

Minor findings include the observation of a higher prevalence of wheezing during the last 12 months and persistent cough or phlegm among children participating in physical activities more than three times a week, in contrast to no such activity (Table 76). Also, a high body mass index (BMI) was associated with a higher prevalence of respiratory symptoms. Children with a BMI above the 80th percentile (BMI of 20.9 in this population) showed a higher prevalence of wheezing during the last 12 months (OR: 1.4; 95% CI: 0.9–2.2); a higher prevalence of asthma ever (OR: 1.8; 95% CI: 1.0–3.1); and a higher prevalence of persistent cough or phlegm (OR: 2.1; 95% CI: 0.9–4.6), all in contrast to children in the lowest quintile of BMI (Table 77).

Table 76. Prevalence and OR of childhood respiratory disorders: activity level

Respiratory disorders and level of physical activity	Number of children	Per cent[a]	OR	95% CI
Wheezing last 12 months				
Never	41	9.6	1.0	–
Occasionally	72	10.3	1.1	0.7–1.7
1–2 times per week	76	11.0	1.2	0.8–1.8
More than 3 times a week	37	11.1	1.2	0.8–2.0
Asthma ever				
Never	28	6.6	1.0	–
Occasionally	56	8.0	1.2	0.7–1.9
1–2 times per week	56	8.1	1.2	0.7–1.9
More than 3 times a week	22	6.6	1.0	0.5–1.7
Persistent cough or phlegm				
Never	13	3.1	1.0	–
Occasionally	21	3.0	1.3	0.6–2.7
1–2 times per week	33	4.8	2.2	1.1–4.3
More than 3 times a week	16	4.8	2.2	1.0–4.7

[a] Per cent of children with respiratory disorders (by disorder indicated), which indicates prevalence.

Table 77. Prevalence and OR of childhood respiratory disorders: child's BMI

Respiratory disorders and BMI (quintiles)	Quintile	Number of children	Per cent[a]	OR	95% CI
Wheezing last 12 months					
≤15.3	1st	41	10.5	1.0	–
>15.3–16.6	2nd	43	11.1	1.0	0.6–1.6
>16.6–18.4	3rd	38	9.7	0.9	0.6–1.4
>18.4–20.8	4th	32	8.2	0.8	0.5–1.3
>20.8	5th	51	13.0	1.4	0.9–2.2
Asthma ever					
≤15.3	1st	22	5.6	1.0	–
>15.3–16.6	2nd	28	7.3	1.2	0.6–2.1
>16.6–18.4	3rd	28	7.1	1.1	0.6–2.0
>18.4–20.8	4th	26	6.7	1.0	0.6–1.9
>20.8	5th	42	10.7	1.8	1.0–3.1
Persistent cough or phlegm					
≤15.3	1st	10	2.6	1.0	–
>15.3–16.6	2nd	16	4.1	1.6	0.7–3.6
>16.6–18.4	3rd	14	3.6	1.5	0.6–3.4
>18.4–20.8	4th	11	2.8	1.1	0.5–2.8
>20.8	5th	19	4.8	2.1	0.9–4.6

[a] Per cent of children with respiratory disorders (by disorder indicated), which indicates prevalence.

Discussion: the cross-sectional study

We compared the results of the cross-sectional study with those of the SIDRIA-2 project (Galassi, Battista & Forastiere, 2005) (Table 78). The comparison can be done only by considering children 6–7 years old. The prevalence of wheezing in the last 12 months was higher than that recorded in the SIDRIA-2 project in 2002: on average 11% versus 8%. The prevalence of known risk factors was somewhat similar to that recorded in the SIDRIA-2 project (Table 79). In the Milazzo–Valle del Mela study, the distribution of the occupations of parents was different, and the number of housewives was particularly high. It is worth noting that the prevalence of children exposed to indoor (passive) smoking and outdoor (traffic) pollutants in the Milazzo–Valle del Mela study was lower; housing conditions (mould and dampness), however, appeared similar for children 6–7 years old, but worse for children 8 years or older (Table 70). The prevalence of children with BMI above the 95th percentile of the reference distribution (SIDRIA-2) was greater than 13%.

Table 78. Prevalence of childhood respiratory disorders: study comparison

Respiratory disorders and gender	Children 6–7 years of age			
	Milazzo–Valle del Mela study		SIDRIA-2 study	
	Number	Per cent[a]	Per cent[a]	95% CI
Wheezing last 12 months				
Boys	47	11.7	9.5	8.7–10.2
Girls	38	9.7	7.2	6.4– 7.9
Asthma ever				
Boys	33	8.2	11.1	10.1–12.2
Girls	11	2.8	7.3	6.6–8.1

[a] Per cent of children with respiratory disorders (by disorder indicated), which indicates the prevalence.

Table 79. Prevalence of childhood respiratory disorder risk factors: study comparison

Risk factor and category	Children 6–7 years of age			
	Milazzo–Valle del Mela study		SIDRIA-2 study	
	Number	Per cent[a]	Per cent[a]	95% CI
Mother				
Education: 14 years or more	488	61.5	61.8	59.3–64.4
Employed	325	41.0	62.9	60.2–65.7
Housewife	324	40.9	26.1	23.9–28.3
Father				
Education: 14 years or more	422	53.2	56.1	53.0–59.1
Employed	700	88.3	91.1	89.8–92.3
Physical activity				
Sedentary	61	7.7	7.0	6.4–7.6
Intense physical activity more than once a week	338	42.6	42.5	40.8–44.2
Smoking				
Mother current smoker	149	18.8	27.4	26.3–28.4
Mother smoker during pregnancy	–	6.9	12.5	11.8–13.2
Father current smoker	244	30.8	35.7	34.7–36.6
Mother and father current smokers	–	11.6	16.1	15.4–16.8
At least one parent current smoker	–	38.0	46.9	45.7–48.2
Traffic intensity				
Absent	115	14.5	13.8	11.9–15.6
Small to moderate	569	71.8	64.3	62.1–66.5
Intense	99	12.5	20.2	16.9–23.5
High regularity of:				
Cars	489	38.8	59.0	55.8–62.1
Trucks	154	12.2	20.0	18.1–22.0
Mould or dampness in child's room				
During the first year of life	121	9.6	12.6	–
Current	127	10.1	10.5	–
Both	39	3.1	–	–

[a] Per cent of children with respiratory disorders (by risk factor), which indicates the prevalence.

In comparison with the SIDRIA-2 study, the Milazzo–Valle del Mela study reported evidence of under-diagnosis: the higher prevalence of wheezing was associated with a lower prevalence of diagnosed asthma (Table 78). We also observed a higher hospitalization rate among children of lower social classes, which is not explained by the greater severity of the disease. Moreover, the prevalence of bronchitis symptoms (persistent cough or phlegm) was higher among children of lower social classes (parents education less than 6 years compared with more than 14 years: OR = 3.6 versus 1.8 in the SIDRIA-2 study) and among children with greater exposure to the outdoor environment, through physical activity (more than three times a week, in contrast to no such activity: OR = 2.2. versus 0.9 in the SIDRIA-2 study), traffic intensity (high versus low: OR = 2.3 versus 1.2 in the SIDRIA-2 study) and regularity of trucks (intense versus not (intense): OR = 3.1 versus 1.8 in the SIDRIA-2 study) (Table 80). The prevalence ORs for other known risk factors were almost identical to those documented in the SIDRIA-2 project (Table 80).

Table 80. Prevalence and ORs of childhood respiratory disorders: comparative study – selected risk factors

Risk factors, respiratory disorders and categories	Milazzo–Valle del Mela area study				SIDRIA-2 study	
	Number	Per cent [a]	OR	95% CI	OR	95% CI
Education						
Wheezing last 12 months						
More than 14 years	52	13.3	1.0	–	1.0	
14 years	120	10.2	0.7	0.5–1.0	1.0	0.9–1.1
9 years	62	10.3	0.8	0.5–1.1	1.0	0.9–1.2
6 years	5	9.3	0.8	0.3–2.0	0.7	0.6–1.0
Persistent cough or phlegm						
More than 14 years	7	1.8	1.0	–	1.0	
14 years	47	4.0	2.3	1.0–5.0	1.0	0.8–1.2
9 years	27	4.5	2.4	1.0–5.6	1.3	1.0–1.6
6 years	2	3.7	2.2	0.4–11.2	1.8	1.6–2.7
Passive smoking						
Wheezing last 12 months						
Non-smokers	62	8.0	1.0	–	1.0	–
Ex-smokers	12	11.2	1.4	0.7–2.7	1.1	0.8–1.6
At least one smoker	87	10.6	1.4	1.0–1.9	1.3	1.0–1.5
Persistent cough or phlegm						
Non-smokers	26	3.3	1.0	–	1.0	–
Ex-smokers	5	4.7	1.4	0.5–3.7	0.9	0.5–1.7
At least one smoker	36	4.4	1.3	0.8–2.2	1.3	1.0–1.8
Mould or dampness						
Wheezing last 12 months						
Never	160	9.9	1.0	–	1.0	–
Only current	36	14.3	1.5	1.0–2.3	1.6	1.2–2.2
In the first year of life	23	10.4	1.0	0.6–1.6	1.6	1.3–2.1
Always	19	11.4	1.8	1.1–3.0	2.0	1.5–2.7
Persistent cough or phlegm						
Never	56	3.5	1.0	–	1.0	–
Only current	14	5.6	1.5	0.8–2.9	1.6	1.2–2.9
In the first year of life	12	5.4	1.5	0.8–3.0	1.9	1.3–2.7
Always	1	0.6	0.2	0.0–1.5	1.6	1.0–2.8
Regularity of trucks						
Wheezing last 12 months						
Never	73	10.2	1.0	–	1.00	–
Seldom	113	11.1	1.1	0.8–1.5	1.0	1.0–1.1
Frequently	45	11.4	1.1	0.8–1.7	1.0	0.9–1.2
Continuously	8	8.9	0.9	0.4–1.9	1.1	0.9–1.4
Persistent cough or phlegm						
Never	27	3.8	1.0	–	1.0	–
Seldom	34	3.3	0.8	0.5–1.4	1.1	0.9–1.2
Frequently	11	2.8	0.8	0.4–1.6	1.4	1.1–1.7
Continuously	10	11.1	3.1	1.4–6.7	1.8	1.4–2.4

[a] Per cent of children with respiratory disorders (by risk factor), which indicates the prevalence.

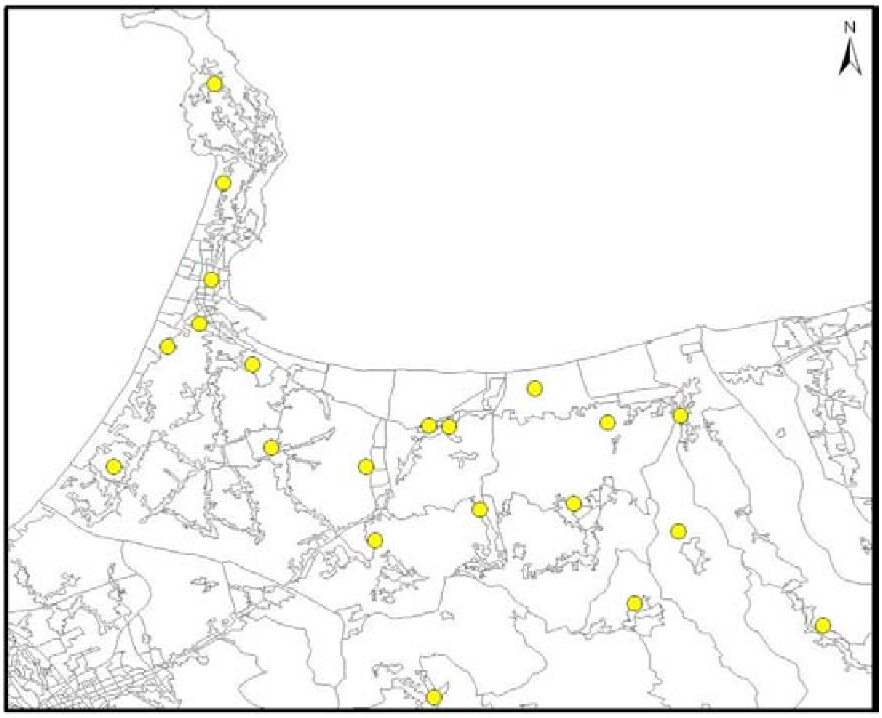
No major biases seem plausible for the 2007 cross-sectional study of the Milazzo–Valle del Mela area: the compliance was very high (89.5%) and the questionnaire used was based on international standards, the International Study of Asthma and Allergies in Childhood questionnaire and the SIDRIA questionnaire, which has been validated in Italy since the mid-1990s.

Environmental monitoring

Concurrent with the longitudinal studies (PANEL 120 and PANEL 50), an ambient air-quality monitoring campaign was undertaken from November 2007 to April 2008. Each primary school of the study area had 21 passive dosimeters (Fig. 20). Sampling was done every two weeks, and dosimeters were left in place for a week, monitoring gaseous pollutants (sulfur dioxide, nitrogen dioxide, and benzene, toluene and xylene). The following sites were monitored:

- Milazzo: Sacro Cuore school, Piaggia school, Lucifero school, Tono school, San Giovanni school, Grazia school, Bastione school and Baronello–Ciantro school;
- San Filippo del Mela: primary school, Cattafi school, Archi school, Church of Archi and Corriolo school;
- Santa Lucia del Mela: primary school;
- Pace del Mela: secondary school, Giammoro school and Gabbia school;
- San Pier Niceto: primary school and San Pier Marina school;
- Condrò: primary school;
- Gualtieri Sicaminò: secondary school; and
- $PM_{2.5}$ was measured from December 2007 to April 2008 by one monitor located in the yard at the secondary school of Pace del Mela.

Fig. 20. Monitoring campaign monitoring sites, 2007/2008 [a]



[a] Monitoring sites in yellow.

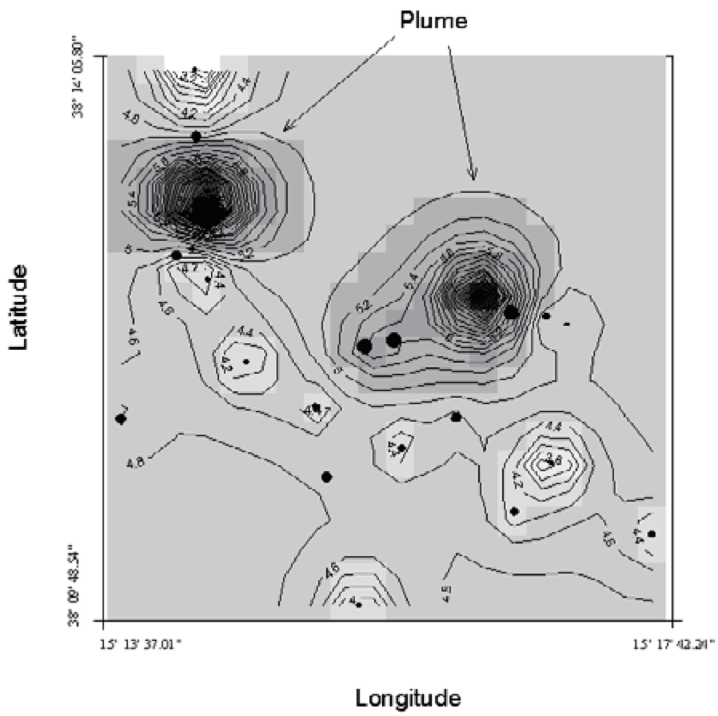
The air quality values recorded varied significantly geographically, suggesting different exposure patterns for each pollutant (see Chapter 12). Piaggia school, Gabbia school, Giammoro school and Archi school showed the highest levels of sulfur dioxide (with one or more weekly averages higher than 20 μg/m^3) (Table 81). Archi school also showed the highest level of nitrogen dioxide (with an overall weekly average in the study period higher than 40 μg/m^3), followed by the monitoring sites at the Grazia school, Piaggia school and Gabbia school (Table 81). Benzene, toluene and xylene, with weekly averages of about 2 μg/m^3, were measured at Archi school and Grazia school.

Table 81. Weekly sulfur dioxide and nitrogen dioxide concentration averages, 2007/2008

Site	Sulfur dioxide concentration ((μg/m^3)			Nitrogen dioxide concentration ((μg/m^3)		
	Mean	Median	95th percentile	Mean	Median	95th percentile
Sacro Cuore school	3.5	0.8	19.5	20.0	20.5	30.4
Piaggia school	14.5	2.6	100.0	25.1	22.4	43.1
Lucifero school	1.6	0.3	7.5	7.9	8.5	12.5
Tono school	4.6	4.8	9.1	15.8	14.0	28.0
San Giovanni school	4.3	3.2	13.9	21.7	22.4	33.9
Grazia school	3.4	3.0	10.9	28.3	27.0	35.5
Bastione school	4.4	2.0	19.9	17.0	13.6	34.1
Baronello–Ciantro school	3.8	2.5	11.7	20.5	19.2	34.8
San Filippo del Mela primary school	4.7	2.9	18.6	15.2	15.8	21.9
Cattafi school	4.0	3.7	12.7	11.5	11.2	15.2
Archi School	6.0	5.4	21.7	47.2	45.6	59.6
Archi Church	6.0	5.0	19.4	46.1	46.2	59.7
Corriolo school	4.2	3.2	11.7	13.1	12.4	19.5
Santa Lucia del Mela: primary school	3.1	1.4	11.4	15.0	15.6	23.7
Pace del Mela	4.4	3.0	14.5	16.6	15.5	37.3
Giammoro school	6.5	3.2	38.1	19.1	19.8	27.3
Gabbia school	11.1	6.6	49.3	24.1	23.4	32.5
San Pier Niceto primary school	3.9	3.8	10.3	12.7	12.1	19.1
San Pier Marina school	4.2	3.0	14.8	20.8	17.3	33.2
Condrò primary school	2.8	1.8	9.5	11.4	10.0	28.2
Gualtieri Sicaminò secondary school	4.1	2.8	16.5	10.2	7.8	31.0

The spatial distribution of sulfur dioxide concentrations showed the typical shape of a point source with a chimney and a plume effect (Fig. 21). The areas with higher sulfur dioxide exposures are located along the line of the prevalent wind. For the years 2007 and 2008, official data confirmed episodes of sulfur dioxide concentrations higher than 100 μg/m^3. However, the completeness of the series and the modification of the monitor locations did not allow a systematic comparison (see the section on "Air quality in the Milazzo–Valle del Mela area" in Chapter 7).

Fig. 21. Monitoring campaign weekly sulfur dioxide averages (µg/m³), 2007/2008 [a]



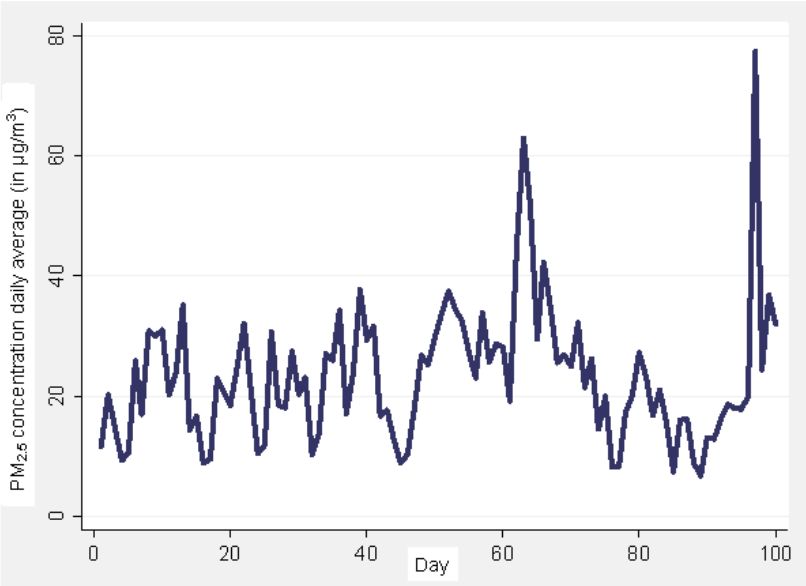
[a] The size of the dots for the monitoring sites are proportional to the overall monitoring period average per site.
Note. Isoconcentration curves – with each curve representing the same value of concentration (in µg/m³) and curves with higher values appearing closer to the source – are estimated by using Bayesian kriging.

Also, $PM_{2.5}$ daily concentrations were, on average, 23 µg/m³ during the period monitored (Table 82). From late January to February 2008, the concentrations were never lower than 20 µg/m³, with a peak of 51.4 µg/m³ (Fig. 22).

Table 82. Daily $PM_{2.5}$ concentration averages, by month, 2007/2008

Month and year	Mean $PM_{2.5}$ concentrations (µg/m³)	95th° percentile (µg/m³)
December 2007	21.6	35.2
January 2008	21.1	34.3
February 2008	29.0	51.4
March 2008	18.5	32.2
April 2008	24.0	36.9
Total	22.8	37.7

Fig. 22. $PM_{2.5}$ concentration daily averages, December 2007 to April 2008



Discussion: environmental monitoring campaign

In the Milazzo–Valle del Mela area, we found largely diverse values for the concentrations of gaseous pollutants. Sulfur dioxide concentrations from industrial sources showed a marked plume effect with high concentrations at Piaggia school, Gabbia school, Giammoro school and Archi school. Nitrogen dioxide showed a different pattern, where linear sources (such as thoroughfares with a stream of heavy traffic) were also important. We did not document high benzene, toluene and xylene concentrations, but the monitoring campaign did not cover the summer months, when raised levels of these chemicals, due to evaporation from petrochemical industry storage sites, were expected.

Also, high concentrations of particulate matter were found. $PM_{2.5}$ is the particle fraction most dangerous to human health, according to WHO air quality guidelines (WHO Regional Office for Europe, 2006). WHO suggests a limit value of 10 µg/m^3. During the monitoring period, $PM_{2.5}$ concentrations in the Milazzo–Valle del Mela area were, on average, 23 µg/m^3, which is more than twice the limit value. Daily averages higher than 30 µg/m^3 were registered on 22 of 100 days, and for a month the daily average was twice the threshold value. The location of the $PM_{2.5}$ monitoring station (the yard of the secondary school of Pace del Mela) was about 5 km from an oil-powered energy plant, the closest industrial source.

Gaseous pollutants were measured at 21 sites, allowing a detailed representation of their spatial distribution. Concentrations of gaseous pollutants are expected to vary spatially, due to several factors, such as emission characteristics and chemical properties. However, particulate matter, particularly ultrafine particles, diffuses more uniformly in the environment. The locations of the monitoring stations were chosen to be representative of human exposure in the immediate surroundings of the industrial area, over a radius of 10 km or more, depending on meteorological conditions and mountainous features.

PANEL 120 study

The first panel study, PANEL 120, was conducted between November 2007 and April 2008 (see Table 83). The children enrolled in the study underwent spirometric examinations and tests for bronchial inflammation markers, performed by a specialized team assisted by a pneumologist. The examination took place every 2 weeks at school. The dosimeters were located in the yard of the same schools.

Of the 154 children enrolled in the study, 129 complied (83.8%). Parents compiled a weekly diary on symptoms and drugs for respiratory disorders. The children enrolled all had symptoms of respiratory disorders, as documented by the cross-sectional study described above in this chapter. The mean age of the two panels was 9 years; the mean height was 1.40 m; the mean weight was 39 kg; 70% were boys, 40% with FEV1 below 95% of the value predicted (10% with FEV1 below 80% of the value predicted); 65% were positive for wheezing during the last 12 months; 76% were diagnosed as having asthma; and 26% reported being treated with inhaled steroids. Measurements of FeNO, a marker of bronchial inflammation, resulted in an average value of 39.5 µg/m^3 (31.6 ppb). Delfino et al. (2006) reported average value of 31.2 µg/m^3 (25 ppb) for FeNO in a similar panel study on asthmatic children conducted in an area with a high level of urban air pollution.

Table 83. PANEL 120 and PANEL 50 studies: characteristics of the subjects enrolled

Characteristics	Panel 120	Panel 50
Mean age (and SD) (years)	9.2 (± 0.9)	8.9 (± 0.8)
Height (cm) Δ = 1.55; 2.32	141.9	139.1
Weight (kg) Δ = –0.23; 1.22	40.8	38.5
Number of boys (and %)	89 (69.0)	34 (77.3)
Number of girls (and %)	40 (31.0)	10 (22.7)
FEV1: number of children (% predicted)		
<80	13 (11.1)	4 (9.1)
80–90	20 (17.1)	5 (11.4)
90–95	19 (16.2)	7 (15.9)
95–99	17 (14.5)	4 (9.1)
More than100	48 (41.0)	24 (54.6)
FEV1 mean in litres (± SD)	1.98 (± 0.6)	1.87 (± 0.6)
Other		
Mean FEF_{25-75} (± SD)	2.16 (0.9)	2.09 (0.8)
Median frequency (interquartile range) [a]	9 (2)	2 (5)
Parental education		
< 6 years: number of parents (%)	4 (3.2)	–
< 9 years: number of parents (%)	36 (29.3)	12 (27.3)
<14 years: number of parents (%)	59 (48.0)	26 (59.1)
Graduation from a university (%)	24 (19.5)	6 (13.7)
Mould or dampness: number of children (%)		
Ever	92 (74.2)	33 (75.0)
Only currently	13 (10.5)	7 (15.9)
Only early	17 (13.7)	4 (9.1)
Early and currently	2 (1.6)	–
Wheezing events	81 (65.3)	44 (100.0)
Asthma	95 (76.6)	44 (100.0)
Nocturnal cough)	11 (8.9)	11 (25.0)
Asthma medications	31 (26.0)	18 (46.0)
No symptoms	43 (33.0)	0 (0)
Expiratory nitrogen oxide mean in mg/m^3 (± SD)	42.4 (± 39.6)	42.01 (± 39.2)

Table 83 (concluded)

Characteristics	Panel 120	Panel 50
Expiratory nitrogen oxide mean in ppb (± SD)	33.9 (± 31.6)	33.61 (± 31.3)
Measurement median (interquartile range)	11 (1)	7 (0)
Smoking		
Passive smoking frequency (%) [b]	64 (51.6)	14 (31.8)
Car regularity		
No	13 (10.6)	6 (13.6)
Seldom	36 (29.3)	10 (22.7)
Moderate	44 (35.8)	18 (40.9)
High	30 (24.4)	10 (22.7)

SD: standard deviation; Δ: the absolute difference between the measurement recorded at the beginning of the study and at the end for Panel 120 and Panel 50.
[a] The median number of measurements per subject and the range.
[b] The frequency of passive smoking is based on having at least one parent as a current smoker.

The PANEL 120 study measured FEV1 for respiratory function and FeNO for bronchial inflammation. All analyses were adjusted for the following confounders: day of the week; parents' education; child's height, weight, BMI, gender and age; exposure to passive smoke; mould or dampness in the child's room; exposure to traffic; recent upper respiratory infections; recent use of inhaled steroids or asthma drugs (bronchodilators); and daily average temperature and relative humidity.

Exposure to ambient gaseous air pollutants (sulfur dioxide, nitrogen dioxide, benzene, toluene and xylene) was assessed by passive dosimeters located at the same schools (attended by the children) as those listed in the subsection on "Environmental monitoring" during the week preceding each examination (weekly averages). $PM_{2.5}$ daily average concentrations were obtained from the station located in the yard at the secondary school in Pace del Mela.

The data for spirometric examinations and bronchial inflammation consist of 1057 valid measurements for spirometric variables and 1370 measurements for FeNO. Table 84 shows adjusted regression coefficients for FEV1 and FeNO, for the potential confounders, obtained from the generalized estimating equation population average model. Among symptomatic children, FEV1 appeared to be related to body dimensions and BMI, age and gender, environmental tobacco smoke, respiratory infections, and temperature and humidity. Table 85 shows the results when ambient air pollutant concentrations are included in interactions with temperature and relative humidity (for temperatures below 10 °C and relative humidity between 60–80%). With regard to fractional exhaled nitric oxide as a marker of bronchial inflammation, FeNO appeared to be related to recent respiratory infections and temperature.

We observed a 19% (90% CI: 12–28%) decrease in FEV1 and a 45% (90% CI: 7–83%) increase in FeNO for a 10 $\mu g/m^3$ increase in $PM_{2.5}$ at lag 0 when the temperature was below 10 °C and the relative humidity was between 60–80%[21]. For FEV1, but not FeNO, there was still a 13% (90% CI: 5–22%) decrease at lag 1. The test for an interaction between pollutants and either temperature or humidity showed $\chi2(4) = 29.77$, $P < 0.0001$ for the FEV1 outcome and $\chi2(4) = 7.55$, $P = 0.1096$ for the FeNO outcome.

21 Percent variations in FEV1 and FeNO for 10 micrograms are obtained as: exp((regression coefficient*10)$^{-1}$)*100. An association at lag 0 means an immediate effect resulting from an association with the pollutant concentrations of the same day; lag 1 refers to the association with the pollutant concentrations the day before, and lag 2 refers to the association with the pollutant concentrations two days before, meaning a delayed effect.

Table 84. PANEL 120 study: regression coefficients for potential confounders – FEV1 and FeNO

Confounders	FEV1			FeNO		
	Coefficient	90% CI		Coefficient	90% CI	
Reference for weekday: Monday						
Tuesday	0.011	–0.005	0.028	–0.009	–0.258	0.240
Wednesday	0.025	0.009	0.040	–0.134	–0.305	0.038
Thursday	0.031	0.012	0.050	–0.059	–0.312	0.194
Friday	0.039	0.014	0.064	–0.212	–0.524	0.099
Saturday	0.099	0.049	0.149	–2.114	–3.197	–1.032
Personal attributes						
Height (m)	0.008	0.007	0.010	–	–	
Weight (kg)	0.008	0.006	0.009	–	–	
Age (years)	0.040	0.018	0.063	0.130	–0.050	0.309
Reference for gender: male						
Female	–0.058	–0.095	–0.022	0.145	–0.185	0.474
Reference: low level of parent's education						
High education	–0.147	–0.201	–0.093	0.400	–0.787	1.586
Reference: child's BMI						
BMI	–0.011	–0.017	–0.004	–		
Reference for environmental tobacco smoke: no						
Yes	–0.061	–0.119	–0.003	0.096	–0.542	0.734
In the past	0.005	–0.039	0.049	0.070	–0.277	0.418
Reference for mould or dampness: never						
Current	0.009	–0.051	0.069	–0.233	–0.664	0.197
Always	–0.021	–0.070	–0.029	–0.151	–0.673	0.371
Reference for traffic: not intense						
Intense	–0.017	–0.065	0.030	–0.082	–0.470	0.307
Reference for respiratory infections: no						
Yes	–0.017	–0.028	–0.006	0.279	0.098	0.461
Reference for drugs for asthma: no						
Yes	–0.020	–0.047	0.007	0.035	–0.388	0.457
Meteorological conditions						
Temperature (°C)	–0.003	–0.005	0.000	0.042	0.025	0.059
Humidity (%)	–0.001	–0.001	0.000	0.002	–0.003	0.006

Table 85. PANEL 120 study: regression coefficients for air pollutant concentrations – FEV1 and FeNO

Air pollutant	FEV1			FeNO		
	Coefficient	90% CI		Coefficient	90% CI	
Sulfur dioxide	0.0098	−0.0007	0.0204	−0.0030	−0.0632	0.0039
Nitrogen dioxide	0.0007	−0.0018	0.0033	−0.0042	−0.0139	0.0057
$PM_{2.5}$ at lag 0	−0.0181	−0.0246	−0.0116	0.0449	0.0068	0.0831
$PM_{2.5}$ at lag 1	−0.0122	−0.0197	−0.0046	0.0122	−0.0329	0.0573
$PM_{2.5}$ at lag 2	0.0037	−0.0123	0.0198	0.0161	−0.0518	0.0841

Discussion: PANEL 120 study

The results of the PANEL 120 study were stable under a series of different modelling approaches (data not shown). Also, the weekly average of gaseous pollutant concentrations appeared not to be associated with the study outcomes. The effects probably occur at shorter time lags, and the effects were diluted when using weekly averages. $PM_{2.5}$ concentrations at lag 0 and lag 1 appeared to be negatively associated with FEV1 and, less precisely estimated, with FeNO at lag 0. This was observed only during particular meteorological conditions in February 2008, when $PM_{2.5}$ daily averages never fell below the threshold of 20 μg/m^3. This result is highly indicative, but it is based on a subgroup analysis and should be viewed with caution.

PANEL 50 study

Between December 2007 and April 2008, we performed a second panel study of children with asthma (PANEL 50), identified during the cross-sectional study (see above). For this panel study, we selected 50 children who: (a) had a physician's diagnosis of asthma; (b) reported wheezing symptoms in the previous 12 months; and (c) had chest tightness and/or used bronchodilators in the last 12 months. The selection of subjects was based on the results of the cross-sectional study. Written informed consent for the children to participate in the panel study was provided by the parents of 44 of the 50 children, and 35 (70%) also gave consent for measurements of epigenetic markers. The study subjects were divided into nine small groups of about the same size. Each group was followed up for seven days. The study started on 8 December 2007 and ended on 18 April 2008. Each child was followed for seven consecutive days, and their parents completed a diary of daily respiratory symptoms (cold symptoms, to rule out acute respiratory infections; wheezing symptoms; and tightness in the chest), and the use of bronchodilators and inhaled steroids.

A visiting nurse performed daily FeNO and FEV1 measurements. On the day before the beginning of the seven-day follow-up, the nurse trained the children on the proper way to do the measurements; and collection of exhaled air for FeNO measurements and the forced expiratory manoeuvre were supervised by the same nurse during the study week. Ambient nitric oxide and FeNO concentrations were assessed by chemoluminescence and by following the American Thoracic Society and/or European Respiratory Society recommended procedures. FEV1 was recorded using an electronic FEV1 monitoring device that uses pressure/flow sensor technology. The occurrence of wheezing (during the day, during the night or during exercise) was recorded by the daily diary. In the afternoon (16:00–18:00) on days 4 and 7 (Tuesday and Friday), each child went to a dedicated outpatient clinic to undergo nasal brushing, to collect nasal cells for analysis of DNA methylation, one of the best markers of epigenetic modifications.

All observations of FeNO levels below the detection limit of 6.25 μg/m^3 (5 ppb) (five measurements) were excluded from the analysis. In addition, to avoid ambient nitric oxide from interfering with the FeNO readings, we excluded readings (two measurements) taken when the level of ambient nitric oxide was higher than the limit of detection. Also, due to missing FEV1 data, one additional observation was excluded. Therefore, of the 70 total observations (35 subjects, two measurements each), we conducted statistical analyses on 62 observations, without missing data for any of the variables of interest.

FEV1, FeNO and DNA methylation data were used as continuous variables, and the results were expressed as per cent variations of FEV1 and FeNO and of the interquartile-range change in DNA methylation – that is, interleukin-6 interquartile range: 16.1 per cent of 5-methylcytosine (%5mC); nitric oxide synthase interquartile range: 9.4 %5mC; Alu interquartile range: 0.9 %5mC; and LINE-1 interquartile range: 4.9 %5mC. We fitted generalized estimating equation regression models that included the independent variables for age, gender, parental education, exposure to environmental tobacco smoke, mould or dampness in the child's room, symptoms of rhinoconjunctivitis, traffic intensity in the street of residence, recent respiratory infections, use of inhaled steroids for asthma, subject's height and weight, day of the week, and outdoor temperature and relative humidity.

Personal measurements of air-pollutant concentrations were taken on one witness per group of children. The groups were assembled so as to be homogeneous by school attendance (the same classroom) and area of residence. One of the children in each group served as a witness and wore a passive dosimeter (daily) for nitrogen dioxide and sulfur dioxide and used a portable instrument to measure $PM_{2.5}$. Eight calibrations were made on study weeks 1, 3 and 5–10 against an ARPA Tuscany gravimetric standard.

Ambient air-pollutant concentrations were measured between November 2007 and April 2008 at 21 locations – in the schoolyards of the primary and secondary schools of the study area – by means of weekly passive dosimeters for gaseous pollutants. Nitrogen dioxide, sulfur dioxide and benzene, toluene and xylene were measured over a week, twice a month. $PM_{2.5}$ daily concentrations were measured for 100 days (between December 2007 and April 2008) by the gravimetric monitor located at Pace del Mela secondary school.

Table 83 shows the characteristics of the subjects in PANEL 50. The data consists of 300 valid measurements for spirometric variables and 302 measurements for FeNO.

Table 86 shows adjusted regression coefficients for FEV1 and FeNO, for the potential confounders. For FEV1, this sample of asthmatic children showed a reverse association with current environmental tobacco smoke and mould and dampness and a positive association with traffic intensity. Table 87 shows the results when personal air pollutant concentrations are included. We observed a 2.4% (90% CI: 1–4%) decrease in FEV1 and an 8.1% (90% CI: 3–14%) increase in FeNO for a 10 $\mu g/m^3$ increase in sulfur dioxide concentration at lag 2 and lag 0–1 (the average of the pollutant concentration of the same day and the day before), respectively.

Table 86. PANEL 50 study: regression coefficients for potential confounders – FEV1 and FeNO

Confounder	FEV1			FeNO		
	Coefficient	90% CI		Coefficient	90% CI	
Reference for weekday: Sunday						
Monday	−0.023	−0.073	0.027	0.120	−0.154	0.395
Tuesday	−0.037	−0.079	0.004	0.144	−0.157	0.445
Wednesday	−0.027	−0.063	0.009	0.314	0.038	0.590
Thursday	−0.037	−0.079	0.005	−0.029	−0.392	0.334
Friday	−0.012	−0.056	0.032	0.113	−0.106	0.333
Saturday	0.020	−0.046	0.085	0.076	−0.094	0.246
Personal attributes						
Height (m)	0.013	0.006	0.021	–	–	–
Weight (kg)	−0.003	−0.008	0.003	–	–	–
Age (years)	−0.026	−0.079	0.027	0.314	0.003	0.626

Table 86 (concluded). PANEL 50 study: regression coefficients for potential confounders – FEV1 and FeNO

Confounder	FEV1			FeNO		
	Coefficient	90% CI		Coefficient	90% CI	
Reference for gender: male						
Female	–0.038	–0.121	0.045	0.012	–0.366	0.390
Reference: low level of parent's education						
High education	0.064	–0.008	0.135	0.136	–0.327	0.599
Reference: child's BMI						
BMI	0.018	–0.006	0.043	–0.176	–0.284	–0.067
Reference for environmental tobacco smoke: no						
Yes	0.076	0.007	0.145	–0.841	–1.322	–0.360
In the past	0.135	0.059	0.212	–0.101	–0.486	0.284
Reference for mould or dampness: never						
Current	0.088	0.004	0.172	–1.186	–1.580	–0.792
Always	0.0169	–0.065	0.098	–0.028	–0.946	0.889
Reference for traffic: not intense						
Intense	–0.067	–0.129	–0.004	0.422	0.007	0.838
Reference for respiratory infections: no						
Yes	–0.020	–0.051	0.012	–	–	–
Reference for drugs for asthma: no						
Yes	–0.023	–0.076	0.030	–0.009	–0.590	0.572
Meteorological conditions						
Temperature (C°)	–0.003	–0.008	0.002	0.002	–0.034	0.038
Humidity (%)	–0.0006	–0.002	0.0008	–0.0005	–0.011	0.010

Table 87. PANEL 50 study: regression coefficients for personal air pollutant concentrations, at different time lags – FEV1 and FeNO

Air pollutant	Regression coefficient	90% CI	
FEV1 at lag 2			
Sulfur dioxide	–0.0024	–0.0040	–0.0008
Nitrogen dioxide	–0.0014	–0.0032	0.0003
$PM_{2.5}$	–0.0003	–0.0009	0.0003
FeNO at lag 0-1			
Sulfur dioxide	0.0081	0.0027	0.0134
Nitrogen dioxide	–0.0201	–0.0330	–0.0007
$PM_{2.5}$	0.0008	–0.0052	0.0068

Table 88 shows the associations between epigenetic markers and exposure to air pollutants. DNA methylation of repetitive elements (Alu and LINE-1) throughout the genome did not appear to be consistently associated with exposure to air pollutants (only sulfur dioxide for Alu at lag 1–2). Exposure to nitrogen dioxide and $PM_{2.5}$ seemed to inconsistently affect DNA methylation of the gene specific promoter for interleukin-6: it showed a positive association for nitrogen dioxide and a negative association for $PM_{2.5}$ at lag 1–2. When considering the promoter region for the nitric oxide synthase gene, we found a clear association – with demethylation being associated with increasing concentrations of sulfur dioxide and $PM_{2.5}$.

Table 88. PANEL 50 study: regression coefficients of personal air pollutant concentrations, at time lag 1–2, for four DNA methylation outcomes

Air pollutant	Regression coefficient	90% CI	
Alu			
Sulfur dioxide	–0.0010	–0.0020	–0.0001
Nitrogen dioxide	0.00004	–0.0010	0.0011
$PM_{2.5}$	0.00002	–0.0003	0.0003
Line-1			
Sulfur dioxide	0.0006	–0.0003	0.0015
Nitrogen dioxide	0.0012	–0.0006	0.0030
$PM_{2.5}$	0.0003	–0.0001	0.0008
Interleukin-6			
Sulfur dioxide	–0.0035	–0.0083	0.0013
Nitrogen dioxide	0.0077	0.0011	0.0144
$PM_{2.5}$	–0.0020	–0.0037	–0.0002
Inducible nitric oxide synthase			
Sulfur dioxide	–0.0041	–0.0078	–0.0004
Nitrogen dioxide	–0.0049	–0.0098	0.0000
$PM_{2.5}$	–0.0018	–0.0030	–0.0006

Discussion: PANEL 50 study

The PANEL 50 findings are consistent with the literature. They are based on personal daily measurements of air pollutants. Some misclassification may have occurred, since the measurements were taken on only one child (the witness) in each group; despite that, children were matched by residence and school attended. The strong association shown for sulfur dioxide suggests industrial sources of pollution played a role in children's respiratory disorders.

The study subjects were asthmatic children, and reverse bias and reporting bias cannot be excluded from observed associations with known risk factors for asthma, such as environmental tobacco smoke, mould and dampness, and traffic intensity. Also, some caution should be taken when considering time-lagged exposure; outcomes were measured in the late afternoon, while exposure was averaged over the day. Associations, however, were stronger at shorter time lags for FeNO than for FEV1.

When considering markers of DNA methylation, we analysed only the average for lagged exposure day 1–2, because there were only two DNA methylation measurements. Global epigenetic markers are difficult to interpret, and the literature reports either positive or negative associations. In our study, the coherent association between sulfur dioxide and/or $PM_{2.5}$ and the nitric oxide synthase gene pathway is important; it is biologically plausible and matches the observed association between FeNO and air pollutant concentrations.

Conclusions

The Milazzo–Valle del Mela study demonstrated a slightly higher prevalence (about +2%) of childhood respiratory disorders than that found in the Italian SIDRIA-2 study. Some peculiarities in exposure to known risk factors were not sufficient to explain the observed difference. The exposure assessment, by ambient monitoring and personal monitoring, documented children's exposure to elevated concentrations of sulfur dioxide, nitric oxide, and $PM_{2.5}$. During some weeks, the average concentration value for sulfur dioxide was more than 20 $\mu g/m^3$, and the $PM_{2.5}$ average in the study period was about 23 $\mu g/m^3$, twice that of the WHO air quality guideline limit and comparable to values observed in big cities, such as Rome.

Two panel studies on symptomatic and asthmatic children living in the area showed positive associations of spirometric measurements and bronchial inflammation with raised concentrations of sulfur dioxide and $PM_{2.5}$ at lag 2. In particular, the associations were not irrelevant – for example, a greater than 2% decrease in lung function (PANEL 50) and an 8% increase in bronchial inflammation (PANEL 50). In a companion study in Sarroch (Sardinia, Italy), we found a similar association (Biggeri, Catelan & Accetta, 2008). The literature on the subject reported mainly relative risks and not an absolute effect, so the issue of clinical relevance of the documented association is still open. With due consideration to these limitations, we can conclude that the observed level of air pollution in the Milazzo–Valle del Mela area threatens childhood respiratory health.

Also, epigenetic markers were associated with air pollutant concentrations – particularly, with regard to the nitric oxide pathway. These findings reinforce the biological plausibility of the associations found in the study – that is, that raised air pollutant concentrations appear to interfere with DNA methylation and, in particular, demethylation of the promoter of the gene for nitric oxide synthase. In turn, nitric oxide synthase is the inducible enzyme responsible for elevated FeNO, a marker of bronchial inflammation in asthmatic patients.

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12. THE ROLE OF SPACE-TIME ACTIVITY PATTERNS IN THE EXPOSURE ASSESSMENT OF RESIDENTS

Arnaud Banos, Elise Beck, Sandrine Glatron and Pierpaolo Mudu

Introduction

Industrial development can generate hazardous situations – in particular, when there is a need to deal with dangerous substances, such as those in chemical or petrochemical plants. Too often, these industries are located in the heart of urbanized areas with high-density populations, as urbanization intrudes on the hazardous sites (originally established outside of cities). Protecting civil populations from these risks – either through precautionary measures or special crisis management plans, if a catastrophe occurs – is a key issue. To better protect citizens, identifying the risks to which they are exposed and also how they perceive the risks in their area can help authorities and stakeholders better understand the risks (Glatron & Beck, 2008). Adequate knowledge of these risks can also dissuade populations from settling in certain zones and thus lower their vulnerability. Finally, authorities need to assess the exposure of populations to hazards – through modelling – to set up appropriate and efficient risk management plans based on land planning.

The present chapter – founded on responses to a questionnaire-based investigation (see the Annex) carried out in the Milazzo–Valle del Mela area of Sicily, in 2008 – explores two main aspects of exposure assessment:

- space-time-pattern methodological challenges; and
- results of individual space-time activity data extracted from the investigation in the Milazzo–Valle del Mela area.

Methods

Since an evaluation of the impact of the petrochemical industry depends on accurate exposure estimates, different procedures have been developed to obtain them. For example, the use of GISs with exposure estimates at the individual level can lead to significant results (Yu et al., 2006). On the other hand, as in the case of the Milazzo–Valle del Mela area, simulation procedures also offer significant results. When trying to assess individual exposure to risk, space-time activity data are of crucial importance, because they allow the description of an individual's activities and mobility at very fine spatial and temporal resolution and in great detail.

Several methods exist to capture such data, their level of technological sophistication depending on budget and feasibility constraints. Some models consider accessibility measures (such as distances between relevant locations or the amount of time available for travel), to emphasize the potential for travel, conditioned by the performance of the transportation system (Wu & Miller, 2001). Other models consider individual decision-making processes and the elementary factors that determine travel activity (Wu & Miller, 2001).

Another research (or modelling) possibility is to adopt an intermediate solution, which proved efficient in other contexts (Banos, 2001). This solution is a survey adapted to *data poor* situations, as in our case study.

The idea of this intermediate solution is simple: sometimes, more is less. So, by using clear assumptions, a bit of simple information on mobility patterns can provide many insights. If fully disaggregated spatial and temporal information proves to be of great interest, several problems need to be solved. First, even if the data-processing technology progresses quickly, it is still difficult to produce a repetitive method that is not time consuming. Second, most of the time it is difficult to obtain information about people's addresses (this can be a problem in some countries, such as France, although Italy can collect individual data), because of a general inclination towards mistrust. Finally, such personalized information is very sensitive, for reasons of privacy and confidentiality, so even if we manage to collect it, it is often impossible to use spatial information at that very fine scale, because single individuals can be easily identified.

The question we then have to answer is: do we really need exact spatial information? Most of the time, more accurate information about activities is needed, rather than *exact* spatial information. Therefore, in our case, we adopted methods that took into account the worst case scenario, where it is both difficult to use a global positioning system and to ask for the address of people surveyed. A solution that has proved efficient is to supplement the questionnaire with a map of the city with a superimposed grid. Using grids helps to convert the different places indicated by the people surveyed into geographical coordinates (S. Novak & E. Beck, unpublished observations, 2008).

The questionnaire on risk perception assessment also contained a table for the people surveyed to indicate their movements of the previous day, the types of activities they performed, their mode of transportation, and the time of departure and arrival of each movement (in intervals of 15 minutes) (see the questionnaire in the Annex). Fig. 23 provides an example of the time activity details of five different people surveyed, who are identified by an alphanumeric code under the heading *ID*.

Fig. 23. Time activity data constructed during the survey

Le Sphinx Plus² - ENQUETES MILAZZ [Saisie des réponses]

REPONSES (mode tableur) - (5 observations)

	1. ID	2. NUM	3. DEP TIME	4. ARR TIME	5. TYP	6. TYP	7. X	8. Y D	9. TYP	10. X	11. Y	12. DEP TIM	13. ARR TIM	14. TY	15. TY	16. X	17. Y	18. TY	19. X	20. Y
n°1	MM52R	4	09h30	09h45	1	1	J	21	7	J	21	11h45	12h00	1	7	J	21	1	J	21
n°2	MM62R	4	08h30	08h45	2	1	M	26	2	M	26	13h15	13h30	2	2	M	26	1	M	26
n°3	MR47R	2	08h00	08h15	2	1	I	24	2	K	19	14h00	14h15	2	2	K	19	1	I	24
n°4	MR70F	0	-	-	-	-		-	-		-	-	-	-	-		-	-		-
n°5	MR72R	2	07h15	07h30	2	1	P	36	2	V	29	16h45	17h00	2	2	V	29	1	P	36

Note. Each individual in the survey has an identification number (1.ID) and a number of activities (2.NUM), plus a vector of data: departure time (3. DEP TIME), arrival time (4. ARR TIME), transport mode (5. TYP), type of departure activity (6. TYP), cell location of departure activity (*x* coordinate: 7. X), cell location of departure activity (*y* coordinate: 8. Y), type of arrival activity (9. TYP), cell location of arrival activity (*x* coordinate: 10. X) and cell location of arrival activity (*y* coordinate: 11. Y). Then information is collected for the following trip: departure time (12. DEP TIME), arrival time (13. ARR TIM), and so on.

As can be seen, the approach is clearly event-based, and even if a temporal unit of 5 minutes is fixed, experience suggests people often approximate time by events. Since we did not want to introduce artificial precision in the questionnaire by asking people for *exact* times, each individual in the survey is assigned a linear matrix – that is, an alphanumeric vector of data. The dimension of this vector is *n* by 9, with *n* being the number of activity changes during the period surveyed (one day here) and 9 being the number of variables collected for each activity – that is:

1. departure time (3. DEP TIME)
2. arrival time (4. ARR TIME)
3. transport mode (5. TYP), such as car, motorcycle, bus or bicycle
4. type of departure activity (6. TYP)
5. cell location of departure activity (*x* coordinate: 7. X)
6. cell location of departure activity (*y* coordinate: 8. Y)
7. type of arrival activity (9. TYP)
8. cell location of arrival activity (*x* coordinate: 10. X)
9. cell location of arrival activity (*y* coordinate: 11. Y).

With the aid of the questionnaire on risk perception, sociodemographic data were also collected, describing each individual's responses, in terms of gender, age, marital status and education level. More than 400 individuals (454) were questioned, although only 390 questionnaires turned out to be exploitable for the individual exposure assessment.

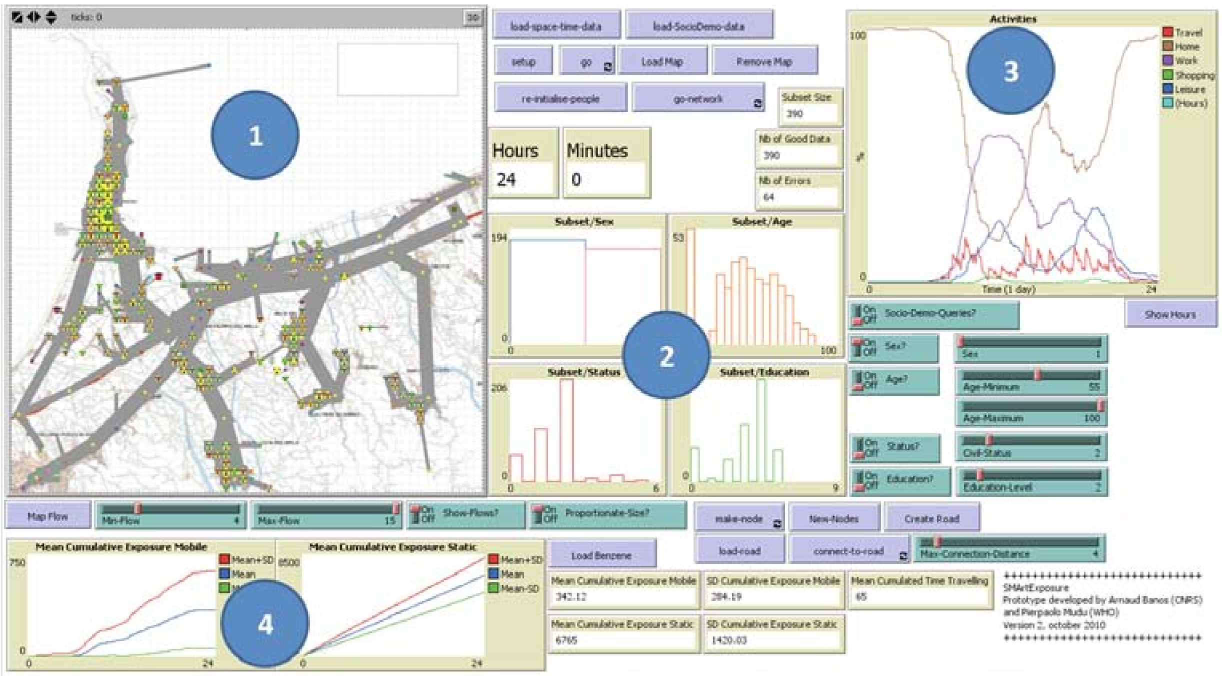
Assessing individual exposure

What can be done with such detailed spatio-temporal information? Three main ideas guide this exposure assessment. First, a lot can be learned from these complex data by properly visualizing them and playing with them. Second, individual exposures to air pollution or to industrial hazards can be estimated, for given scenarios, as long as these data can be linked to those on hazards. Third, the accuracy of the present study can be much greater than that of studies in which populations in the vicinity of industries are expected to receive the largest exposure (Newhook et al., 2003).

Exploring data on space-time activity

To allow precise exploration of these spatio-temporal data, we designed and implemented a specific prototype, called SMArtExposure (Fig. 24).

Fig. 24. SMArtExposure spatio-temporal navigator



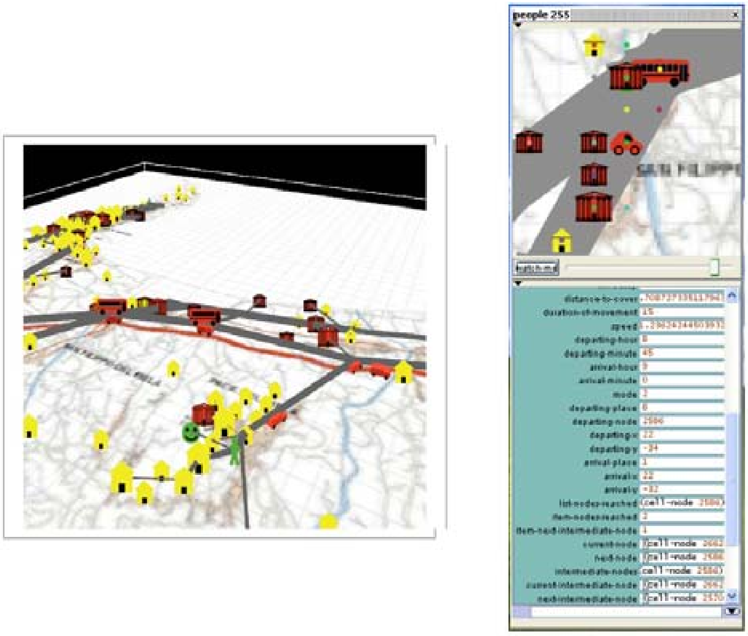
SMArtExposure may be seen as a spatio-temporal navigator, allowing the space-time activity data collected during the survey to be explored, and it is developed in NetLogo (for further details about this agent-based modelling platform, see Wilensky, 1999). SMArtExposure is composed of four graphic components (Fig. 24):

1. a map that displays activity types and locations, as well as transportation modes and movements (the line width is proportional to the amount of traffic);
2. sociodemographic plots, based on the four sociodemographic data subsets (sex, age, status and education) and allowing the definition of specific subsets;
3. a time–activity plot, displaying the proportion of activities (with sums up to 100%) realized by the subset members during the day (24 hours); and
4. plots, displaying mean cumulative exposure to benzene that occurs during the day for the subset defined, with this individual cumulative exposure aggregated for group comparisons and divided into static and mobile components.

The road network was digitized from the map used for the questionnaire, and the most probable routes that correspond to individual trajectories were simulated using a shortest path algorithm (Floyd, 1962).

Each individual surveyed is then displayed on the graphical user interface and their space-time activity trajectory is constructed and produced dynamically in two and three dimensions (Fig. 25). Primarily, activities, transportation modes and routes are displayed, as they convey the main information.

Fig. 25. Three-dimensional (3D) view of SMArtExposure [a]



Transportation mode	Symbol
Pedestrian	Green person
Car	Red car
Motocycle	Red bike
Bus	Red bus
Taxi	Yellow car
Train	Red train
Bicycle	Green bike
Others	Red star
Activity	**Symbol**
Home	Yellow house
Work	Red building
Shopping	Blue store
Sport	Green smiley
Market/Supermarket	Green store
Leisure	Green smiley

(a) Three-dimensional view of the area (b) Individual's identification card (updated during the simulation) (c) Symbols for activities and transportation modes

[a] Each individual moves along the road network between successive activities, using various transportation modes.

Based on the representative sample of those surveyed, group comparisons can be conducted.

Assessing exposure

While exposure assessment methods work mainly for aggregated populations, individual exposure assessments provide complementary results that shine a different light on this complex issue. In practice, the general exposure model by Duan (1982), which follows, holds for individuals, groups and larger populations:

$$E_i = \sum_{j=1}^{m} T_j C_j$$

where the cumulative exposure E_i of any individual *i*, during a given time period, may be seen as the sum of the product of the local concentration C_j (for example of a pollutant) in various micro-environments *j* and the time (*T*) spent in *j*. Therefore, a static component of exposure, ES_i, can be distinguished from a mobile component of exposure, EM_i, the latter focusing on individual exposure during travel (see results of the case study in the next section).

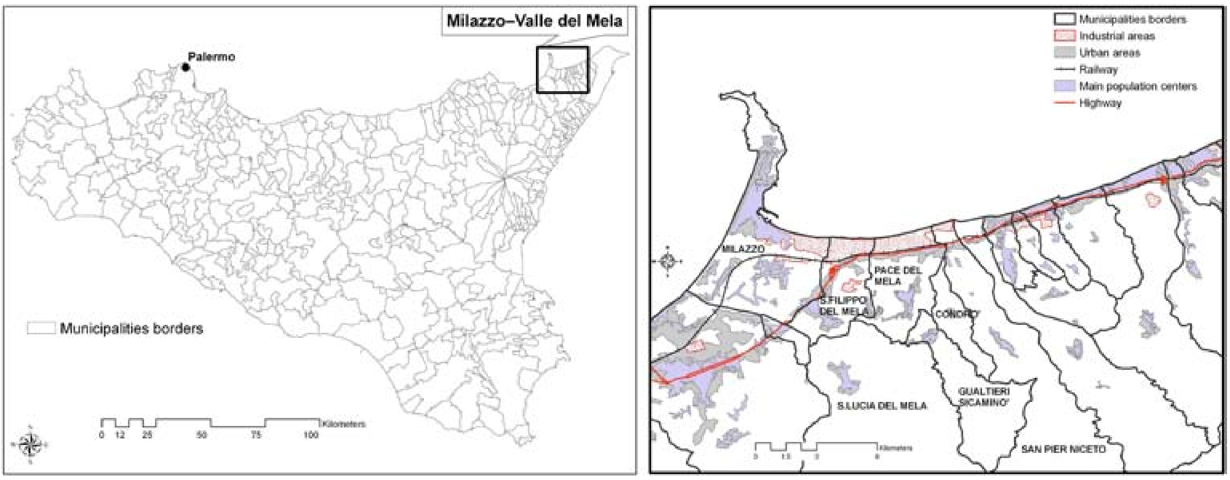
The first thing to do is to introduce a risk distribution in the model. As we are in a data poor situation, we cannot expect detailed and accurate data on pollutant concentrations. To perform a case study, it is necessary to have data of some kind on targeted pollutant dispersion or on a number of different pollutants. In our case, we had data on only a single pollutant – benzene. The reader, however, must consider that, in some cases investigated in the literature, exposure is estimated for a mixture of pollutants (Nadal et al., 2006).

The Milazzo–Valle del Mela case study

Sicily is an appropriate place to study both exposure to risk and risk perception, because the eastern part of the island includes many zones that accumulate natural and industrial risks (seismic, volcanic, and industrial – with petrochemical plants and power stations). Because Sicilians are constantly exposed to these risks, it is important to assess exposure and to estimate whether or not (and the manner in which) the population is conscious of these risks (see Chapter 15).

However, Sicily may also be characterized as being data poor: only a few data are available; and, basically, most of the relevant data have to be gathered without reference to previous work that normally helps to carry on exposure and risk-perception studies. Milazzo–Valle del Mela is located in the north-eastern part of Sicily (Fig. 26). The main municipality in this area is Milazzo, but it is not the only municipality of concern in this study. Many other small villages (such as Gualtieri Sicaminò, Santa Lucia del Mela, San Filippo del Mela, Condrò, Pace del Mela and San Pier Niceto) are also involved in the study (Fig. 27). With the major economic activities of the island being agriculture, fishing and tourism, the area of Milazzo–Valle del Mela prospers principally from the presence of heavy industries. Abundant oilfields and methane fields were discovered on the island 60 years ago, and a large petrochemical complex was built in this part of Sicily to produce and refine hydrocarbons.

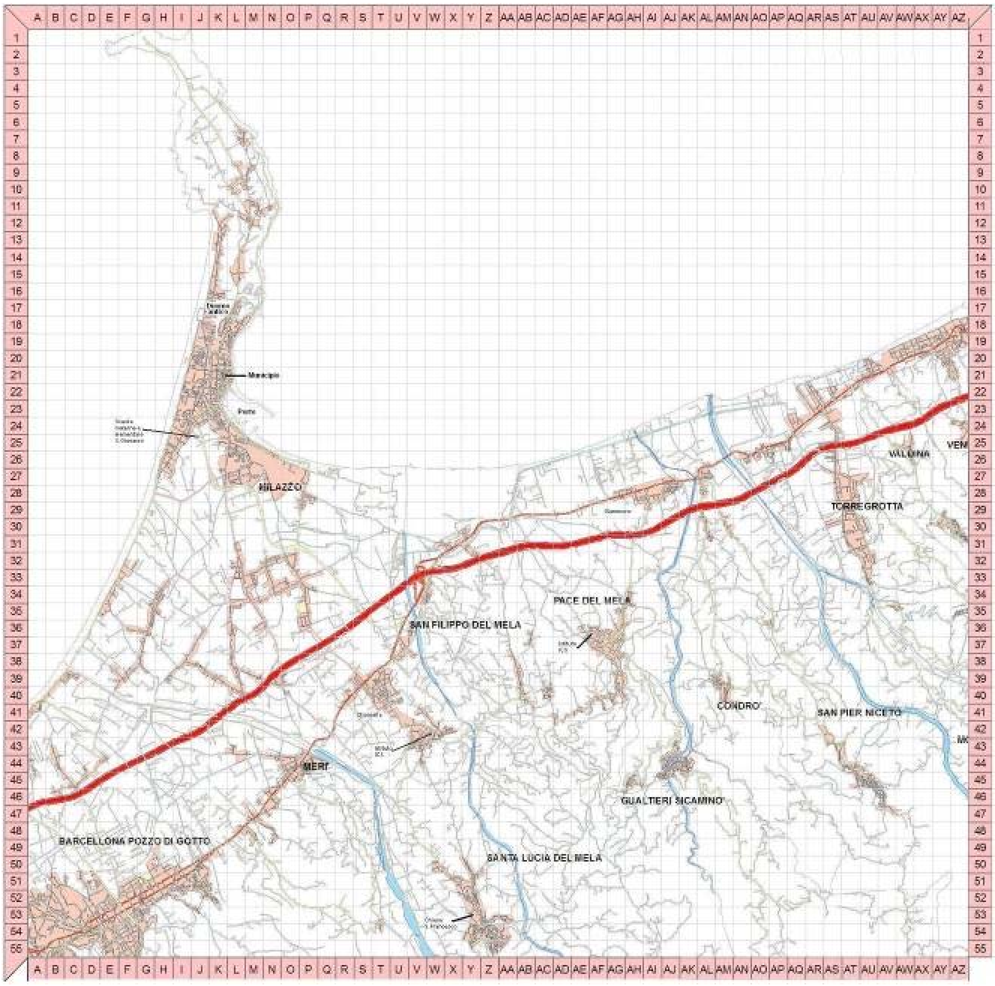
Fig. 26. Location of Milazzo–Valle del Mela



From a couple of different perspectives, the huge petrochemical plants in the Milazzo–Valle del Mela area constitute a hazard to the population. First, the pollution generated by the plants leads to health problems for the population exposed to it (Cernigliaro et al., 2008). Second, the industrial process can create such major accidents as fires and explosions. In this context, it is important to know the space-time patterns adopted by the population. Knowing when, where and which activities are carried out can offer (at least) relevant information for potential differential exposure patterns and for potential accidents.

To assess the exposure of the individuals surveyed – that is, to gather individual daily timetables – people were simply asked to draw a mark in the cells (width 250 m) of the grid that correspond to the different locations of their activities (Fig. 27). In the present study, this map was also used as a support for so-called mental maps – that is, a representation of the perceptions and knowledge a person has of an area (see Chapter 15).

Fig. 27. The map used for the Milazzo–Valle del Mela survey [a]



[a] Cell size: 250 m.

The space-time data for people's displacements were processed, as described in the section on "Methods", and displayed within the SMArtExposure navigator (Fig. 24). The time activity plots were computed to analyse time activity budgets of different sociodemographic groups; the example of men and women is described in Fig. 28.

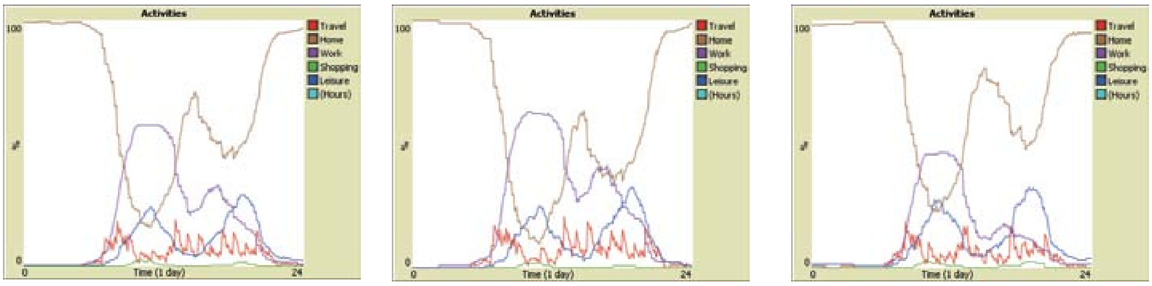
Evidence of significant differences between men and women can be emphasized (Fig. 28). Time activity budgets present different patterns, in the morning and even more so in the afternoon: the proportion of men working is higher, while the proportion of women at home or shopping is higher. Moreover, while activities present a clear bimodal distribution, the distribution of mobility seems to be more chaotic. The resulting traffic and origin–destination flow also presents differences that deserve attention, since they may lead to differences in individual exposures.

Also, the road assignment algorithm could be improved – for example, by introducing a multimodal network (multigraph) or constraining routes by the times provided by the people surveyed. Such improvements, however, have to fit the objectives of the study and, especially, the nature and accuracy of data obtainable on hazards. As Fig. 29 shows, both the spatial and temporal resolutions of pollution data have a much larger scale. Therefore, one has to find a good balance between algorithmic complexity, phenomenon accuracy and scales of integration. Once precise space-time activity profiles are defined, hazards (such as pollutants) can be introduced, to assess the individual cumulative exposure of the population surveyed.

With regard to exposure to a given pollutant, simulations can be carried out – also with rough data (see the case of benzene in Fig. 29). Data on benzene were available from the study discussed in Chapter 11.

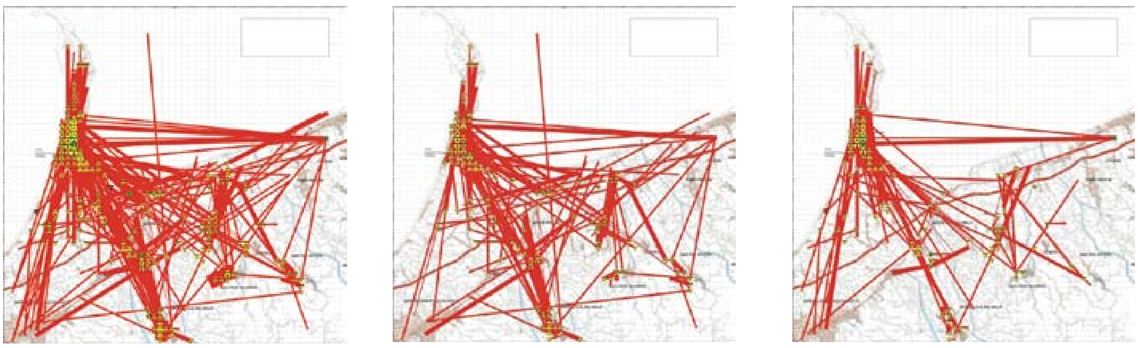
Fig. 28. Time activity budgets and traffic for men and women

Whole population (n = 390; missing data on gender = 53)	Subset: men (n_1 = 176)	Subset: women (n_2 = 161)



(a) Proportion of individuals occupied by a given activity during the day

(b) Total traffic assigned to the road network during the day (line width proportional to traffic)



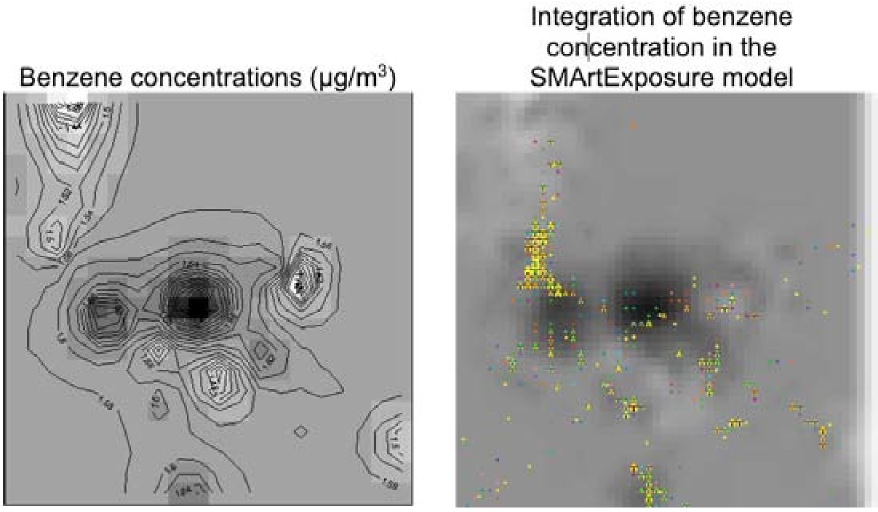
(c) Total origin/destination flows during the day (line width proportional to the number of movements)

Note. In parts (b) and (c) of this figure, the yellow areas indicate the residence of individuals.

The concentration levels were directly incorporated in the time activity model and graphical interface, to estimate individual exposure to benzene, using the formula for exposure that appears in the subsection on "Assessing exposure" (Duan, 1982). Here again, a group comparison between men and women leads to notable results (Fig. 30). On each plot, the horizontal axis displays time (24 hours), while the vertical axis displays the mean cumulative exposure for the mobile and static component.

While the static component of exposure (*ES*) presents a linear signature, the mobile component (*EM*) presents a non-linear one, coupled with an inflating variance. Also, while the static component is comparable for the two subsets, the mobile one is significantly higher for men. As exposure is a cumulative during one day (24 hours), this difference may be explained – partly at least – by the different travel budgets: 1 hour on average for women versus 1 hour and 15 minutes on average for men. However, other factors that affect activity location (and therefore routes taken) may also need to be investigated.

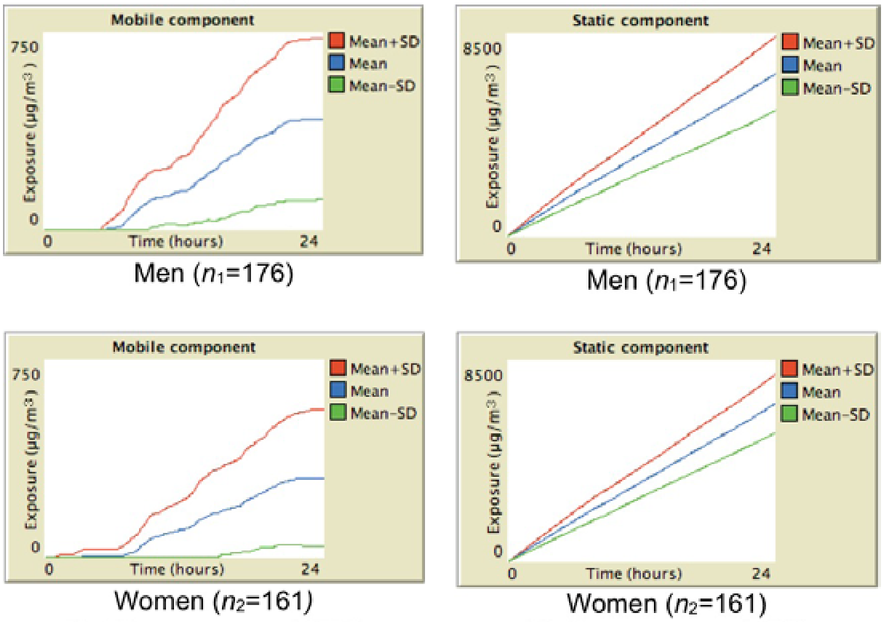
Fig. 29. Time activity budgets and traffic for men and women



Note. The yellow areas indicate the residence of individuals.

Fig. 30. Comparison of men and women, for both mobile and static components of mean cumulative exposure to benzene

$$EM = \frac{1}{n}\sum_{i=1}^{n} EM_i \qquad ES = \frac{1}{n}\sum_{i=1}^{n} ES_i$$



Mobile component (*EM*)
EM_1 = 407 µg/m³(SD = 295 µg/m³)
EM_2 = 302 µg/m³ (SD = 262 µg/m³)
$EM_1 > EM_2$ ($P < 0.05$),
where the subscript 1 indicates men and the subscript 2 indicates women

Static component (*ES*)
ES_1 = 6823 µg/m³ (SD = 1546 µg/m³)
ES_2 = 6640 µg/m³ (SD = 1226 µg/m³)
$ES_1 \approx ES_2$,
where the subscript 1 indicates men and the subscript 2 indicates women

SD: standard deviation.

Here again, the approach is very generic: even if it was more detailed and dynamic concentration data were used, the process would be exactly the same. Therefore, another important issue concerns the perception people have of their own exposure to risks (see Chapters 15–17).

Conclusions

The integration of different models is an apparent objective when studying the effects of complex risk scenarios (Mudu et al., 2006; Mudu & Beck, 2012). In the case of Sicily's contaminated areas, concentration and exposure are fundamental variables to be combined in a risk assessment (IPCS, 2005). This chapter provides an example of integration of different data and models by using a simulation platform. Also, even in *data poor* situations, disaggregated spatio-temporal information (and mental maps) can be constructed.

The protocol proposed here, based on a cartographical approximation, leads with acceptable accuracy to individual-based exposure estimates and group comparisons. A spatio-temporal navigator, called SMArt-Exposure, was developed, allowing the exploitation of complex data on space-time activity (at both the individual and group level) and its coupling to data on hazards (concentration of a pollutant here).

The results indicate very precise patterns of space-time activity where the population tends to spend its time far from the core of polluting activities. Evidence of significant gender differences should be stressed. Time activity budgets present different patterns, in the morning and even more so in the afternoon: the proportion of men working is higher, while the proportion of women at home or shopping is higher. Moreover, while activities present a clear bimodal distribution, the distribution of mobility seems to be more chaotic. These results represent not only the first step towards building precise exposure profiles of the population, but also represent a dynamic picture of the population that can be used as scenarios and for political discussions and policy planning.

Acknowledgements

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13. SIMULATION OF ACCIDENT PATTERNS

Sergio Bajardi and Pierpaolo Mudu

Introduction

The activities of petrochemical plants – if not carefully operated and monitored – can result in accidents, ranging from leaks of toxic substances to fires or dangerous explosions and associated adverse effects on health. In Sicily, a vast range of accidents have occurred since the start-up of petrochemical industry activities (see the section on "Chronology of major accidents in the three Sicilian petrochemical areas" in the Annex). This chapter introduces: (a) the issue of a major accident; (b) the legislative framework for dealing with it; and (c) some examples of the simulation of accident patterns.

What is a major accident?

Unlike risks directly related to natural events, industrial or technological risks are associated with human activities that produce effects on land, that involve the use of production facilities, and that involve the utilization of infrastructure and technology networks that can be a source of danger to people and the environment (Crowl & Louvar, 1989). According to the Seveso II Directive (EC, 1996b), implemented in Italian legislation (Parliament, 1999), after Presidential Decree No.175 of 17 May 1988 (President of the Republic, 1988b):

> [a] major accident shall mean an occurrence such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any establishment covered by this Directive, and leading to serious danger to human health and/or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances.

This definition does not take into account the gravity of an accident. Instead, it refers only to the nature (detailed and well identified) of an accident that may be more or less harmful to people and things according to its magnitude and radius of damage. It follows then that, whatever the radius within which there may be consequences as a result of an accident – and also independent of the actual consequences that the event implies – the term *major accident* is attributable only to the activities of those facilities where *dangerous substances* are stored, processed and/or produced. In this context, the vehicles on which these substances move – travelling by road, rail or sea – are also to be considered.

The modelling of major accidents – and the potential threat to public health – is usually carried out as a quantitative risk analysis. To draw the same conclusions as those of a full risk assessment, rapid risk assessment tools were also proposed, albeit with lesser accuracy and precision (Khan & Abbasi, 1999). Briefly, the methods and procedures followed for a quantitative risk analysis of a chemical installation handling a hazardous substance can be divided into the following 10 major steps (Papazoglou et al., 1999):

1. hazard identification
2. accident sequence modelling
3. data acquisition
4. accident sequence quantification
5. assessment of hazardous-substance release categories
6. extreme phenomena modelling
7. dose and consequence assessment
8. parameter estimation for consequences
9. consequence quantification
10. integration of results.

These steps were followed to introduce a real case study, and some of these studies are presented in detail to show the results of simulations.

Legislative framework

In Europe, the Seveso accident in 1976 encouraged the adoption of legislation aimed at the prevention and control of major accidents – in particular, in the chemical industry. The operators of industrial establishments located in states belonging to the EU are subject to the so-called Seveso directives. In 1982, the first EU directive (Seveso Directive) was adopted (EEC, 1982). In 1996, the Seveso Directive was replaced by the Seveso II Directive (EC, 1996a), which was adopted in Italy in 1999 (Parliament, 1999). This directive was extended by Directive 2003/105/EC (EC, 2003b).

The Seveso II Directive applies to industrial plants where dangerous substances are present in quantities that exceed the thresholds it specifies. The Directive aims at preventing major accidents and mitigating their consequences. Industries subject to the requirements of the Directive need to strictly organize safety management systems and emergency planning. The industrial operator must take all measures necessary to prevent major accidents and to limit their adverse effects on people and the environment. According to Article 6 of the Seveso II Directive (EC, 1996a; Parliament, 1999), operators can be requested to notify the competent authority, and according to the Article 9 (EC, 1996a; Parliament, 1999: Article 8) operators have to provide a safety report when their establishments have dangerous substances in quantities equal to or in excess of the thresholds specified in the Directive. In recent years, legislation on industrial risk has proliferated (Ministry of the Environment, 1996, 1998; Parliament, 1999; Ministry of the Environment and Territory, 2000b,c; Ministry of the Environment and Territory, 2001b; Ministry of the Interior, 2001; Ministry of Public Works, 2001; Parliament, 2005b,c; President of the Council of Ministers, 2005).

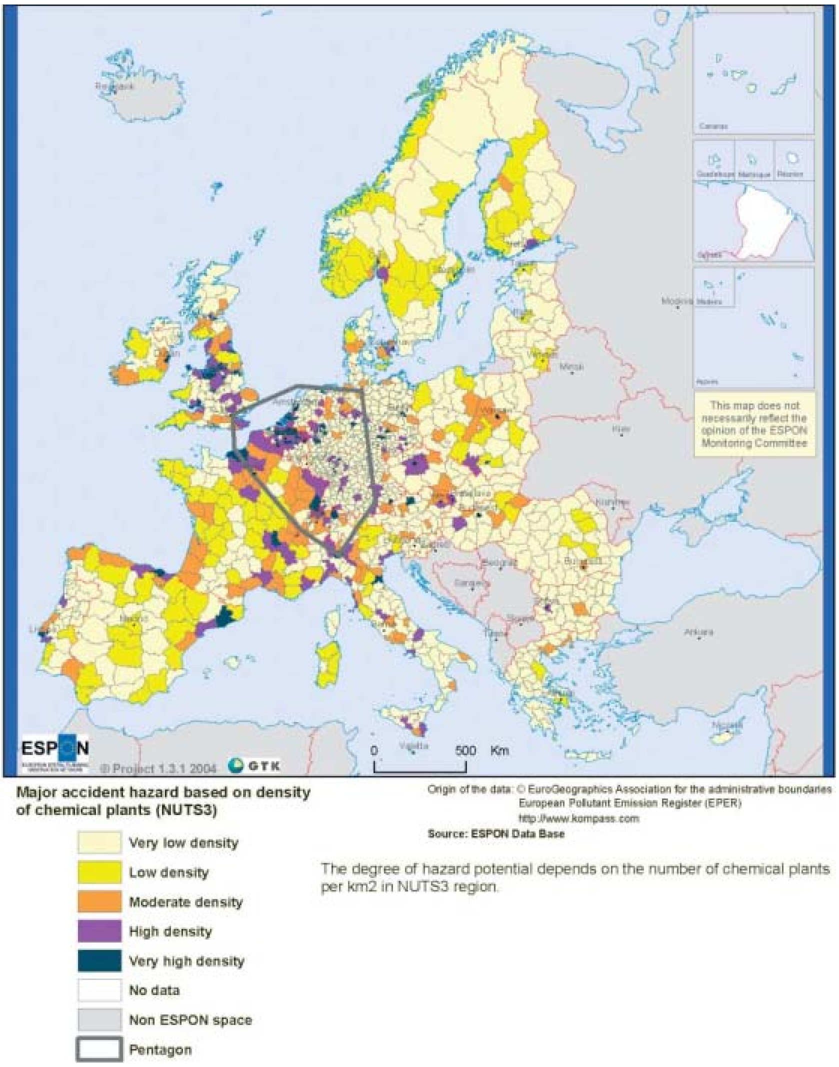
Also, the populations potentially affected by industrial accidents need to be informed regularly about emergency procedures and new plans. Authorities responsible for decisions in this area should set up appropriate consultation procedures when planning the siting of new establishments or the modification of existing ones, to give the public the opportunity to offer its views.

The examples provided in the text refer to Sicily, but the petrochemical industry is worldwide, and preventive measures are necessary to protect populations in similar situations (see Fig. 31). In Europe, the Major Accident Reporting System was developed and has been operating since 1984 to handle information on major accidents submitted by Member States of the EU to the European Commission, in accordance with the provisions of the Seveso Directive. Between 1985 and 2002, 85 accidents in petrochemical installations were registered; they accounted for 17% of the total number of industrial accidents: in most cases (21 major accidents), gasoline and its products were involved, as well as liquefied petroleum gas (21 cases) (Nivolianitou, Konstandinidou & Michalis, 2006). Of the 85 accidents registered, 20% led to human fatalities and 50% to injuries to people (Nivolianitou, Konstandinidou & Michalis, 2006).

Simulation of accident patterns

It is important to consider real case scenarios based on the three high-risk petrochemical areas in Sicily. The construction of simulation scenarios is based on a sequence of steps and choices. In the following examples, only major accidents – based on documents produced by the industrial operators in the safety report (for plants subject to Article 9 of the Seveso II Directive) or by notification (for plants subject to Article 6 of the Seveso II Directive) – were considered. The accident scenarios considered have a radius of damage that starts from the perimeter of the plant and produces effects that extend outside the border of the industrial site. Internal accident scenarios were not considered. The safety reports or notifications for each accident scenario list the potential radius of damage under one or two meteorological conditions, D5 or F2: D and F indicate two different Pasquill atmospheric stability classes – D being neutral and F stable – and 5 or 2 indicate surface wind speed in metres per second. In modelling scenarios, meteorology is a crucial factor.

Fig. 31. Major accident hazards based on the density of chemical plants



Source: Schmidt-Thomé & Kallio (2006:50).

The Seveso II Directive defines three types of notifications for industrial operators, ranked by increasing order of danger, according to the substances used and/or produced and their quantities (EC, 1996a). Also, the Italian National Environmental Protection Agency and the regional environmental agencies considered it important to establish an appropriate GIS, to collect data on companies at risk of major accidents in the country (APAT, 2002). This GIS focuses particularly on data related to hazardous substances in industry, the industrial processes involved, the safety measures taken, the accident scenarios envisaged and their radius of damage. This information – evaluated jointly with the characteristics of vulnerability of the surrounding area – constitutes the data for mapping, at the national level, industrial and technological risk. This information is also useful for proper planning, for providing the public with correct information and, especially, for developing methods for managing emergencies (Vismara, 2001).

The frequency of occurrence of top events – which potentially cause injury or death – and subsequent accident scenarios are calculated statistically. The *top event* indicates the event that initiates the development of an accident scenario, such as a break in a pipe. Calculations take into account accidents that have already occurred while using equipment and/or tanks of the same nature and practical use; they also take into account the type of substances involved and failure patterns for the technical units in a plant. In the following examples, cases of scenarios with two meteorological conditions, the case with the larger radius of damage was selected.

Dedicated software calculates the radius of damage for a given scenario, and that is then implemented in a GIS for visual representation. Georeferencing – that is, the process of aligning spatial data to an image file, such as an aerial photograph – allows various analyses, including visual inspection of the consequences of the accident modelled. In Italy, the database adopted (although not uniformly throughout the country) by the environmental protection agencies (the Italian National Environmental Protection Agency, ARPA and provincial agencies) is ARIA334 (developed by ARPA Veneto and Tuscany). This database organizes all the necessary information extracted from safety reports and notifications produced by companies at risk of a major accident, to allow the calculation of the radius of damage for all hypothetical accident scenarios and their presentation on a GIS. Also, the database allows immediate access to extremely important information (relevant in case of emergency), such as the types and quantities of substances held and/or worked in each specific site of the plants considered to present a risk.

Briefly, to model major accident scenarios requires:

- collecting data from the industries
- organizing them in a GIS
- running simulations.

Understanding the scenarios modelled required additional details. Orthophotos (aerial photographs geometrically corrected so that the scale is uniform) from the high-altitude flights ATA0708, which cover the whole of Sicily, constituted the cartographic base. The vectorial drawings (in DWG format, for storing two- and three-dimensional design data and metadata) provided by the industrial operators and the shape files (a geospatial vector data format for geographic information system software that can represent geographical features) of the establishments and the plants were projected onto this cartographic base. In the case of toxic releases provided by the safety report of the Gela Refinery, another file, produced by the Department of Land and Environment for the Sicily Region, was also used in the GIS.

It is worth noting that the safety reports are compiled by consultants or private firms, and these reports have to be revised every five years. In the safety report, the effects of accident scenarios are assessed according to methods that offer the most likely hypothesis. Safety reports are validated by a regional technical commission, which is made up of representatives from ARPA, firefighters, local authorities, the National Institute for Occupational Safety and Prevention, and the Labour Inspectorate.

Augusta–Priolo: major industrial establishments

In this area, 21 establishments are subject to the Seveso directives, of which 7 establishments are the major ones (see Fig. 32). The majority of establishments are located in Priolo (Table 89).

ESSO tank farm in Augusta

According to safety reports, the Augusta area has very few potential accident sites that could affect external zones. An example of a scenario for a potential accident is that of an ESSO plant in Augusta (Fig. 33). In this scenario, the radius of the damage curves for a shock wave from a pool fire – starting from a containment basin, due to of a loss of gasoline and with spillage at the loading area where road tankers operate – reaches the highway. In this case, considering the threshold of the low flammable limit (LFL) that causes lethal effects, LFL = 55 m (in yellow: irradiation equal to or greater than 12.5 kW/m^2, where this number represents the amount of power delivered in terms of intensity of the hypothetical shock wave) and ½ LFL = 80 m (in red: irradiation equal to or greater than 5.0 kW/m^2, but less than 12.5 kW^2).

Fig. 32. Major establishments in the Augusta–Priolo area

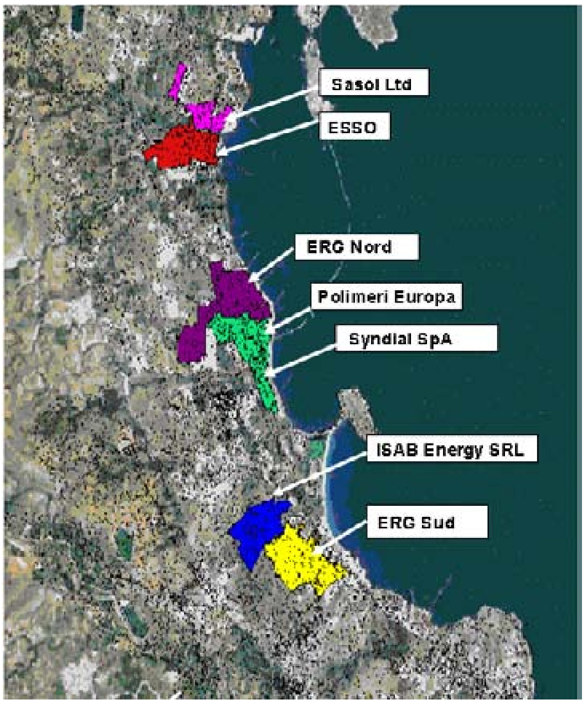
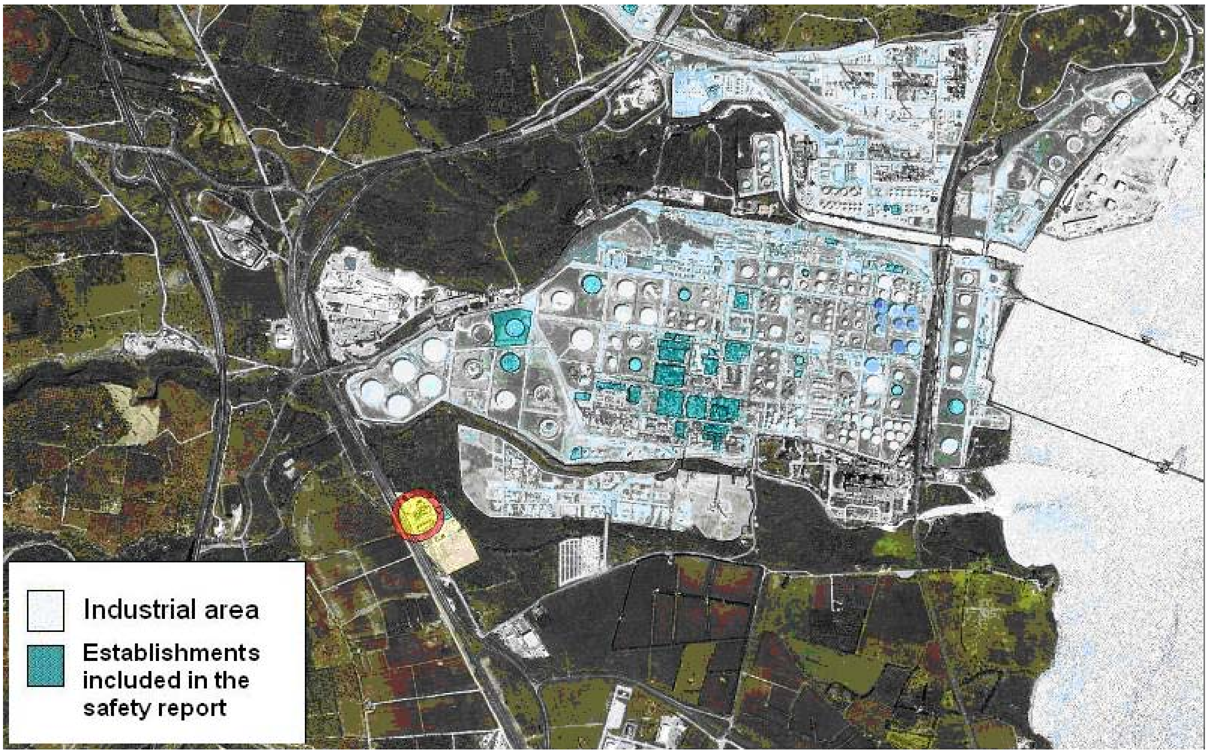


Table 89. Major establishments in the Augusta–Priolo area

Location	Establishment
Priolo	Air Liquide Impianti di Gassificazione SRL Centrale 1
Priolo	Air Liquide Impianti di Gassificazione SRL Centrale 2
Priolo	Air Liquide Italia Produzione SRL
Priolo	Air Liquide Sicilia SpA
Priolo	Dow Poliuretani Italia SRL
Priolo	Enel Produzione SpA
Priolo	EniMed SpA
Priolo	ERG Nord
Priolo	ERG Sud
Augusta	ESSO Italia SpA
Priolo	GM Gas SRL
Augusta	Ionica SRL
Priolo	ISAB Energy SRL
Syracuse	ISPE2 SRL
Augusta	Maxcom Petroli SRL
Priolo	Polimeri Europa SpA
Priolo	Polimeri Europa SpA (Ethylene-Pipeline)
Augusta	Pravisani SpA
Augusta	Sasol
Priolo	Syndial SpA (formerly EniChem SpA)
Augusta	STELGAS SRL

Fig. 33. ESSO tank farm in Augusta: accident scenario for a pool fire



Note. The yellow circle and red ring indicate the low flammable limit and half the low flammable limit, respectively, of the accident scenario. The pale blue land area indicates the industrial area, while blue indicates the establishments included in the safety report.

Gela: major industrial establishments

Major hazardous processing plants subject to the Seveso directives in the Gela area (Fig. 34) include:

- Gela Refinery (including: Agip Gas SpA, Polimeri Europa SpA, Agri-Isaf, Syndial SpA (formerly EniChem SpA);
- Gela Gas SpA
- EniMed's new oil collection centre in Gela
- EniMed 3 oil collection centre.

Gela Refinery

With regard to the Gela Refinery, all the yellow curves (Fig. 35) were produced using the data available in the 2005 safety report for the whole Refinery. The representation (by damage curves) of flash fires of flammable substances (such as pesticides, methyl tertiary butyl ether, fuel oil, ethylbenzene, isobutanol and benzene), highly flammable substances (such as diesel fuel, high sulfur fuel oil, octane, cyclohexane, asphalt and crude oil) and liquefied petroleum gas gives limited external effects, such as glass breakage due to the shock wave, but does not show the damage to people except for possible reversible injuries from projectiles of various materials (Fig. 35). In the figure, the curves for both the possible irreversible effects on people (in brown) and possible reversible effects on people (in yellow) are within the industrial area.

It is worth noting that the safety report does not specify the substance potentially involved in an accident, but does specify the group of flammable substances listed in the files of the chemical substances treated by each plant. Large areas are affected by fires due to flammable substances, according to the data from the 2005 safety report for the whole Gela Refinery (Fig. 36). The first radius (in brown in Fig. 36) indicates the threshold of the LFL that causes lethal effects, and the second damage radius (in yellow in the figure) indicates the value of ½ LFL that causes irreversible injuries. These two values are established by law (Ministry of the Environment, 1996). The possibility of similar accidents is higher in the tank farm area of the establishment (including about 100 different tanks) where four curves intersect.

Fig. 34. Major establishments in Gela

Fig. 35. Flash fires of flammable and highly flammable substances and liquefied petroleum gas

Fig. 36. Fire of flammable substances

Different results are obtained when considering a flash fire of highly flammable substances (Fig. 37). In Fig. 37, the area within the first radius (in brown) indicates possible lethal effects (irradiation equal to or greater than 12.5 kW/m^2). The second radius indicates the area of possible irreversible injuries (irradiation equal to or greater than 7.0 kW/m^2, but less than 12.5 kW/m^2). All scenarios are hypothesized under D5 meteorological conditions. The first radius indicates the LFL value that causes lethal effects – for example, between 0 m and 8 m, between 0 m and 25 m, or between 0 m and 71 m (the latter distance includes and covers the former smaller curves that are obscured by the larger ones in the figure). The second damage radius indicates the value ½ LFL that represents the security zone – for example, between 8 m and 12 m, between 25 m to 39 m or between 71 m to 104 m (again, the latter distance includes and covers the other smaller curves that are obscured by the larger ones in the figure) – where there is a risk of reversible and lethal effects on people.

The risk of a flash fire of liquefied petroleum gas is present at four distinct refinery locations (Fig. 38). In the damage curves, the first radius indicates when the value of LFL that causes lethal effects is reached – for example, it could be between 0 m and 205 m (in two cases), between 0 m and 120 m, or between 0 m and 123 m. The second radius indicates when the value ½ LFL that represents the security zone is reached – for example, it could be between 205 m and 289 m (in two cases), between 120 m and 174 m or between 123 m and 167 m – where there is the risk of reversible and irreversible effects on people.

Modelling the dispersion of flammable substances provides damage curves (Fig. 39). In the damage curves, the first radius indicates the LFL value for which individuals can suffer lethal effects – for example, between 0 m and 59 m or between 0 m and 67 m. The second radius of the damage curves indicates the value ½ LFL that represents the security zone, where there is a risk of reversible and irreversible effects on people – for example, between 59 m and 91 m or between 67 m and 103 m. The concentric scenario curves shown in Fig. 39 are related to two tanks and their containment basins, within the tank farm area.

Fig. 37. Flash fire of highly flammable substances

Fig. 38. Flash fire of liquefied petroleum gas

Fig. 39. Dispersion of flammable substances

The most serious situation modelled is the one of possible toxicity due to the release of benzene, liquefied petroleum gas and ammonia (Fig. 40). Damage curves have to be interpreted, taking into account that the first radius indicates when the concentration value defined as that immediately dangerous to life and health is reached (in brown). This value indicates the maximum concentration of a toxic substance tolerable by a healthy individual for 30 minutes, without immediate or delayed permanent adverse health effects or ability to escape from it. The second radius of the damage curve (in yellow) indicates when the concentration values required to kill half the members of an exposed population are reached. A further analysis of the results shown in Fig. 40, considering also the real street network, adds more information about the seriousness of potential effects. This accident simulation shows serious effects to buildings and infrastructures when a layer with a vector (a detailed data structure that represents such geometrical primitives as points, lines, curves, and shapes or polygons) is used to describe the roads and buildings of the area (Fig. 40).

Gela gas

The last scenario modelled in the Gela area uses data from the safety report of a liquefied petroleum gas plant dedicated to bottling the gas and transferring it to tank trucks. In the accident modelled – a pool fire due to broken pipes – the scenario shows the possible involvement of the main road for 440 m (Fig. 41).

Other simulated accidents based on the safety report have more limited effects; apparently, they do not involve the resident population, although they involve the activities of other companies in the surrounding area.

EniMed's new oil collection centre in Gela

This firm has a depot for crude oil and is subject to Article 6 of the Seveso II Directive. No top event or accident is reported in the notification.

Fig. 40. Toxicity due to the release of benzene, liquefied petroleum gas and ammonia

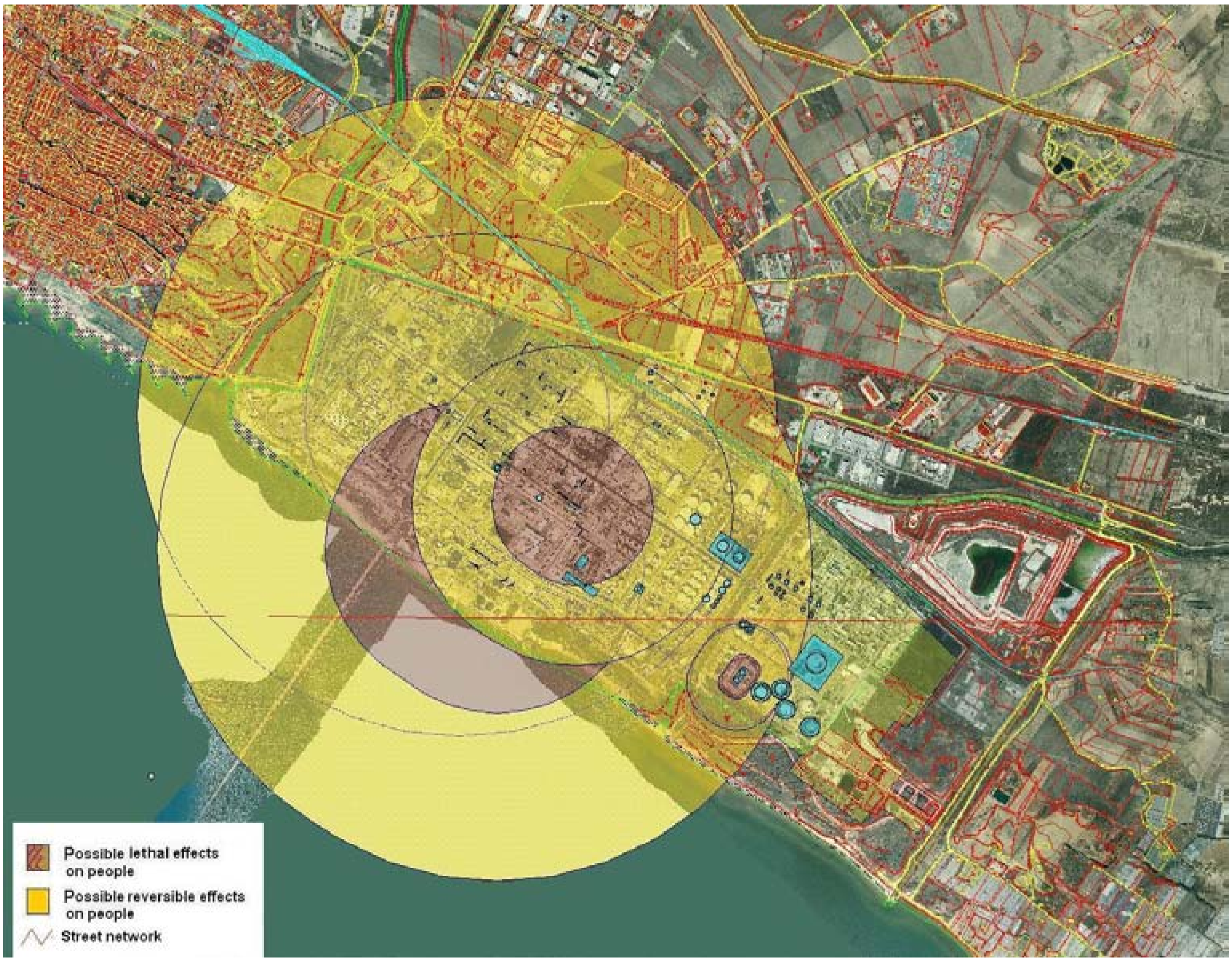
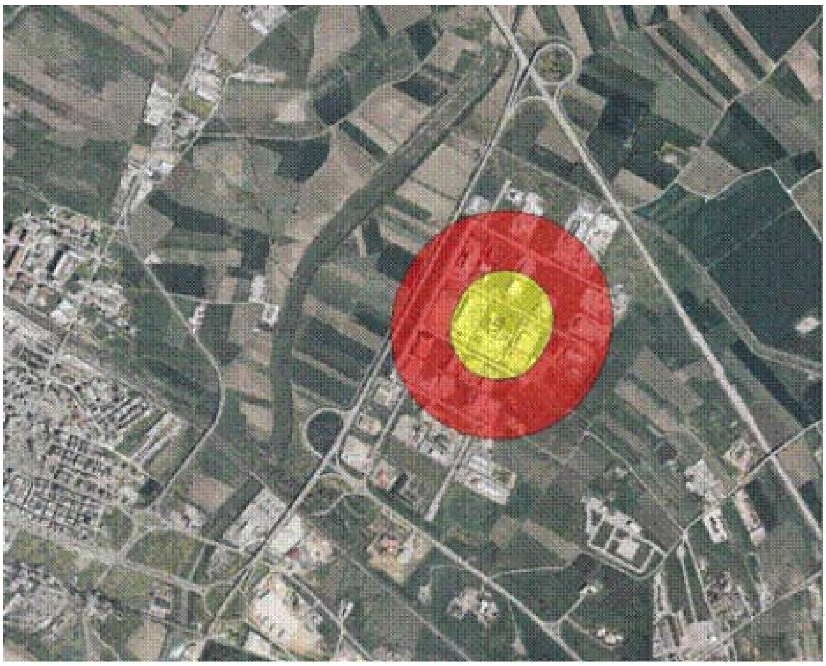


Fig. 41. Gela gas: pool fire due to broken pipes



Note. The yellow circle and red ring indicate the low flammable limit and half the low flammable limit, respectively, of the accident scenario.

EniMed 3 oil collection centre in Gela

This firm is engaged in the storage of natural gas. The establishment is subject to Article 5 of the Seveso II Directive, which means it has to present an information file to the competent authority. According to the information file provided by this industrial operator, a top event is possible – that is, a flash fire due to a fire in a containment basin. Radius damage curve modelling gives LFL = 130 m and ½ LFL = 180 m. The operator did not give the exact location of the tanks potentially involved in the flash-fire accident. Radius damage effects are not supposed to affect the population, but they can affect some units in the Gela Refinery (the plant and facilities for storage and for mobile storage of acrylonitrile).

Milazzo–Valle del Mela: major industrial establishments

In the Milazzo–Valle del Mela area, three establishments (Fig. 42) are subject to the Seveso directives:

- ESI SpA (treatment of exhausted batteries with dioxide and sulfate of lead)
- Milazzo Refinery (petroleum refining)
- Ultragas CM SpA (marketing of liquefied petroleum gas).

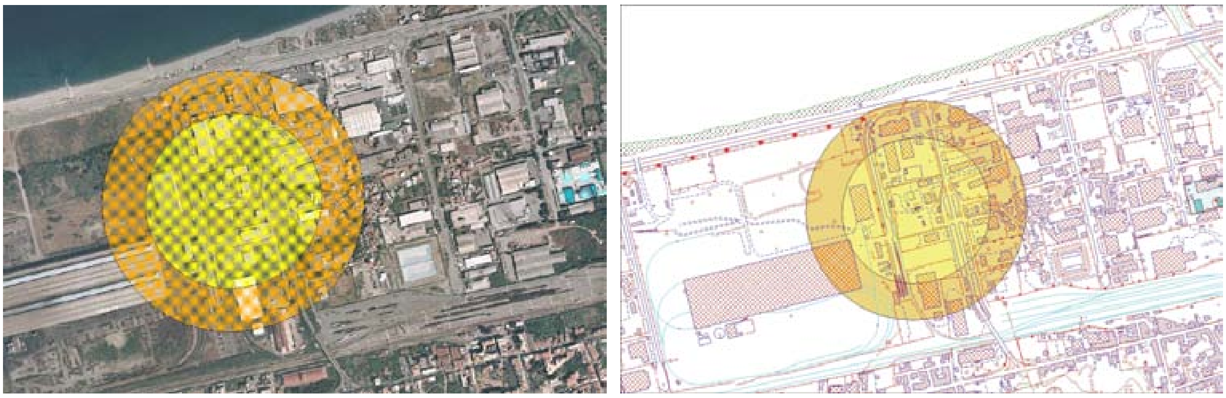
Fig. 42. Major establishments in the Milazzo–Valle del Mela area

Ultragas CM SpA: marketing of liquefied petroleum gas in Pace del Mela

An accident scenario for this establishment was modelled. Its output was a flash fire due to ignition of liquefied petroleum gas, with large radius curves of damage: ½ LFL = 306 m (orange); LFL = 202 m (yellow) (Fig. 43a and 43b). A further modelling of the results (shown in Fig. 43b) adds more information about the seriousness of potential effects. In particular, this accident simulation shows serious effects to buildings and infrastructures when a layer with a raster (a detailed data structure that represents a generally rectangular grid of pixels or coloured points) that represents houses and buildings in the surrounding neighborhood (particularly on the eastern part of the neighborhood of Contrada Gabbia) is added.

Fig. 43. Ultragas CM in Pace del Mela: accident scenario for flash fire of liquefied petroleum

(a) Accident scenario (b) Detail



Conclusions

The legislative framework for preventing and controlling major accidents (the so-called Seveso directives) is quite clear in providing instructions and guidance. Because of their potential effects on populations and infrastructures, accidents that have consequences outside industrial areas are relevant. The effects of industrial accidents are not limited to workers, and if they pose a threat to a large number of people epidemiological assessments are useful (Cullinan, 2002). Research findings indicate that populations exposed to industrial accidents may experience stress, which increases their vulnerability to psychological and physical harm (Cutchin et al., 2008).

To model major accident scenarios, data need to be collected from the industries and organized in a GIS, and then simulations need to be run. In Sicily, due to the lack of controlled safety reports, running scenario models is quite complicated (Gravagno & Messina, 2008). In comparison with real accidents, industry tends to underestimate the potential effects of their activities (see the section on “Chronology of major accidents in the three Sicilian petrochemical areas” in the Annex). In the case of the Augusta–Priolo and Milazzo–Valle del Mela areas, critical seismic activity and a tsunami hazard should be carefully considered among the existing factors of vulnerability, in 1908 an earthquake followed by a tsunami destroyed the city of Messina (APAT, 2004; Serva & Fumanti, 2012).

Rights, responsibilities and the reduction of accidents need to be combined to support serious sustainable development plans (Collins, 2009). Also, any peculiar social construction of living space in highly contaminated areas requires new geographic perspectives on health and environment (Wisner et al., 2004; Cutchin, 2007). In practice, more sophisticated approaches are needed, such as ecological risk assessments (Suter et al., 2000). Nevertheless, an overarching political perspective is needed and not just a reductive technical approach that considers only the individual elements of the problem. The famous and tragic cases of Seveso (WHO Regional Office for Europe, 1997), Bhopal (Broughton, 2005) and the Niger Delta (Watts, 2008) demand serious preventive action to avoid similar disasters in the future.

14. INDUSTRIAL POLLUTION IN A PETROCHEMICAL AREA AND THE IPPC DIRECTIVE: LIFE-CYCLE ASSESSMENT PERSPECTIVES

Wataru Machida, Pierpaolo Mudu and Gaetano Settimo

Introduction

The aim of this chapter is to consider the type of information that can be retrieved from public databases to evaluate industrial pollution. The chapter also illustrates the procedure for applying a site-specific inventory analysis and impact assessment that is compatible with life-cycle assessment methods. Site-specific inventory analysis allows a useful data catalogue of chemical flows from specific production process. Data on chemical flows are classified according to their potential impact on the environment or human health, in categories that relate to each type of impact. Such analytical tools, compatible with life-cycle assessment, allow an integrated approach that can characterize the parameters that define the environmental behaviour of a production system – for example, a refinery.

The procedure is applied to Gela, where a large petrochemical complex is subject to the IPPC Directive. The chapter will also consider the IPPC Directive and its methodological perspectives and implications. A site-specific inventory analysis and an air pollution model were run to show the possibilities and limits of public data available from the European Pollutant Emission Register (EPER) and other sources, such as air pollution monitoring stations.

Life-cycle assessment is defined by international standards (ISO, 2006a,b), and it allows both an assessment of direct impacts (such as emissions from industrial plants in the area) and indirect impacts (such as emissions occurring outside the area of production). This chapter considers only the direct impacts – thus being called, a site-specific inventory analysis and impact assessment, which is compatible with life-cycle assessment; such assessments of direct impacts are used to support strategic decisions and to adopt the best available techniques, as requested by the IPPC Directive (Machida et al., 2009).

This chapter will also raise some questions about integrated perspectives. In particular, it is important to consider integration as a way of moving from a segmented perspective to a more comprehensive one that includes multiple matrices (that is, water, air and soil), the production–emission chain of events and different space-time scales.

The IPPC Directive

Until very recently, the division of environmental regulations into water, air and soil, and also segmented administrative and monitoring procedures, prevented a global vision of environmental crisis and hindered the optimal capacity for intervention. To tackle these problems, the EU issued the IPPC Directive (EC, 1996c), adopted in Italy in 2005 (Ministry of the Environment and Territory, 2005). The European Directive was abrogated recently and recodified (EC, 2008a), by including all the previous amendments and introducing some linguistic changes. This chapter will refer to Directive 2008/1/EC (EC, 2008a) as the IPPC Directive.

Although different approaches to separately controlling emissions into air, water or soil may encourage the shifting of pollution between the various environmental matrices, these approaches do not protect the environment as a whole (EC, 2008a:8). The IPPC Directive, according to the principles regulating EU environmental policy, aims to prevent, reduce and, as far as possible, intervene directly at the source of pollution, in line with preventing pollution. The IPPC Directive is one of the EU's most ambitious legal measures and applies the pollution prevention principle to industrial activities (Barros et al., 2006).

The necessity to deal with highly complex systems of production and pollution has led to the consideration of more *integrated* approaches. The IPPC Directive mentions two important approaches to integration. The first, defined as *horizontal integration*, considers the combination of all relevant pollutants, all environmental matrices and all important environmental impacts. The Directive states "the objective of an integrated approach to pollution control is to prevent emissions into air, water or soil wherever this is practicable, taking into account waste management" (EC, 2008a:9, Item 9). The Directive also states: "emission limit values, parameters or equivalent technical measures should be based on the best available techniques" (EC, 2008a:9, Item 18), thus expressing the need to integrate production processes and emissions. Moreover, the Directive suggests an extended meaning for *emissions*, as emissions include the whole technological cycle: "the direct or indirect introduction, as a result of human activity, of substances, vibrations, heat or noise into the air, water or land" (EC, 2008a:11, Article 2.2).

The second integrated approach can be defined as *vertical integration*. The IPPC Directive has three core principles related to vertical integration, each of which corresponds to three stakeholders (industrial operators, the public and competent authorities) and to current knowledge: (a) best available techniques, (b) public participation and (c) flexibility (EC, 2008c).

The first aspect of current knowledge, best available techniques, is targeted at industrial operators. The permit conditions, including emission limit values, must be based on the best available techniques, as defined in the IPPC Directive. The best available techniques are of direct interest to industrial operators, as these techniques have a major impact on the production–emission chain of events. Best available techniques can be defined as the most effective measure in the development of an activity, providing the basis for emission limit values designed to prevent, eliminate or reduce an emission and its impact on the environment as a whole (Mirasgedis et al., 2008). Such techniques must comply with the planning instruments adopted in each individual territory (Ministry of the Environment and Territory, 2005).

The second aspect of current knowledge pertains to public participation. The "public has a right to participate in the decision-making process, and to be informed of its consequences, by having access to, (a) permit applications in order to give opinions, (b) permits, (c) results of the monitoring of releases and (d) the European Pollutant Emission Register (EPER)" (EC, 2008c). Thus, while the public's direct concern is health and other environmental impacts, it can also be involved in the control of the upper stream of the chain – that is, pollutant concentration, emission and production. Public action on pollution problems is linked to the possibility of participation. Also, it is linked not only to accessing data, but is also linked to the mobilization of authorities, experts and laboratories, among other stakeholders.

The third aspect of current knowledge, flexibility, is related to government activities. The IPPC Directive allows licensing authorities – that is, regional authorities – flexibility in determining permit conditions, "to take into account a) the technical characteristics of the installation, b) its geographical location and c) the local environmental conditions" (EC, 2008c). All these points are related to the possibility of accessing data and information. It is then critical to consider the data available.

The European and Italian pollutant emission registers

The two fundamental sources of information that support the IPPC Directive are the reference documents on the best available techniques (EIPPCB, 2011) for production processes and EPER for pollutant emissions. To support these sources of information, "An inventory of the principal emissions and sources responsible shall be published every three years" (EC, 2000b). As mandated by the IPPC, a national inventory of emissions and their sources – the INES – was set up in Italy. INES is a part of EPER, and both contain qualitative and quantitative information on pollutant emissions to air and water that originate in the main production sectors and large plants. The information currently available in EPER for Italy is for the years 2002 and 2004. INES is updated yearly, and in 2008 its information was available for the years 2002–2005.

EU regulation 166/2006 established an integrated and coherent European Pollutant Release and Transfer Register, in the form of a publicly accessible electronic database (E-PRTR, 2011). This regulation was proposed to fulfil the United Nations Economic Commission for Europe Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (UNECE, 1998),[22] to improve public access to environmental information and to create more effective public participation in environmental decision-making. In the future, the Pollutant Release and Transfer Register will replace EPER (EC, 2006b). The newer register builds on the same principles as EPER, but goes beyond it by including reporting on more pollutants, more activities, and pollution releases to land, from diffuse sources and off-site transfers of pollutants.

The road to an integrated approach: some questions

This chapter also focuses on the impact on air of pollution from a large refinery complex in Gela, starting with a site-specific inventory analysis, an impact assessment of the area and dispersion modelling of air pollutants. At the beginning of the investigation, we decided to take an integrated approach. In recent years, several proposals have addressed the issue of integration. A broad range of approaches can be used to pursue integration: theoretical discussion of the components to be integrated; definitions of different models and their inputs and outputs; and the construction of integrated software or an integrated device. The attempt to integrate the links to different effects generates a number of questions in need of answers. Such questions are fundamental to creating an integrated approach (Canter & Kamath, 1995). Some fundamental questions were translated into a checklist, taking into account the IPPC Directive (Table 90).

Table 90. List of general questions about integration in risk assessment

Spatial boundary
S1. Are proper geographical issues addressed? How is the area at risk identified?
Temporal boundary
T1. For which year(s) should data on production of pollutants be gathered?
T2. Are historical stocks, as well as yearly production of pollutants in different matrices, considered?
Vertical integration
V1. Is the mechanism that links production, technology and emission clearly understood?
V2. Is the relationship between emissions and pollutant concentrations in different matrices clearly established?
V3. Is the relationship between exposure of targets at risk and pollutant concentrations clarified?
V4. Does the exposure fully explain the damage to targets — for example, adverse effects on health?
Horizontal integration
H1. Are all emission locations — that is, point sources and non-point sources — considered?
H2. Are all pollutant emissions covered?
H3. Are all the pathways through different matrices examined?
H4. Are all risks to each target (such as people and agricultural fields) considered?
H5. Are the locations, pollutants, pathways and targets at risk considered simultaneously?
H6. Are important synergetic or antagonistic reactions taken into account?

The questions in S1 are part of a well-known problem that, if not tackled, can produce ambiguous results – for example, when considering the modifiable areal unit problem, a concept in GISs and a source of

22 The Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention) (UNECE, 1998) was adopted at the Fourth Ministerial Conference "Environment for Europe" in Aarhus, Denmark, on 25 June 1998. Thirty-nine countries and the European Community have ratified it.

statistical bias that can radically affect the results of tests of statistical hypotheses. When considering the time lag between the cause and effect of many diseases, the temporal sequence of data available is relevant. Both space and time scales have to be considered as intertwined, and a potential solution to the modifiable areal unit problem would be to clarify both scale choice and scale effects – that is, the extent the results can be manipulated, according to the size of the area studied in relation to the assessment of the cumulative effects (Karstens, Bots & Slinger, 2007).

To complete the categorization of the issue of integration, we also considered vertical and horizontal integration. Each connection in the whole chain of events, from production to impacts, needs to be vertically integrated. In each stage, all the emission sources, pollutants emitted, pathways through matrices, and targets at risk must be systematically treated and horizontally integrated. It is worth noting that life-cycle assessment is primarily designed to analyse networks of production activities, rather than analysing the environmental risk of the particular space and time in which such activities take place. Space and time themselves, however, are the main parameters to be considered in the decisions based on the IPPC Directive.

One way to integrate different methods is to use a GIS. Through the use of a GIS, integration of risk assessment and spatial planning can improve the efficiency of managing contaminated land (Bień et al., 2004). Evaluating the risks associated with existing industrial activities involves either importing and exporting data files produced by existing stand-alone computer tools or an application that integrates the risk analysis tools with the general-use GIS program (Hellweger et al., 2002).

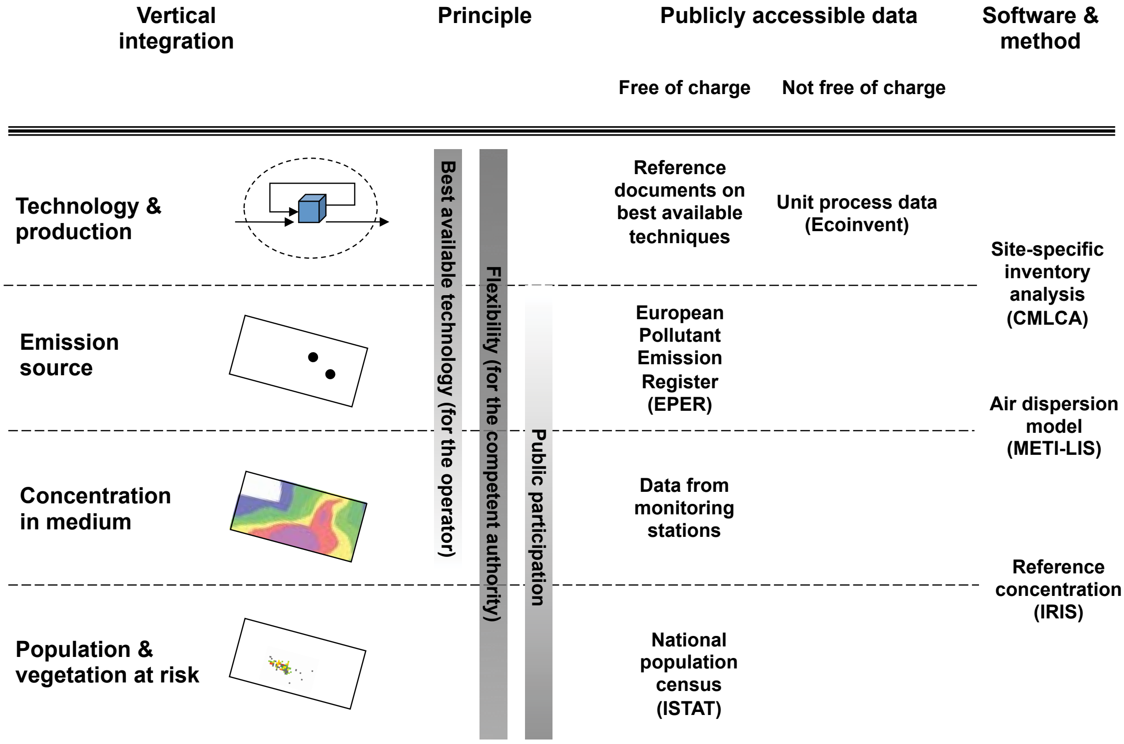
Available public data: IPPC and methods

The IPPC Directive takes into account the positions of three types of stakeholder: the industrial operator, the competent authority and the public. Although this is a very simplified triangular vision, we can use it as a starting point, by assuming the perspective of the general public. It is worth noting that this public perspective must be followed by definite set of actions and decisions, which involves the choice of expertise needed to assess complex phenomena such as industrial contamination.

Based on a real case study, another question that needs to be addressed immediately emerges: to what extent can the public have access, comprehend and utilize the data in an integrated manner to participate in the decision-making process and be informed of the consequences of different decisions? To answer the question of public access and integration of different information, the data and software – that is, operational methods – have to be selected, following precise criteria: (a) all the data to be used are publicly accessible; (b) preferably, public data free of charge are used; (c) among public data, web-accessible data that do not need to be requested are used, rather than data that require a formal written request; and (d) all the software to be used should be free of charge for public use. In the case study, three types of software and methods were selected, and five data sets were used (Fig. 44).

Scientific software for life-cycle assessment – Chain Management by Life Cycle Assessment (CMLCA, version 4.2), developed by the Institute of Environmental Sciences (CML), Leiden University – was chosen (free of charge for non-commercial use only). This software allows consideration of the consistency between production data and emission data. Although life-cycle assessment normally analyses all the processes (from cradle to grave), in our case only the processes and emissions occurring in the area (the direct impacts) were considered – that is, we used a site-specific inventory analysis and impact assessment. This is because of the need to simplify spatial and temporal variety in each area, in which case life-cycle assessment can only provide rough estimates that, in turn, provide suggestions on pollution patterns useful for risk assessment.

Fig. 44. Data and software that the public can use for IPPC methodologies



Quantitative data on industrial processes are needed to fill the gap between production and emission and to run a site-specific inventory analysis. In the IPPC Directive, the public is supposed to have access to permit applications, to voice its opinions (EC, 2008a:10, Item 27). Although the reference documents on the best available techniques contain rich information on technology, it is difficult to link production data and emission data, in quantitative terms, for a specific site. To solve this problem, the Ecoinvent database (version 1.2), which contains up-to-date and consistent life-cycle inventories for about 4000 industrial processes, was used to assess the quantitative relationship between production and emission. For a site-specific inventory analysis, only part of the life-cycle assessment database – the unit process data on the site – is used to run the model.

In the IPPC Directive, certain industrial plants must report their pollutant emissions in air and water to EPER, which is publicly accessible. The emission data calculated by the site-specific inventory analysis, based on the processes and outputs of products, can be compared with the emission data reported to EPER. Through this comparison, whether the two data sets are consistent and whether introducing better techniques in a certain process contribute to reducing emissions can be investigated.

To identify which pollutants are of relevance, the EC's Environment Directorate-General refers to Annex III of Directive 96/61/EC (EC, 1996c), to EPER (INES in Italy) and to the already available reference documents on the best available techniques. At the European level, the reference documents are: *Integrated pollution prevention and control: reference document on the best available techniques for mineral oil and gas refineries* (EC, 2003a) and the Italian equivalent of the reference documents on the best available techniques (Ministry of the Environment, Land and Sea, 2007). Based on the EC's Environment Directorate-General position and suggestions about priority contaminants (see Chapter 6), we made a first selection of pollutants linked to the technological cycle operating in Gela (see Table 91).

Table 91. Pollutants originating in oil refineries selected for analysis

Type of pollutant	Substances or properties
Air pollutants	Particulate matter, PM_{10}, carbon monoxide, nitrogen oxides, sulfur oxides, polychlorinated dibenzo-*p*-dioxins and dibenzofurans, metals (copper, lead, arsenic, nickel, cadmium, zinc, chromium, mercury and tin) and their compounds, hydrogen sulfide, ammonia, volatile organic compounds, benzene
Water pollutants	Suspended particles, chemical oxygen demand, biochemical oxygen demand, total organic carbon, total nitrogen, total phosphorus, metals and their compounds, hydrocarbons, phenol, benzene, cyanide, sulfur, methyl tertiary butyl ether

We chose the METI-LIS program (version 2.03, free of charge to the public) air dispersion model.[23] The emission data from EPER, together with meteorological and topographical elevation data and data on the heights of chimneys, are entered into the METI-LIS program, resulting in dispersion data on the ambient air. The modelled dispersion results can be compared with the measured concentration data from monitoring stations. Furthermore, dispersion maps can be layered with population data from the national census, which allows identification of where and which population is affected by particular concentrations. The reference concentration method in the United States Environmental Protection Agency's Integrated Risk Information System (IRIS) can be useful for this.

By using free software and established methods, it should be possible to identify the impact of a large industrial complex and to make proposals for managing its emissions, such as the emission types to be reduced, chimney height, location and timing of emissions.

The case of Gela

As of 31 December 2006, according to the population registers, Gela had 77 311 inhabitants, making it the sixth largest population in Sicily – after Palermo, Catania, Messina, Syracuse and Marsala. The high-risk Gela area includes a large urban centre and industrial area and extensive agricultural land use. The charge capacity (the input or feed capacity of the refinery processing facilities) of the Gela Refinery is the eighth largest in Italy. The Gela Refinery was built in 1960, and in 1962 the Refinery started its activities – refining 3 million tonnes of oil a year. Currently, it transforms more than 5 million tonnes of oil a year, more than 20% made up of local oil. The industrial area covers about 5 km^2. In 2001, Gela and the municipalities of Butera and Niscemi were recognized by the Italian state as a *high-risk environmental area*, which implies the local government has a mandate to start remediation of polluted zones and rehabilitating the territory (President of the Council of Ministers, 1990; Ministry of the Environment and Territory, 2000a).

Gela has a system of six monitoring stations, managed by the Province of Caltanissetta. The stations record hourly the concentrations of sulfur dioxide in air, originating partly from the petrochemical plants (see Chapter 7). Data from five stations were analysed. The stations are classified in three cases as *urban* and in one case each as *rural* and *industrial*. High concentrations of nickel, vanadium and, to some extent, barium and chromium in road dust were associated with emissions from the petrochemical plant (Manno, Varrica & Dongarrà, 2006). Another study on the chemical composition of airborne particulate matter over the city of Gela found that the petrochemical plant appears to be associated with raised levels of arsenic, molybdenum, nickel, sulfur, selenium, vanadium, and zinc (Bosco, Varrica & Dongarrà, 2005).

In soil, threshold limit values were exceeded for some carcinogenic pollutants: heavy metals (such as arsenic, nickel, chromium, cadmium, vanadium and mercury), hydrocarbons, (benzene, toluene, ethylbenzene and xylene), chlorinated derivatives of aliphatic compounds, halogen derivatives of aliphatic compounds and polycyclic aromatic hydrocarbons (Paris, 2007). Also, threshold limit values were exceeded for heavy metals, polycyclic aromatic hydrocarbons, methyl tertiary butyl ether, chlorinated derivatives of aliphatic compounds, and benzene, toluene, ethylbenzene, xylene in the water table (see Chapter 6). In the

23 METI-LIS was developed by the Ministry of Economy, Trade and Industry of Japan, based on the EPA's ISC model, with improved parameterization after new experiments, including basic GIS. This software and its manuals are provided in English as well as in Japanese.

water table, the registered concentration value of arsenic was 70 000 µg/l, in contrast to a threshold value of 10 µg/l, and concentrations of mercury reached 6600 µg/l, in contrast to a threshold value of 1 µg/l (Paris, 2007).

In following the IPPC Directive, the main objective of the Gela case study was to examine what was feasible with public data. In particular, the aims of this case study were to: (a) run a site-specific inventory analysis and impact assessment; (b) run dispersion models; and (c) provide information on the likely impacts of the industry.

To estimate the degree to which these objectives were achieved – going back to the checklist presented in Table 90 – we investigated how this could be fulfilled by using the criteria introduced (in the previous section) for the question about public access and integration of different information. The investigation followed three steps: (a) addressing the general questions about integration in risk assessment, summarized in Table 90; (b) performing a site-specific inventory analysis and impact assessment for the Gela Refinery; and (c) selecting the pollutants to be compared.

First, the questions in the checklist were answered (Table 92). We decided to work with the emission data that corresponded to the petrochemical activity in the main industrial area. The data available covered the period 2002–2005. We considered emissions and concentrations in the air. Emissions that entered water were also registered in EPER, but not considered to select pollutants, since not enough data were available to run the water dispersion model, to calculate concentration. Data on the chemical characterization of soil were not considered, because they were not available at the time of the study and because only results from non-systematic investigations were available.

Table 92. Checklist for the IPPC Directive, applied to the case of Gela

Spatial boundary
S1. Among the areas with industrial activities in Gela, the site managed by Eni was chosen (other industrial sites in Gela were not relevant). The Eni industrial area is clearly delimited by a natural park, a highway, a river and the sea.
Temporal boundary
T1. The data available for 2002–2005 were chosen, with emissions from previous years not included.
T2. Historical stocks of pollutants in the environment were not available.
Vertical integration
V1. In the case of Gela, only the production output of crude oil was available, without the input of all chemical substances and compounds industrially processed. Ecoinvent's process data were supplemented to analyse the sequence of production emissions.
V2. The METI-LIS dispersion model was used to relate emissions and concentrations in air – but not in water or soil.
V3. The location of the population was identified. Rough exposure to air pollution was possible. Exposure through water, soil or food was difficult to assess with the data available.
V4. Only the risk of cancer from inhalation exposure, E-6 in IRIS (1 in 1 million lifetime excess cancer risk following exposure), was considered, to evaluate the result of the air dispersion model. In assessing the impact by CMLCA software, a broadly defined health effect, human toxicity potentials, was used.
Horizontal integration
H1. Two sites of point sources were registered in EPER. A linear source (such as road traffic) was not considered.
H2. In the site-specific inventory analysis, the entire emission of pollutants could be covered sufficiently. From the CMLCA software, we had 50 pollutants (some, such as vanadium, were missing). In air pollution monitoring, only select pollutants were measured, such as sulfur and nitrogen oxides. In the reference concentration method in IRIS, not all the important pollutants had reference values.
H3. The pathway through air was examined, but not the pathways through water and soil.
H4. Only the risk to the general population was considered, not that to agricultural fields, fish and other organisms.
H5. Two locations (nearby sites registered in EPER), 13 pollutants in air and the general population were considered simultaneously.
H6. Synergetic or antagonistic reactions were not taken into account.

Although the investigation faced several limitations, the results were nonetheless rewarding.

Emission data quality issues

A site-specific inventory analysis and impact assessment, focusing on direct emissions in the area, was carried out for the Gela Refinery. These investigations used CMLCA software and used the part of the unit process database of Ecoinvent (2005) relevant to the site. To help define the level of the final output of production, highly aggregated data (such as the aggregated amounts of benzene, gasoline and liquid petroleum gas produced) specific to the Gela Refinery were available (Eni Division of Refining & Marketing, 2007). Thus, it was assumed that 13 different petrochemical products were produced in equal proportions – that is, bitumen, two kinds of diesel fuel, heavy fuel oil, kerosene, light fuel oil, two kinds of naphtha, two kinds of petrol, petroleum-coke, propane and/or butane, and refinery gas – with 7.7% for each product. The Refinery's own process data, needed to run the model, were not publicly available; thus it was assumed that the processes were the same as those in the Ecoinvent database, where 137 petrochemical processes were assumed to take place in Gela. The emissions from the Gela Refinery area only were called direct emissions. Of the more than 2000 types of environmental emissions in the Ecoinvent database, 142 were relevant to this analysis for Gela. Also, EPER covered 50 pollutants that needed to be reported, among which, 23 were actually reported by the Gela Refinery. However, even when the substance of the emission was the same, emissions into air, water and soil were considered as different emissions.

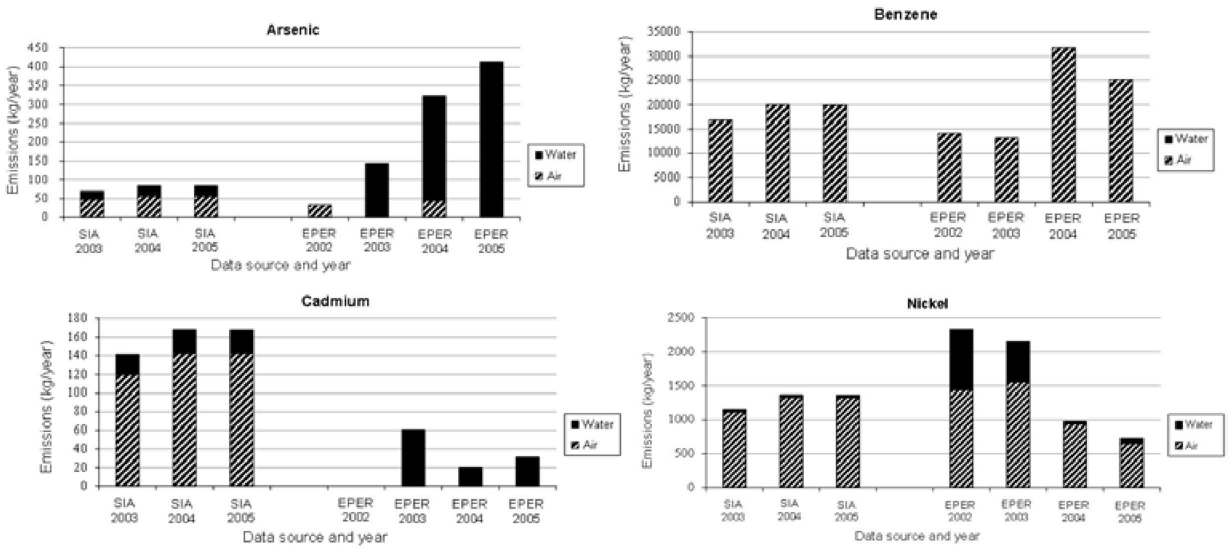
Thirteen pollutants (carbon dioxide, nitrogen oxides, sulfur oxides, benzene, phenol, arsenic, cadmium, chromium, copper, mercury, nickel, zinc and vanadium) were chosen for comparing the calculated emissions by the site-specific inventory analysis with EPER's registered emissions. Among these 13 pollutants, only vanadium was not included in the 50 pollutants to be registered in EPER, though according to the results of the site-specific impact assessment, vanadium was also important and should have been considered, in particular, for its toxic effects on people. Also, metals were particularly relevant, because they are adsorbed on particulate matter, $PM_{2.5}$ and PM_{10}. It should be noted that EPER emissions were registered only if they exceeded certain threshold values, while all the emissions were used in the inventory analysis, regardless of the threshold.

The comparison of emission data calculated (by a site-specific inventory analysis) and reported (to EPER) for four important pollutants (well-known carcinogenic agents with no threshold value without effects on human health) – that is, cadmium, arsenic, nickel compounds and benzene – is shown in Fig. 45. These pollutants are subject to specific regulation by the EU (EC, 2004a; 2008c). The results from the site-specific inventory analysis and the EPER registered emission data appear inconsistent. Two points about this inconsistency need to be considered.

First, before comparing the calculated and reported data, the data from EPER have to be analysed critically; the rather large fluctuation of the data registered has to be explained, since the Refinery's production was relatively stable (which is why the results of the inventory analysis are more stable), although abatement technologies might have changed. Assuming no large technological change, it is very difficult to explain the following trends: the arsenic emissions reported increased rapidly; benzene emissions fluctuated; nickel emissions decreased; and cadmium emissions in air disappeared. Although beyond the scope of the current investigation, these trends deserve more careful control and investigation.

Second, a comparison of the calculated and reported emission data shows that it would be better if production and process data were publicly available in more quantitative detail. The inventory analysis run in this case is an example of what can be developed from the public data, but it is not possible to judge whether the registered or calculated data are wrong or if they are both wrong. In the current EPER reporting system, only emission data are registered. However, if data on production, data on the processes used and information about each change in abatement technologies were also publicly registered, it would be possible for *third parties* to perform the analysis, to check the consistency between production and emission; if this were so, eventually the type of inconsistency found might be understood, as well as the fluctuation in the registered data.

Fig. 45. Comparison of calculated and reported emission data (kg/year)

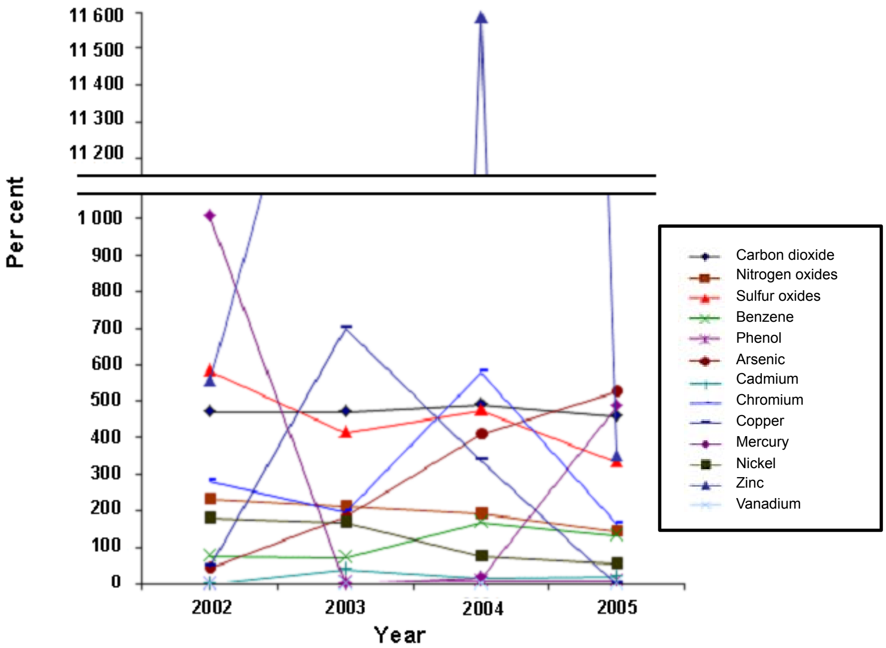


SIA – site-specific inventory analysis – represents the calculated data; EPER represents the reported data.
Note. A site-specific inventory analysis for 2002 was not performed, because no data were available on production output for that year. Also, in the notation used to represent exponential numbers, the letter E represents times ten raised to the power of, replacing × 10, followed by the value of the exponent. The character E is not related to the mathematical constant e or the exponential function e^x.

It is very difficult for authorities to determine limit values for emissions without officially obtaining data for each process and for the production of each specific industrial operator and without understanding the degree of cause and effect between process, production and emissions – since emission limit values should be based on best available techniques, according to the IPPC Directive.

Fig. 46 depicts emissions (aggregated for those in air and water). If EPER's registered data were stable, the yearly ups and downs of each line should be diminished (or explained by a change in technology). Meanwhile, if inventory analysis data and emission data reported to EPER were consistent, each line should approach 100%, because the average value of the analysis (for 2003–2005) is set at 100%. In Fig. 46, neither of these postulated occurrences is observed.

Fig. 46. EPER's yearly fluctuation and the scale difference from the calculated data, for each pollutant



Note. The scale difference from the data of the site-specific inventory analysis is 100%.

Emission, dispersion and monitored concentration data

We ran a dispersion model, METI-LIS, to calculate concentrations of pollutants in ambient air for emission data from EPER and the inventory analysis. The heights of chimneys vary in the Gela Refinery – for example, 10 m, 15 m, 20 m, 30 m, 90 m, and a maximum height of 130 m – and the data available from INES did not show the amount of a particular pollutant emitted from the different chimneys. For this reason, two cases were assumed in the dispersion model – that is, all the emissions are from a chimney with a (a) height of 30 m and (b) height of 130 m. Data on when the refinery operated was not obtained; thus, 24-hour operation was assumed – that is, the total production is equally distributed in time. This assumption could lead to an underestimate or overestimate. For example, if peaks in emissions occur at night with stable atmospheric conditions, night-time pollution could be underestimated and daytime pollution overestimated. Also, Gela faces the sea, with the wind blowing in opposite directions during the daytime and night-time (from south-west to north-east during the day and vice versa during the night). Thus, the more they blow during daytime, the more the region north-east of the refinery is affected by emissions. For meteorological data – that is, wind direction and strength, solar radiation and temperature for 24 hours of 365 days – the monitoring station data for 2004 in Gela was used as input to the dispersion model for all calculations. The elevation data of the area was also used as input.

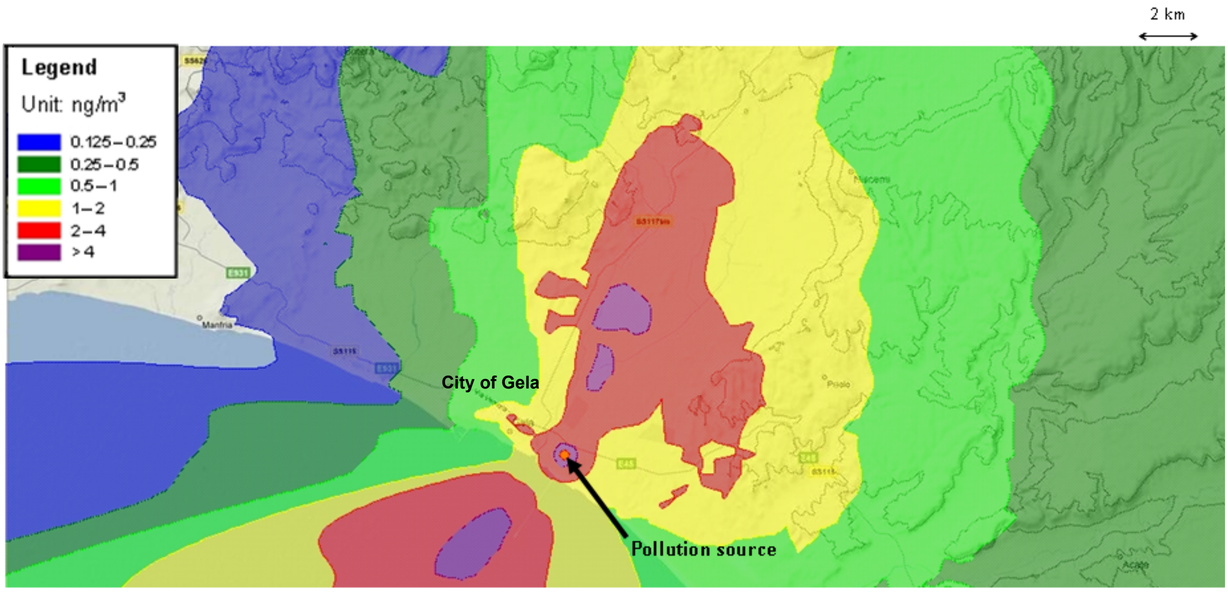
Among the 13 pollutants targeted, the air emission levels for 12 of them (no phenol emissions in air) from the Gela Refinery were selected. For the air emissions of two pollutants, vanadium and cadmium, no data are reported in EPER; thus, the results of the inventory analysis (maximum value from 2004 data) were used. For the other 10 emissions, the maximum values reported in EPER (and in the Declaration of Emissions, which is a national reporting system that corresponds to EPER) in 2002–2005 were chosen. The choice of the maximum value ensures an evaluation of the worst possible conditions. In the Gela area, there is another site (Polimeri Europa SpA) registered in EPER, which emits benzene and nitrogen oxides to the air. These emissions were added to those of the Gela Refinery. These two sites are close to each other; thus, when running the dispersion model, it was assumed that they are in the same location.

In life-cycle assessments, hundreds of pollutants are often considered, but 50 pollutants are registered in EPER, and the air quality monitoring system in Gela covers a limited number of pollutants – that is, sulfur dioxide , nitrogen dioxide, carbon monoxide, ozone, non-methane hydrocarbons, PM_{10} and benzene. In such a situation, the inventory analysis and the air dispersion model can calculate the concentration of vanadium in air, even though this pollutant is not registered in EPER and is not monitored in Gela (Fig. 47).

The simulation results showed that the areas especially affected appear to be the agricultural lands to the north-east of Gela. This, if confirmed by environmental monitoring controls, implies an increase in the concentrations of vanadium in the air and its potential increase in the soil, with a likely influence on the food-chain. Vanadium affects the food-chain by contaminating a variety of foods, with relatively low efficiency, but in sufficient quantities to be absorbed at detectable levels in many body tissues (Bharti et al., 1990). Vanadium is also released during oil combustion in electric power generation. Moreover, it is introduced into the environment during the extraction of petrochemical products and the production of steel and insecticides (Colina et al., 2005).

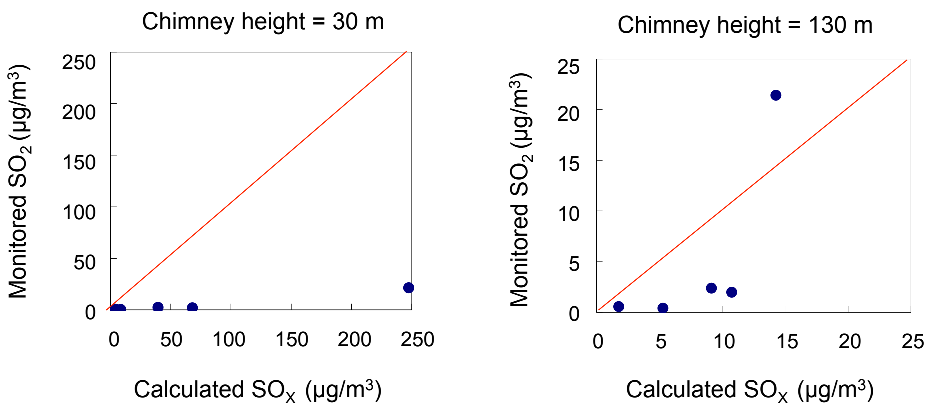
Data on sulfur dioxide concentrations recorded by monitoring stations were compared with those for sulfur oxides (sulfur dioxide and sulfites) calculated by the METI-LIS dispersion model. Sulfur dioxide is monitored in stations managed by the provincial authority. The comparisons are based on two assumptions: all emissions of sulfur oxides are from chimneys (a) 30 m in height and (b) 130 m in height (Fig. 48). Calculations based on the latter assumption provide slightly more consistent results between monitored and calculated data. When monitored and modelled data are perfectly correlated, all the points should lie on the diagonal lines (Fig. 48). This is not the case.

Fig. 47. Concentration of vanadium in the air calculated from the inventory analysis and the METI-LIS air dispersion model



Note. The chimney height is assumed to be 130 m.

Fig. 48. Concentration of sulfur oxides and sulfur dioxide) monitored by five stations and calculated by the METI-LIS air dispersion model

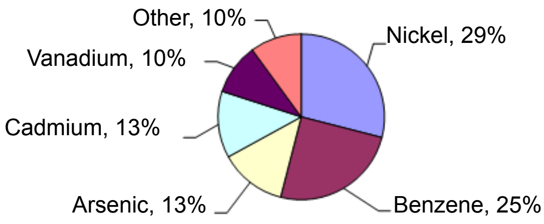


Note. SO_x (sulfur oxides) include sulfur dioxide (SO_2) and sulfites.

Risk to people

The procedures of life-cycle assessment can provide inventory analysis and also input for interesting impact assessment exercises – for example, on assessing human toxicity linked to inhaling air pollution. To calculate human toxicity from emission inventory data, the linear coefficient of human toxicity potential (HTP_{inf}) (Huijbregts et al., 2000a,b), adopted by CMLCA software, was used (for further details, see Guinée, 2002). The results of the impact assessment (see Fig. 49) suggest that five air emissions – nickel, benzene, arsenic, cadmium and vanadium – are the largest potential contributors to human toxicity, and they are all carcinogens. Other air emissions include 57 pollutants, among them, for example, are selenium, hexavalent chromium, cobalt, copper, hydrogen fluoride and nitric oxide (see Fig. 49).

Fig. 49. Contributions of emissions in air from the refinery to human toxicity



With regard to non-carcinogenic pollutants, air quality guidelines indicate the level of air pollutant concentrations, associated with time of exposure, that do not have adverse effects on health (WHO Regional Office for Europe, 2006). For carcinogenic pollutants, we can use the unit risk. The incremental unit risk estimate for an air pollutant or for a pollutant in drinking-water is defined as the additional lifetime risk of cancer that occurs in a hypothetical population in which all individuals are exposed continuously from birth throughout their lifetime to a concentration of 1 μg/m^3 of the agent in the air they breathe or to 1 μg/l in water (WHO Regional Office for Europe, 2006)[24]. The results of calculations expressed in unit risk estimates provide the opportunity to compare the carcinogenic potency of different compounds and can help set priorities in pollution control, taking into account current levels of exposure (WHO Regional Office for Europe, 2000). IRIS is available on the Internet (EPA, 2011), to determine the concentration thresholds for toxic effects. For arsenic, benzene, cadmium and nickel, the IRIS reference dose and quantitative estimate of carcinogenic risk from inhalation exposure E-6 was selected.

Arsenic, benzene, cadmium and nickel were the four pollutants with the greatest impact, calculated using data from the inventory analysis (Fig. 50). The area in the figure in purple denotes the concentration is above the threshold of E-6. If all the emissions are from lower chimneys, 30 m in height, the concentrations of these pollutants in the city of Gela approach these thresholds, according to the results of this dispersion model (Fig. 50). In these maps, densely populated areas (Gela, Niscemi and Manfria) are in black.

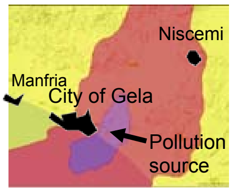
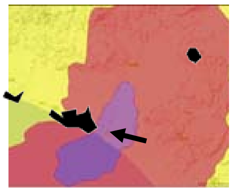
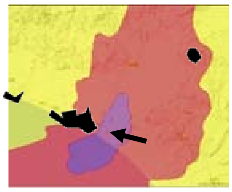
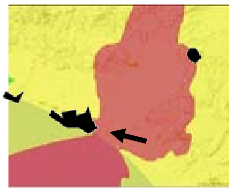
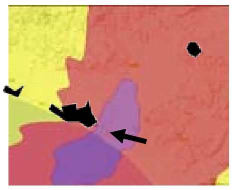
Discussion

The case study in Gela clarified three main points related to the IPPC Directive: (a) access and use of public data; (b) the possible inconsistency of public environmental data; and (c) specific area problems with air pollution and contamination surveillance, in general.

The political participation of the general public is essential to arranging information for decision-making. This information, however, is developed by (and is available from) various professions that have little experience in integrating it. One of the main challenges to integrating different types of information is to create a framework that brings together diverse inputs, to appraise the effects of industrial contamination on health. Region-wide ecological risk assessment assumes that multiple stressors have a spatially explicit effect on multiple end-points (Landis, 2006). The general public can participate in political decision-making only if a coordinated approach promotes the provision and circulation of reliable information, thus allowing knowledge-based decisions. The democratization process can be improved only by the transparent production and collection of data and free access to them. This is a fundamental prerequisite for such an improvement (UNECE, 1998).

24 The interpretation of unit risk for a substance in drinking-water is as follows: if unit risk = 2 × 10-6 per μg/l, 2 excess cancer cases (upper bound estimate) are expected to develop per million people if exposed daily for a lifetime to 1 μg of the substance in 1 litre of drinking water (EPA, 2011).

Fig. 50. Concentrations of arsenic, benzene, cadmium and nickel, calculated by the METI-LIS air dispersion model

Substance	Reference dose threshold (µg / m³) (1 in 1 000 000)	Legend (µg / m³)	Chimney height = 30 m	Chimney height = 130 m
Arsenic	>0.0002	0.000002 - 0.00002 0.00002 - 0.0002 > 0.0002		
Benzene	>0.13	0.0013 - 0.013 0.013 - 0.13 > 0.13		
Cadmium	>0.0006	0.000006 - 0.00006 0.00006 - 0.0006 > 0.0006		
Nickel	>0.004	0.00004 - 0.0004 0.0004 - 0.004 > 0.004		

We stressed that the IPPC Directive takes two important approaches to integration: vertical and horizontal. Vertical integration is important to integrate actors and principles, different fields of work, production, emission, monitoring and impact data and to determine proper emission limit values. While looking at horizontal and vertical integration, several inconsistencies and missing data problems were discovered. In particular, the results from the site-specific inventory analysis and EPER emission data appear to be generally inconsistent. This inconsistency is related to particular pollutants, such as carbon dioxide, sulfur oxides and zinc, while benzene and nickel are correlated.

It is not possible, by only looking at the data, to discover the factors that contribute most to the inconsistency among data, but it is an important first step to clarify these inconsistencies among data sources. When the data are inconsistent, the following four questions need to be addressed.

1. Does the production of data present problems, such as errors in measurement or sampling?
2. Do monitoring plans and methods describe the situation properly?
3. Who certifies the reliability and validity of the data and how?
4. Do the actors who produce data have incentives to distort them?

The first question is usually linked to employing data with few controls in checking them. The second question, however, deserves some consideration. The elaboration of the results of the site-specific impact assessment provided some indications about critical aspects that have to be considered. For example, the concentration levels of vanadium should be monitored with an environmental surveillance plan – say, for emissions, air and soil. Also, the monitoring system is inadequate for some pollutants – for example, the concentration of benzene in air is monitored hourly in only one station in Gela. Moreover, Gela lacks an environmental surveillance plan, including biological monitoring for food, such as milk and fish. Furthermore, there is no plan for monitoring persistent organic pollutants.

The third and fourth questions are linked. The last question, however, requires further discussion. When an authority checks emissions from chimneys, industrial operators may be motivated to manipulate the emissions they declare. Unlike other industries, the plants that make up a refinery have no specific authorized emissions limits, but the group of plants have to respect an overall limit called a *bubble*, which means they have to consider the refinery as a whole and to sum up concentrations and volumes of all the emission sources. Using the site-specific inventory analysis to compare registered and directly measured emissions (and to tackle this problem) would reduce such incentives to distort data. Moreover, even when the registered data is incorrect – and those measured by the authorities do not reflect the distortion of regular emission activity – using the dispersion model to compare the calculated concentration of pollutants in environmental matrices with directly measured concentration values from monitoring stations demands greater consistency in data, which would further reduce the incentive to distort such data.

The case study in Gela also offers some suggestions for further research. We organized a checklist of basic questions on integration in risk assessment. This checklist – in particular, the items not sufficiently answered (Table 92) – represents the future direction for making more contributions to the IPPC Directive. This includes the following suggestions.

- Quantitative process data specific to Gela should be investigated further. So far, the Ecoinvent database is available, but more geographically and technologically specific data should be produced and made available. Also, the IPPC Directive has a mechanism of exchange of information (EC, 2008a: Article 17). Moreover, the reference documents on the best available techniques have fostered an exchange of information among sites, though there is not enough quantitative information to run a site-specific inventory analysis.
- The methods to be used for analysing water and soil need to be specified. Although dispersion models for water and soil exist, they demand more data. So, the balance between the data available and the models needs to be clarified.
- The stocks of pollutants in different environmental matrices and targets at risk have to be considered, especially in the case of Gela. The data on past emissions and the quality of air, water and soil are scarce; thus, we have to rely on the accumulation of pollutants at present to analyse the cause–effect chain of events, even for the activity of a particular industrial operator in the past.
- EPER's data on registered emissions are limited. For example, vanadium is not included in the 50 pollutants to be registered, though according to our simulation of impact assessment vanadium is relevant and should be considered, in particular, for its toxic effects on people.
- Future complementary work should envisage the possibility of substance flow analysis – a method of quantifying flows and stocks of materials or substances in a well-defined system. Such analysis will help to further identify the main environmental impacts and the most polluting stages in the production processes that generate persistent and/or bioaccumulative pollutants, such as polychlorinated dibenzo-*p*-dioxins and dibenzofurans, dioxin-like polychlorinated biphenyls, polycyclic aromatic hydrocarbons and persistent organic pollutants.

Conclusions

The aim of this chapter was to obtain an initial impression of the environmental impact associated with the presence of a large refinery in Gela, using a site-specific inventory analysis and impact assessment that focuses on direct emissions from the high-risk area. Such analytical tools, compatible with life-cycle assessment, allow an integrated approach that can characterize the parameters that define the environmental behaviour of a production system, for example, a refinery. This chapter has followed some of the key points made by the European IPPC Bureau. Based on publicly available data, the approach of the IPPC Directive was illustrated for the case of the refinery and petrochemical industry in Gela. In particular, the inventory analysis and impact assessment provided the opportunity to check the availability of environmental data from publicly accessible sites, such as the European IPPC Bureau. The chapter also shows some of the limits and possibilities of publicly available data.

The application of the IPPC Directive in Italy, as in other countries (Barros et al., 2006), presents some problems, because the Italian Government transferred the country's environmental competences to the regions (Ministry of the Environment and Territory, 2005). In general, the control of activities in high-risk areas is organized on a regional basis (run by the ARPAs), while the national authority grants the environmental permit to a given IPPC installation, having established previously the emission limit value based on best available techniques. Also, note that life-cycle assessment is commonly used to analyse products and their processes, from cradle to grave – for integrated product policy, for instance. Moreover, in this chapter, the logic of inventory analysis and impact assessment of life-cycle assessment methods was applied to a site, in the framework of the IPPC Directive, where decisions need to be made for each area at risk, rather than for each product.

Integrating long chains of actions and their effects is a social construction in which scientific evidence, industry interests, the legislative framework and political discussions meet to find compromises and resolve conflicts. In dealing with high-risk areas, powerful actors – in particular, state officials, scientists and doctors – create confusion about the sources and effects of pollution (Auyero & Swistun, 2008). This confusion often leads to legal disputes, an influential political factor.

Healthy and sustainable development, however, should be pursued as an important goal of contemporary policy. This means ensuring that health issues also become a driving force in remediation plans – by developing integrated assessments, monitoring progress, accounting fully for social and environmental costs, and identifying the strategies with the greatest net benefits.

Initially, integration requires combining scientific knowledge, methods and evidence into a single broad structure. Also, integration of measurements from different sources makes it feasible to create an image of community exposure (Pless-Mulloli et al., 2000). Moreover, integration implies the selection of practices that make the best contribution to the overall objective of healthy and sustainable development. Overcoming the shortcomings of fragmented (and occasionally inconsistent) approaches is also important. Still more important, integration develops a shared language and tools that help promote a dialogue between various sectors of society (such as health, industry and environment) and stakeholders.

Nevertheless, strategies and tools to pursue an integrated assessment of areas with industrial contamination have been unavailable or inadequate. Also, although oil residues and products create mixtures of pollutants, little is known about the toxicity of such mixtures on living organisms (Jonker et al., 2006). Still, areas with petrochemical industries, with few exceptions (Nadal et al., 2009), lack systematic and integrated environmental monitoring programmes where, for example, the levels of polychlorinated dibenzo-*p*-dioxins and dibenzofurans, polychlorinated biphenyls, polychlorinated naphthalenes, polycyclic aromatic hydrocarbons and metals (arsenic, cadmium, chromium, mercury, manganese, lead and vanadium) are monitored.

ADDRESSING RISK PERCEPTION AND LOCAL ATTITUDES

15. RISK PERCEPTION SURVEY IN TWO HIGH-RISK AREAS

Guido Signorino and Elise Beck

Introduction

This chapter presents the main results of a survey on risk. The survey used a questionnaire (see the section on "Questionnaire: multipurpose investigation on a population in an area at risk" in the Annex) on a representative sample of 1200 people living in the petrochemical areas of Augusta–Priolo (n = 700) and Milazzo–Valle del Mela (n = 500). The aim of the survey was to increase comprehension of the risk perception characteristics of the local populations and of their socioeconomic determinants – a topic crucial to defining appropriate communication strategies and to elaborating and supporting land remediation policies based on bottom-up methodologies and public health plans for preventing illness.

The Spatial Perception of Risk, Health, Environment, and its Communication (PRITASC) survey provided a comparison of the risk perception profiles of the two populations and studied the association between risk perception and many social and economic characteristics of populations, finding that gender, working conditions, being parents (and especially mothers), age, and education affect risk perception patterns. The research results show that the two populations have different perceptions of diverse risks, except those more strictly associated with the presence of industrial plants – that is, risks that relate to health, the environment and industrial hazards, for which the survey showed identical risk perception profiles.

By combining socioeconomic information and geographic methods, the survey also investigated the localization of people and their mobility and spatial perception of risk, applying the *logbook* and *mental map* methods (see the subsection on "Mental map methods in this chapter), to elucidate both the pressures of human origin on the territory and the perception of risk by local populations. The logbook consisted of a table in which the respondents indicated their daily displacements, step by step (see Chapter 12 for further details about this method).

This chapter is structured as follows:

- a theoretical introduction to risk perception and risk communication
- the methods and main findings of the research
- the mental-map approach to characterizing people's territorial representation of risk
- the result of the application of the mental-map approach.

Risk perception and communication: the PRITASC model

Risk perception, risk communication, and behaviour

The effectiveness of risk reduction strategies in risk contexts is influenced considerably by human behaviour which, in turn, is related to risk perception. Grothman & Reusswog (2006), after stressing that self-protective behaviour by residents may reduce the monetary damage of floods by 80%, observed that private precautionary damage prevention and mitigation by residents is determined by people's risk perception and awareness (see also Botzen, Aerts & van den Bergh, 2009). Similarly, the perception of risks related to personal health affects people's desire for access to medical services (Atkinson & Facanha Farias, 1995), and the perception of risks related to food influences its consumption (Dosman, Adamowicz & Hrudey, 2001; Lobb, Mazzocchi & Traill, 2007). On the other hand, risk (and, more specifically, risk perception) can be interpreted as a combination of objective factors (such as exposure levels) and subjective evaluations derived from a person's education, culture, values and beliefs.

Klinke & Renn (2002:1076) stated, "There is no doubt that the term 'risk' refers to the experience of something that people fear or regard as negative. … Since risk refers to a potential of 'real' consequences … it is both a social construction and a representation of reality." It follows that, to assess risk, a "dual strategy" that includes both physical elements (technically and scientifically defined and measured) and sociopsychological criteria should be initiated. These "should be treated as criteria in their own right and not be regarded as modifiers of the physical consequences."

Furthermore, as already mentioned, a respondent's risk perception is affected substantially by such economic, social and cultural variables as gender, number of children in their family and their education (Flynn, Slovic & Mertz, 1994; Konè & Mullet, 1994; Dosman, Adamowicz & Hrudey, 2001) and by the quality of information about health and territorial conditions (Wallquist, Visschers & Siegrist, 2010).

Given the complex relationship that exists among perception, behaviour, and socioeconomic characteristics of local populations, discussions of the field of risk perception and communication are increasing – with associated interactions (both from methodological and operative perspectives) – among social scientists, epidemiologists, environmental scholars and policy-makers, especially when remediation plans and risk management strategies need to be defined. In line with increasing dialogues about risk, risk communication has gained increasing importance in the design and definition of the goals and policy instruments of environmental epidemiology, including the creation of guidelines, recommendations and definitions of goals for territorial governance. Also, risk communication is increasingly considered to be an instrument for protecting public health (Ropeik & Slovic, 2006).

As a consequence of increasing interest, the assessment of risk perception should be considered a fundamental instrument for creating proper risk communication plans that sustain the implementation of risk-management and territorial-remediation strategies.

Imperatives and models of risk communication

According to its ends (goals) or to its ethical content, risk communication responds to three alternative imperatives (that is, influences or factors that make it necessary): normative, instrumental and substantial (Wardman, 2008).

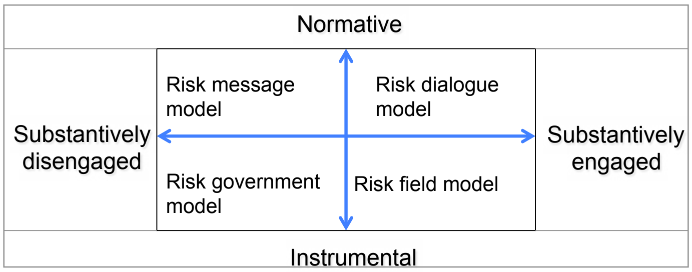
The *normative* imperative considers risk communication to be an end in itself, suggesting that, in a democratic society, risk communication is essentially an expression of a general *right to be informed*, to make correct and optimal choices. This gives rise to: (a) a parallel obligation to fully and correctly inform the public about risks that concern human behaviour or (b) specific activities for governments, business organizations, or even individual agents. The common procedure of informed consent is an example of the normative imperative of risk communication.

The *instrumental* imperative treats risk communication as a *means* of helping organizations or interest groups reach strategic objectives (such as survival or adaptation) when interacting with a potentially (or actually) hostile social setting. Examples of this kind of communication follow specific accidents or crises, such as Chernobyl (Wynne, 1989, 1992), the so-called mad cow disease crisis (Leiss, 1996), the Brent Spar oil platform dumping in the North Sea (Löfstedt & Renn, 1997) and the Bophal disaster (Chess, 2001). Instrumental communication is also used extensively by environmental organizations, such as Greenpeace, to support specific campaigns (Bakir, 2005; Wardman, 2008).

Finally, the *substantial* imperative orients communication towards change, and its goal is to improve government strategies or people's behaviour in risk scenarios. This approach could be interpreted as *instrumental*, if it is related to the objective of realizing an informative framework aimed at supporting the choices made by governments. However, to the extent that it pursues the general interest, rather than particular private interests, it differs from instrumental communication in its goals and tools.

By making different combinations of the normative or instrumental goals and the level of *substantial engagement* of social actors, Wardman (2008) provides a general framework for outlining four conceptual models of risk communication, which is expressed in the following scheme (Fig. 51).

Fig. 51. Four conceptual models of risk communication



Source: Wardman (2008:1623).

According to Wardman (2008:1623),

> The vertical axis [of Fig. 51] conveys the implied communicative intent of [the] driver of risk communication (i.e. normative or instrumental), whereas the horizontal axis characterizes the co-involvement of different agents in the social construction of risk (i.e. how potential participants are seen to be substantively engaged in constituting communicative action and risk meaning).

The upper left-hand corner of Fig. 51 combines the normative imperative with substantial disengagement of stakeholders and social actors, producing the *risk message model* of risk communication. This model provides a unidirectional approach to risk communication, where emphasis is placed on institutions' and policy-makers' *duty to inform*. In this approach, experts play the primary role within a communication strategy, focusing on the content and comprehensiveness of the message, while the target population plays a passive, receptive role. In many cases, this traditional top-down approach – which does not imply any interactive involvement for groups receiving information – revealed itself to be unable to generate either changes or awareness in the communities targeted (Sturloni, 2003), especially when the communication strategy did not take into account such factors as the cultural background, the economic and social variables, and the moral values of these communities.

The *risk dialogue mode*l, which combines the normative imperative with substantial engagement of social actors, takes a different and more participatory approach to risk communication and views it as the right to be informed. This model of communication attempts to outline rules and methods for the creation of forums that aim to share knowledge on the existing conditions of risk (Pellizzoni, 2010) and to define shared strategies for ruling the territories. The risk dialogue model is apt to process and communicate information on environmental and sanitary risks in contexts characterized by general or specific risks – that is, risks the address either entire areas or specific groups. Some experiences, however, show that the involvement of communities in the decision-making process that relates to the management of risk contexts presents several problems.

The first problem involves the difficulties related to the popular understanding of science, which occurs when populations require and expect ultimate answers that experts cannot provide. The *paradigm of uncertainty* causes a lack of trust in *technicians*, which may stop and worsen (rather than enhance) public awareness. The second problem is that of public involvement potentially generating an *excess of demand* – that is, a number of claims (either general or particular) that cannot be satisfied by policy-makers, so generating frustration and discontent within populations. The third problem, involves the cost of participation: attending meetings and forums implies a sacrifice of time and (sometime) money, so those who participate are particularly motivated to do so. As a consequence, meetings organized to hear public opinion are often biased and the participants self-selected (Campbell & Townsend, 2003). Finally, it is possible that the particular interests of participants generate conflicts that cannot be resolved (Pellizzoni, 2010), producing conditions of indeterminacy, in line with Arrow's impossibility theorem.[25]

Directly linked to the instrumental imperative – and reflecting a potential contrast between the different stakeholders just mentioned – the *risk field model* (on the lower right-hand side of Fig. 51) regards risk communication as a strategic tool used by competing social actors (such as business firms and environmental associations). These actors use risk communication to influence public opinion and policy-makers' decisions about specific *fields* (such as nuclear plants, vaccination campaigns and social reforms) that can create hazards for the socioeconomic or environmental habits of society or for public health. Such conflicting aims and the biased distribution of risks (or hazards) – which can occur when public audits are established to plan land use – may lead to impasses to a unified social representation of risk (Boholm, 2008); in the risk field model, however, public awareness may increase, due to information that competing actors provide to mobilize public opinion or political power.

The last of the models in Fig. 51, the *risk government model*, suggests that risk communication should have an educational content, thus stimulating behavioural population responses that reduce social risk, under the assumption that persuasion is more effective than prohibition (Fischhoff, 2005)., The purpose of this model of risk communication is to involve local populations, providing them with full responsibility for risk-reduction strategies. However, within this framework, people actually play a passive role within the communicative strategy, with the public viewed as a mere *receptor* of information aimed at coping with hazardous situations. Under a Foucaultian perspective, the risk government model can be viewed as an exercise in power relations, where political actors use the media to transfer the responsibility of risk prevention to citizens, through various forms of self-restricting behaviour (Rose, 1999; Wardman, 2008). For example, people may be independently driven to stay at home during days of peak pollution; in this way, prevention strategies are privatized and no specific responsibility is assumed by policy actors or by polluting firms.

Clearly, the risk government model of risk communication attributes great importance to knowledge of risk perception, as persuasion requires deep insight into human psychology. In line with such persuasion, social scientists may be manipulated to reach political ends within a biased context (Fischhoff, 1990). According to this perspective, Wardman (2008:1634) warns that:

> … social science can quite feasibly be put to work against the public interest on occasions when:
>
> 1. Political aspersions, which cast the public as troublesome, are simply and uncritically accepted by academics, thus undermining the public's political credibility.
> 2. Social scientific remedies prescribed to deal with such behaviour shift the political balance against the public interest.
> 3. Claiming to know how [to] explain their behaviour reduced the perceived need to let different publics speak for themselves.
> 4. Assisting policymakers leads to the fortification of their power, by helping them fine tune programmes, anticipate and overcome resistance, or guide and legitimize initiatives.
> 5. Claiming to know what particular publics might want and need without seeking their clarification is used to justify current actions.
> 6. Research findings are misappropriated by policymakers to justify decisions that actually disadvantage and disenfranchise the people concerned.

The PRITASC risk communication model

Given the theoretical framework outlined above, the PRITASC survey, within a normative–substantial perspective, adopted an original combination of risk dialogue and risk government approaches that can be defined as the *participative risk management model*. The intent of this approach is to increase the qual-

25 Economist Kenneth Arrow's theorem states that, when voters have three or more distinct alternatives, no voting system can be designed that converts their ranked preferences into a broad ranking while also satisfying a set of criteria of fairness.

ity of the information available to policy-makers and – at the same time – to raise the awareness of the populations, thus improving their ability to interact with institutions, within the definition of effective public health improvement strategies. The role of so-called experts is then twofold: to provide a scientific base for political decisions and to correctly (and in an understandable way) inform populations about the actual risk context. In the general context of the public being concerned, due to uncertainty and lack of information, risk perception has been analysed deeply to find the proper communication mode, aiming to transfer knowledge not only to policy-makers, but also to the public.

Within the communication plan, two specific instruments were established to enhance public participation and sharing: (a) the initial results of the survey were discussed within *restitution (or feedback) focus groups*,[26] where researchers met with groups of citizens to verify their general acceptance of the conclusions of the research; and (b) after having reported scientific evidence to the Sicilian Council, local assemblies were asked to disseminate and publicly discuss information with the populations studied, stakeholders and political administrators.

The PRITASC survey: methodological issues

A total of about 265 000 people live in the areas of Milazzo–Valle del Mela (55 504 inhabitants) and Augusta–Priolo (209 352 inhabitants), which the Italian and Sicilian governments have declared to be at high risk of environmental contamination. Within a broader project of scientific assistance to the regional administration, from December 2007 to June 2008, a survey of risk perception was conducted on a representative sample of 1200 people living in the petrochemical areas of Augusta–Priolo (n = 700) and Milazzo–Valle del Mela (n = 500), to compare risk perception patterns between the two populations.

The questionnaire and the samples

Under the scrutiny of an international committee, a specific questionnaire was developed and administered person to person. The questionnaire was composed of six sections, which aimed to investigate: (a) the characteristics of individuals; (b) daily mobility habits and home and/or work locations; (c) risk perception; (d) the characteristics of the home; (e) family socioeconomic information; and (f) living standard (see the Annex).

The section on daily mobility required the interviewees to indicate on a map the locations of their home and school and/or work; it also required them to report their individual movements in the time frame of 00:00–24:00 hours of the previous day, within 15-minute intervals. The section on risk perception progressed from general and social risk perception to risk conceptualization and territorial risk and personal exposure evaluation. These two sections were quite complex and two different versions of the questionnaire were edited: in the second version, the mobility section was positioned after risk perception and home characteristics.

Before being administered, the questionnaire was tested in 20 cognitive interviews and a series of focus groups held in Milazzo, testing both its wording and comprehensibility (Gatto, Mudu & Saitta, 2008; Gatto et al., 2009). In line with the participative approach of the PRITASC model, a second series of focus groups were carried out in Augusta, to test the preliminary results of the survey, so starting a restitution (feedback) process aimed at discussing and democratizing the survey's interpretation.

Samples of the two populations were selected from the electoral registers and stratified according to the demographic size of the municipalities. The sampling error was estimated to be lower than 5%, both in the Augusta–Priolo and Milazzo–Valle del Mela areas.

26 Restitution (feedback) – originally understood as an exchange between the researcher and the groups observed, which consists of delivering the results of a study to the groups targeted for their internal use – has gradually come to indicate the involvement of the subjects studied in the research, to assess their agreement with the opinions that result from the study (Whyte, 1983). The origin of this trend is the growing awareness of the political importance of any scientific description.

Risk perception index and risk perception profiles

From a list of 15 so-called social risks (road accidents, food risks, drug addiction, deterioration of the environment, war, poverty and social exclusion, natural disasters, terrorism, unemployment, serious illnesses, nuclear threats, industrial disasters, insecurity and uncertainty, extremely low-frequency electromagnetic fields, and extremely high-frequency electromagnetic fields), respondents were asked to express their degree of preoccupation on a Likert-type scale, which assumes the intensity of feeling about a topic is linear; in this case, they were asked to respond to four choices: most worried, very worried, moderately worried and no worry. From their answers, a synthetic *risk perception index* and an analytical *risk perception profile* were estimated within the two samples and used to compare territorial differences and similarities (Signorino, 2012).

The risk perception index (RPI), ranging from 0 (no worry) to 1 (top worry), is calculated as a weighted average of absolute frequencies of each choice:

$$RPI = (\Sigma_i \, n_i \cdot \pi_i)/\mathrm{N} \cdot 3,$$

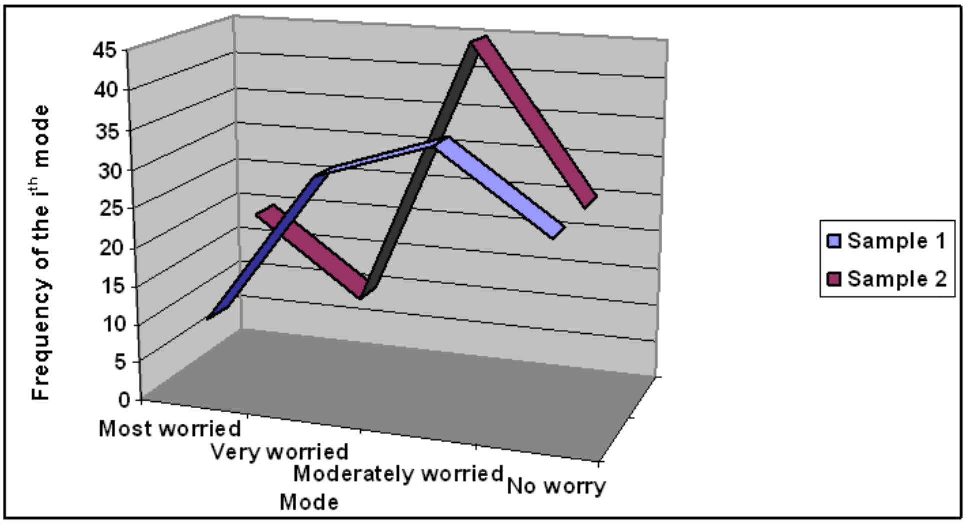
where: n_i represents the absolute frequency of the ith mode; π_i represents the weight assigned to the ith mode (that is, most worried = 3; very worried = 2; moderately worried = 1; and no worry/doesn't know = 0); and N represents the total number of observations.

In its present use, the expression *risk profile* means the way in which risk perception is distributed among different modes within the populations. As RPI is a weighted average of $n = 4$ modes, it is possible that identical values reflect different distributions of the modes among respondents belonging to distinct samples. For example, suppose two samples, each with 100 subjects, revealed the following distribution of modes in a risk perception survey:

- Sample 1: most worried = 10; very worried = 30; moderately worried = 35; no worry = 25; and
- Sample 2: most worried = 20; very worried =10; moderately worried = 45; no worry = 25.

The RPI would be the same in the two populations ($RPI_1 = RPI_2 = 0.4167$), but the distribution of frequency among the modes is very different, as Fig. 52 clearly shows.

Fig. 52. Hypothetical profiles of risk perception for identical RPIs



In particular, in spite of almost identical *synthetic* risk perception indexes, Sample 1 shows a higher proportion of both "most worried" and "moderately worried" people, and a lower proportion of "very worried" people, so expressing a different risk perception profile than Sample 2. To evaluate differences in risk perception profiles between the two samples, a χ^2 test for the equivalence of relative frequencies was implemented.

Mental map method

Besides considering the socioeconomic characteristics of risk perception, a map of the area was also integrated into the survey, to evaluate the spatial representation of risk, which is one component of risk perception (or the cognitive representation of risk). On a simplified map of the area studied; the questionnaire respondent was asked to draw the area he or she considered at risk.

Few studies of risk perception use mental maps – that is, interviewees are asked to draw a sketch map of an area or draw, as in our case, one or more areas, or points or streets that are associated with risk areas – to take into account the spatial dimension. Most use questionnaires (Duchene & Morel-Journel, 2004) that are processed through multivariate analysis to define social profiles (Guéguen et al., 2009) or, when these data are compiled to identify vulnerable areas or groups, use synthetic indexes (D'Ercole, 1996; Cutter, Mitchell & Scott, 2000; Glatron & Beck, 2008).

The spatial dimension can also be integrated into these surveys, as a tool that represents data: being the respondents are georeferenced, their answers can be mapped (Bonnet, 2002; Beck, 2006), and the spatial dimension can be taken into account as an explanatory variable of the variations of risk perception, especially when the question of distance to the source of risk is addressed (D'Ercole, 1996; Peacock, Brody & Highfield, 2005; Howe, 2010).

Mental maps (or sketch maps) have been used mainly in the study of the cognitive representation of the environment, especially to understand the variables that influence the mobility of people in cities (Lynch, 1960; Cauvin, 1999).The use of mental maps is not yet widespread in the field of risk (Bonnet, 2002), and sometimes the survey consists of asking respondents to draw the area already affected by a disastrous event (Brilly & Polic, 2005).

Mental maps can be collected through various methods.

- **White sheet.** Respondents are asked to draw their environment (such as district in which they live or city centre) on a blank sheet of paper. They are free to choose the scale, number of elements they represent and so on. Only the size of the white sheet can influence the respondent. The resulting map shows the distortions of the mental construction of space with respect to real space.
- **Simplified or detailed map.** Respondents are asked to locate a specific area that relates to the topic of the survey. The difference between the two methods (simplified or detailed) comes from the amount of information present on the map.
- **Spatial reconstruction game** (Ramadier & Bronner, 2006). In this method, the respondent is asked to build, with wooden pieces and strings, a three-dimensional map of their environment. According to the authors of this method, it is especially adapted to an illiterate population – that is, one with difficulties in drawing. The resulting map also shows the distortions of the respondents' mental construction of space.

Each method presents disadvantages that need to be carefully considered in applications.

- **White sheets.** The resulting drawings are difficult to process. They can be digitized, but need special tools to tackle anamorphosis – that is, from a distorted projection or perspective find a suitable reprojection to reconstruct an image that appears normal.
- **Simplified map.** This technique implies the need to choose the details that will appear on the map.
- **Detailed map.** The map is not easy to read and is not always understandable.
- **Spatial reconstruction game.** It is difficult to use this method on a large sample for different reasons, such as the equipment and time needed to administer the survey, and the processing of the resulting three-dimensional map.

Among others, Bonnet (Bonnet, 2002; Amalric & Bonnet, 2010) introduced the use of mental maps to the field of risk. The maps were used to integrate the spatial component of the cognitive representation of risk into the mapping of vulnerability to industrial hazards. The preferential use of the simplified map, instead of the white sheet, is suggested for allowing respondents to locate things in space. Even if this method can be criticized (Beck, 2006), it allows easy and fast processing through the use of GIS, as was the case in the PRITASC survey.

In the PRITASC survey, the choice of the details that would appear on the simplified map was not left entirely to the researchers – to minimize subjectivity. In the case of Milazzo–Valle del Mela, 24 adults participated in focus groups, whereas in-depth interviews were carried out in the area of Augusta–Priolo (Gatto, Mudu & Saitta, 2008). The different meetings allowed the definition of what would be represented on the map and which scale would best fit the objective of the survey (see Fig. 53). A grid was overlaid on the maps, to help process the information. In Milazzo–Valle del Mela, the grid-cell size was 250 m; it was 440 m for the case of Augusta–Priolo. The size of the printed maps was a standard A3 paper format.

Fig. 53. Maps used for the survey in Milazzo–Valle del Mela and Augusta–Priolo

Note. Red lines indicate main roads; reddish areas indicate main urban areas.

In the Milazzo–Valle del Mela area, 484 respondents provided a mental map, and 646 respondents provided them in the Augusta–Priolo area. In Fig. 54, the Milazzo–Valle del Mela chart shows an example of a sketched map. Each polygon drawn by respondents, representing an area at risk, was digitized and superimposed on the map (see Fig. 54).

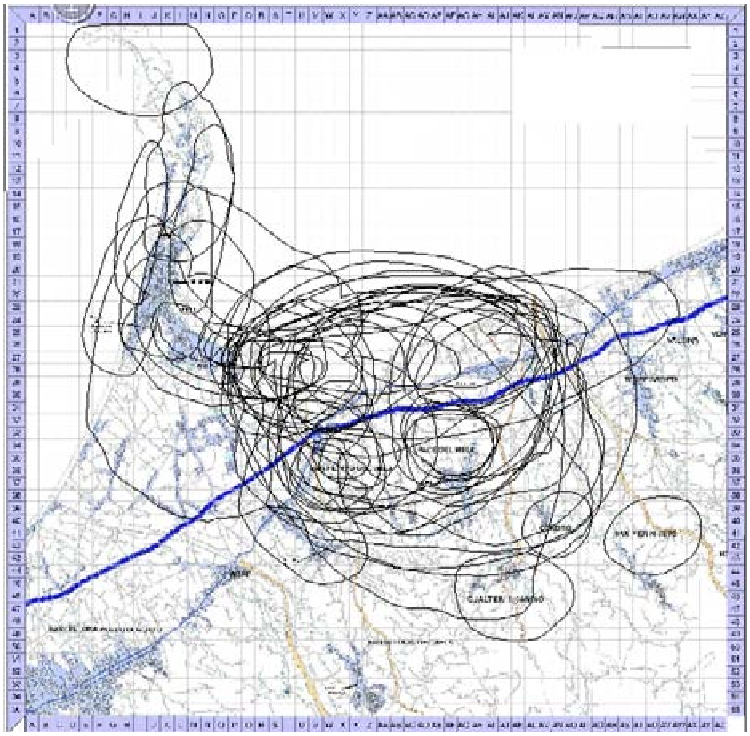
Following Bonnet's method (Bonnet, 2002), a grid (with the same resolution as indicated previously) was overlaid on the digitized polygons. For each cell, a spatial join (which associates attributes from one data layer – a single set of files in GIS – with the objects in another layer) allowed the number of overlapping polygons to be counted, to identify which areas the respondents considered to be at greatest risk. The resulting synthetic map was then compared to the limits of the so-called official area at risk, to identify the distortion of the perceived risk from the so-called real risk, as indicated in the official definition of site of national concern.

In addition to sociodemographic factors, such as age and gender, the following factors also influence an individual's cognitive representations of spatial risk.

- The experience of space or an environment influences the capacity to describe the risk related to it, so that living or travelling in the same environment every day helps to provide a better understanding of it (Lynch, 1960; Cauvin, 1999).

- Knowledge of the spatial extent of a risk, which is often not communicated and thus poorly integrated by the population (Beck & Glatron, 2008), is another factor. Since the spatial extent of a risk is complex (usually different from other risks, such as earthquakes and floods, for the industrial boundaries of a hazardous site), the population identifies the risk less easily. This is especially true when different spatial extensions are communicated by local authorities, which is often the case. This results in a mismatch between the spatial extent of perceived risk and the spatial extent of official risk.

Fig. 54. Example of digitized polygons for the Milazzo–Valle del Mela area



PRITASC survey results for the two areas studied

Table 93 shows that, on average, risk perception seems to be quite high (RPI greater than 0.5 for all risks, except extremely low-frequency electromagnetic fields in the Augusta–Priolo area). Also, despite some differences in ranking, average risk perception is very similar within the two areas. The four most perceived risks, showing RPI > 0.75, are the same items both in Milazzo-Valle del Mela and in Augusta-Priolo (serious illnesses, environmental degradation, unemployment and industrial disasters). As a result, risk perception is found to be strictly connected with the environmental and socioeconomic sustainability of the local development model (described in Chapter 8).

However, investigating the relative frequencies of the *most worried* option shows it to always be higher in the Milazzo–Valle del Mela area, in relation to all 15 items. This implies that, given the similarity of the average index value, a different distribution of frequencies in the risk perception profile characterizes the two high-risk areas (Signorino, 2012).

To investigate the differences in risk perception profiles between the two populations, a χ^2 test was performed for each risk. The test showed that the null hypothesis – that is, that the relative frequencies are equal between the two populations – is rejected when the estimated χ^2 is higher than its tabular value. Table 94 shows that risk perception profiles are statistically different when considering all risks. An exception, where they are similar, is the three risks (in bold type) that appear to be most related to the territorial impact of industries: environmental degradation, serious illnesses and industrial disasters.

Table 93. RPI in the two areas: a statistical test of independence

Risk		RPI[a]		Percentage of most worried	
		MVM	AP	MVM	AP
1	Road accidents	0.68	0.67	30.6	24.1
2	Food risks	0.59	0.59	23.4	18.5
3	Drug addiction	0.66	0.65	34.0	22.6
4	Deterioration of the environment	0.81	0.79	52.4	46.2
5	War	0.63	0.64	30.9	24.4
6	Poverty and social exclusion	0.68	0.67	34.9	23.6
7	Natural disasters	0.64	0.69	31.9	31.2
8	Terrorism	0.62	0.63	29.3	22.0
9	Unemployment	0.77	0.86	46.2	44.5
10	Serious illnesses	0.82	0.82	56.9	54.6
11	Nuclear threats	0.57	0.55	27.2	17.7
12	Industrial disasters	0.75	0.75	44.7	42.8
13	Insecurity and uncertainty	0.67	0.67	29.5	20.9
14	Extremely low-frequency electromagnetic fields	0.56	0.47	19.5	10.9
15	Extremely high-frequency electromagnetic fields	0.58	0.52	19.6	13.4
	Average	**0.670**	**0.665**	--	--

[a] MVM: the Milazzo–Valle del Mela area; AP: the Augusta–Priolo area.

Table 94. Risk perception: a statistical test of independence of the two populations

Risk		Estimated χ^2 versus a tabular χ^2 = 7.8	Risk perception profile
1	Road accidents	13.2	Different
2	Food risks	10.8	Different
3	Drug addiction	38.8	Different
4	**Deterioration of the environment**	**5.0**	**Similar**
5	War	28.4	Different
6	Poverty and social exclusion	36.7	Different
7	Natural disasters	27.7	Different
8	Terrorism	28.3	Different
9	Unemployment	8.9	Different
10	**Serious illnesses**	**3.4**	**Similar**
11	Nuclear threats	24.0	Different
12	**Industrial disasters**	**5.5**	**Similar**
13	Insecurity and uncertainty	32.3	Different
14	Extremely low-frequency electromagnetic fields	37.9	Different
15	Extremely high-frequency electromagnetic fields	14.7	Different

* Degrees of freedom = 3; α = 0.05.

It follows that the features of the local industrial development model (see Chapter 8) assimilate the risk perceptions of health and environmental hazards of populations that have, in general, different risk perception profiles.

Socioeconomic characteristics of risk perception

As already mentioned, in running preliminary focus groups to set the survey's analytical framework, the following hypothesis emerged: specific socioeconomic characteristics of populations (such as gender, education, working conditions, age, and being parents, especially mothers) may influence risk perception.

As environmental, health and industrial risks showed identical perception profiles within the two areas, the two populations were studied to elucidate whether these socioeconomic characteristics influence risk perception. We built contingency tables that relate the four modes of risk perception (most worried, very worried, moderately worried and no worry/doesn't know) to serious illnesses, industrial disasters and environmental degradation and then applied χ^2 tests. Table 95 shows the result of the testing procedure.

High *P* values show that the number of family members does not influence the perception of risk to health and the environment in the two populations, while gender, education, or being parents (especially mothers) significantly differentiate risk perception for health and industrial hazards.

Table 95. Risk perception and the populations' socioeconomic characteristics

Risk	Socioeconomic characteristics						
	Gender	Education	Working conditions	Family members	Age	Parents	Mothers
Serious illnesses	$\chi^2 = 22.9$** df = 2 $P = 0.000$	$\chi^2 = 21.4$** df = 6 $P = 0.002$	$\chi^2 = 30.1$** df = 12 $P = 0.003$	$\chi^2 = 10.7$ df = 4 $P = 0.379$	$\chi^2 = 1.9$ df = 4 $P = 0.758$	$\chi^2 = 11.1$** df = 4 $P = 0.025$	$\chi^2 = 8.8$** df = 2 $P = 0.016$
Industrial disasters	$\chi^2 = 14.6$** df = 2 $P = 0.001$	$\chi^2 = 20.1$** df = 6 $P = 0.003$	$\chi^2 = 14.7$ df = 12 $P = 0.260$	$\chi^2 = 4.3$ df = 6 $P = 0.930$	$\chi^2 = 8.1$* df = 4 $P = 0.088$	$\chi^2 = 10.3$** df = 4 $P = 0.036$	$\chi^2 = 7.7$** df = 2 $P = 0.021$
Deterioration of the environment	$\chi^2 = 3.8$ df = 2 $P = 0.153$	$\chi^2 = 8.2$ df = 6 $P = 0.222$	$\chi^2 = 17.0$ df = 12 $P = 0.151$	$\chi^2 = 10.0$ df = 10 $P = 0.441$	$\chi^2 = 18.6$** df = 4 $P = 0.001$	$\chi^2 = 6.6$ df =4 $P = 0.160$	$\chi^2 = 5.5$* df = 2 $P = 0.064$

df: degrees of freedom.
* Statistically significant at the 95% confidence level.
** Statistically significant at the 90% confidence level.

More specifically, on average, and referring to the three categories of risk indicated in the table, women are more worried than men, less educated people are more anxious than more educated people, and people with children (especially mothers) are more troubled than people without children. Also, working conditions do not influence the perception of industrial hazards, but they do differentiate the perception of health risks: members of the labour force and housewives are more worried about them than students, retired workers and workers without a permanent job. Moreover, age does not influence the perception of health risks, but it does differentiate (at the 90% confidence level) the perception of industrial hazards (adults are more worried than young people and the elderly).

Environmental degradation is intensely perceived by populations, independent of gender, education, working conditions and being a person with a child(ren), while being a mother and, especially, age (adults are more worried than young people and the elderly) differentiate risk perception for this hazard.

The space dimension of risk perception: mental maps

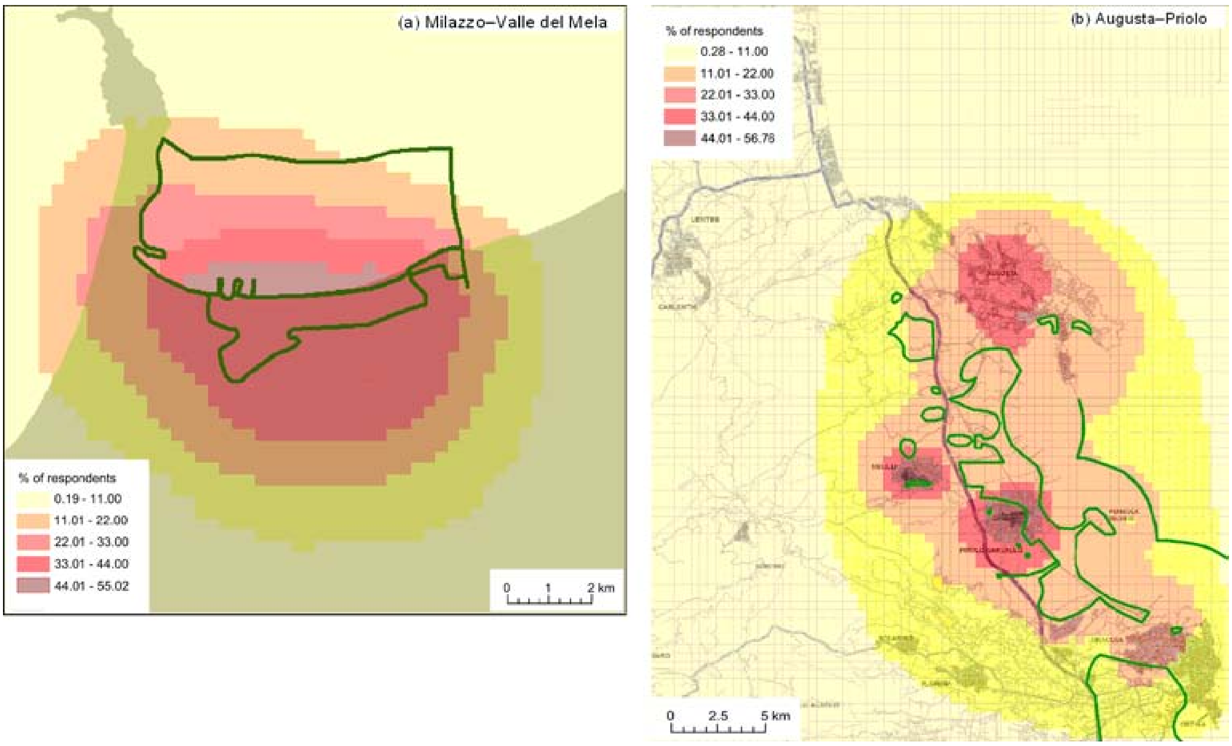
To survey the spatial cognitive representation of risk in the two areas, the mental map method (described earlier in this chapter) was used for each sample (Milazzo–Valle del Mela and Augusta–Priolo). Considering that some sociodemographic variables – such as age (Pelling, 2003; Beck et al., 2010), gender (Fordham, 2000), education (Buckle, 2000; Beck et al., 2010), and being or not being employed or having children – were supposed to influence risk perception (see preceding sections in this chapter), we processed the mental maps of subsamples after distinguishing Milazzo–Valle del Mela and Augusta–Priolo respondents by age, gender and education.

The influence of age, gender and education

In both populations, at least one respondent considered the entire area represented on the map to be at risk. Very few survey respondents did not produce a mental map in the questionnaire: 5% in the Milazzo–Valle del Mela area and 8% in the Augusta–Priolo area. We cannot assume, however, that these people considered that the area in which they live was free of risks; we can only say that at least 95% of the respondents in the Milazzo–Valle del Mela area and at least 92% in the Augusta–Priolo area thought that in the territory in which they live some residential areas are exposed to a petrochemical hazard.

In the case of the Milazzo–Valle del Mela area, the overlap between the perceived and the official (real, in green) area at risk is quite good (Fig. 55a), even if the risk in the maritime area –located on the northern part of the map – is denied, as fewer surveyed people circled it on their mental map. This means an overall shift of the perceived risk, compared with the official mapped risk, and a darker red area on the map out of the green polygon that represents the official mapped boundaries (Fig. 55a). We assumed that the boundaries of the hazardous area are much more difficult to identify in the sea, which constitutes a rather specific environment. The cognitive representation of this territory can therefore differ from that of a continental territory. We also observed that risk perception is biased towards the south (the inhabited land).

Fig. 55. Synthetic map of perceived risk for the two areas



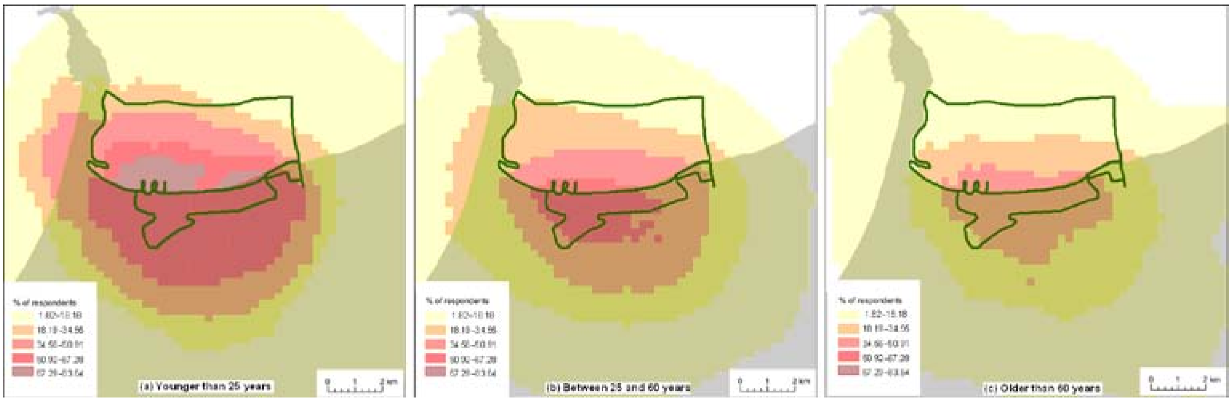
Note. The green lines correspond to the official boundaries of the sites of national concern.

Of the two areas, the boundaries of the official risk are much more complex in the case of Augusta–Priolo (Fig. 55b), because there are pockets of risk areas, instead of one well-defined area; therefore, the match between perceived and real risk is less obvious. The particular details of the Augusta–Priolo case lie in there being some areas without petrochemical danger that were considered as such, especially around the cities of Augusta, Melilli and Priolo Gargallo. This comes from the population knowing that some dangerous plants are located on the territory of these cities. However, the survey respondents do not know exactly where in the territory they are located; thus, many of them circled the name of the city or the spatial extent of its urban space on the map instead of the precise high-risk area. This reflects respondents often not being able to accurately identify the spatial extent of a risk, though they are conscious of it (Beck, 2006).

When trying to understand which social groups tend to overestimate or underestimate risk, we first focused on the influence of age. Three social groups were considered: young people (younger than 25 years), corresponding to students and young workers; workers (between 25 and 60 years of age); and, finally, elderly and retired people (older than 60 years of age). These three groups also allowed us to see whether being a student, worker or retiree influences perception.

Fig. 56 shows that, for older respondents, the area of perceived risk is smaller, while for the younger respondents a higher proportion of people circled the same area, and these people have a common perception of risk. The young people tend to overestimate risk (spatially speaking) more than the elderly, whereas the elderly seem to globally underestimate risk.

Fig. 56. Synthetic map of perceived risk by age groups in the Milazzo–Valle del Mela area



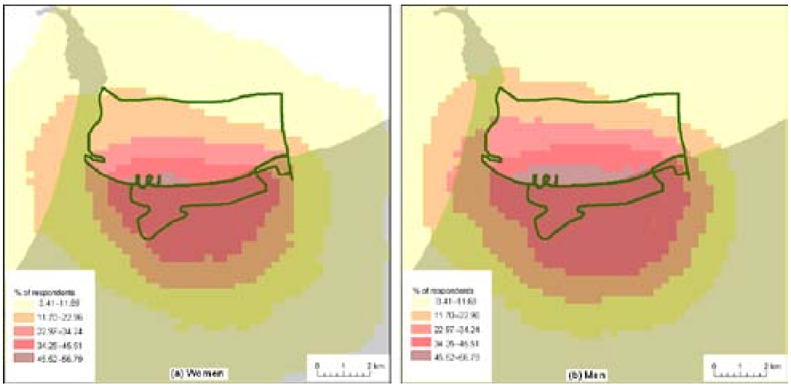
Note. The green lines correspond to the official boundaries of the sites of national concern.

We can assume that experiences of life, of places or of previous accidents (which can be, among other factors, related to age) help create a more precise idea of the spatial extent of risk. The higher proportion of young people having a common risk perception can be linked to the special context of their education.

In general, gender is one factor known to explain risk perception (Flynn, Slovic & Mertz, 1994). Usually, perception studies show that women tend to overestimate risk or, at least, to have a rather coherent perception of so-called real risk. In the case of Milazzo–Valle del Mela, however, more men tended to have circled a larger area – that is, a smaller dark red area (the area considered as risky was smaller in that case for women than it was for men). Thus, men tended to overestimate risk. As for the elderly (Fig. 56c), women were less numerous to have a common risk perception (Fig. 57a), compared with men. The opposite observation was made in Augusta, where women tended to overestimate the territorial extension of risk, compared with men.

Concerning the influence of education, very slight differences were observed between people with a higher level of education and those with no diplomas or a lower level of education.

Fig. 57. Synthetic map of perceived risk by gender in the Milazzo–Valle del Mela area



Note. The green lines correspond to the official boundaries of the sites of national concern.

Conclusions

The PRITASC survey applied and combined statistical methods and spatial analysis techniques to assess and compare risk perception in the two high-risk areas of Milazzo–Valle del Mela and Augusta–Priolo.

The research shows that, within the different risk perception patterns observed in the two areas, populations have identical risk perception profiles for health and environmental hazards. Also, their socioeconomic characteristics (such as gender, education, age, working conditions and the presence of children) influence risk perception.

The deep insights provided by the mental map show that local populations have a quite clear understanding of the spatial dimension of risk in their territories, especially in the Milazzo–Valle del Mela area, where the localization of the contaminated area is more similar to the official one than in the Augusta–Priolo area. In the latter area, the risk is more complex, which does not help people identify its spatial extent. In Milazzo–Valle del Mela, the maritime area is barely considered as hazardous, as it consists of a specific environment with imprecise boundaries.

The combination of statistical analysis of risk perception and cognitive spatial analysis in the PRITASC survey revealed a strong gender distinction for the perception of territorial risk (especially in the area of Milazzo–Valle del Mela). Also, the male population is in general less worried, but their territorial perception is wider – for example, it incorporates the whole remediation site – than the one offered by the women interviewed. Finally, health risk perception is influenced by gender, education, working conditions, and the presence of children.

In light of people's involvement in prevention strategies aimed at risk reduction and management and territorial remediation, the results of the PRITASC survey are of major importance to risk communication.

16. STUDYING COMMUNITIES AT HIGH ENVIRONMENTAL RISK: THE CASE OF GELA

Pietro Saitta and Luigi Pellizzoni[27]

Introduction

Research activities that aim to redevelop areas that present a risk may be carried out in different ways, using various methods developed by the social sciences. Among the methods that take on a particular meaning when applied to these areas are focus groups, qualitative analysis and participant observations. Which work tools to choose, what to investigate, what to look at and for how long, and how to communicate the results of the research are among the issues that need to be addressed at the beginning of research. Research in areas that present risks implies a clear commitment to issues of development, to relationships with the environment, to the perception of well-being and the definition of risk.

Through an example of research and observations carried out in Gela, the present chapter provides some useful clues for social scientists working in these areas. The events analysed started in the early 1950s, when oil was discovered in Sicily and the populations enthusiastically welcomed the petrochemical plants. Then, many people thought of Sicily as Texas. Half a century later, the bright dream has turned to dark reality: congenital malformations, diseases related to industrialization, natural resources depleted, and organized crime. The present chapter discusses redevelopment plans and describes the socioeconomic impact of the petrochemical industry, of which Gela is one of the Italian capitals.

Research designs and the ethics of inquiry

The study of the social aspects of health and environmental risks raises issues linked peculiarly to the designs and ethics of research. Compared with scientific research, in general, the choice of methods to be used in studies of the social aspects of health and environmental risks are more broadly related to theoretical assumptions and research aims. First, the social aspects of risk have no unique or widely accepted theoretical framework, and the variety of methods of assessment to choose from impinges on research designs and measurement tools. Second, the definition of research aims crosses the intersection of three distinct reference communities that need to be considered simultaneously. Both these issues will be addressed briefly.

With regard to the first issue, studies of the social aspects of risk are addressed in three different frameworks: psychological, anthropological and social. The psychological framework was developed in the early 1970s, together with technical risk assessment and management techniques, in an attempt to understand and address opposition to technological development. Such opposition often appears irrational or unjustified when compared with the evident benefits of industrial sites, which are supposedly counterbalanced by relatively tiny or well-controlled risks. The task then is to understand the source of public attitudes and opposition.

The so-called psychometric approach (Slovic, 1992) seeks to clarify the subjective components of risk perception and evaluation. Through questionnaires and laboratory experiments, scholars study the cognitive processes by which everyday or *lay* reasoning leads to systematic over- or underappreciation of actual (that is, probabilistically measured) risks. For example, risks that people take voluntarily or those with which they have a long acquaintance are easily downplayed, whereas risks that are imposed or come from novel technologies are overemphasized. Typical policy replies to this type of analysis either seek suitable incen-

27 This chapter is the outcome of shared intellectual work. Luigi Pellizzoni wrote sections on "Research designs and the ethics of inquiry" and the "Discussion"; Pietro Saitta wrote the other sections. This article is based partly on Saitta & Pellizzoni (2009).

tives (such as monetary compensation, jobs and services), to increase the acceptability of risks, or try to strengthen (or restore) trust between people, firms, authorities and experts. Accordingly, risk communication shifts from a let-experts-decide or a let's-communicate-the-numbers approach, to a let's-show-that-it-makes-sense-for-them approach (Fischhoff, 1995).

From the perspective of the psychometric approach, perceptions and reactions to risk depend on how the human brain works. From another perspective, the anthropological approach, linked mostly to the work of Mary Douglas (Douglas & Wildawsky, 1982; Douglas, 1986; Schwarz & Thompson, 1990), risk is seen as a cultural construct. What is a risk? Who is to deal with it? To what extent? Why and for whom is risk justified (or not)? The answers to these questions are related to general worldviews and cultural understanding, with special reference to institutionalized ways of assigning duties, responsibility and blame and accounting for undesired events. Cultural diversity helps explain why different cultures find different themes relevant and why within a complex society the same argument in defence of a technology or a policy choice sounds convincing to some and flawed to others. From this perspective, the best way to manage risk communication is to listen to the worries and concerns of the different communities and groups involved and then set up suitable places and procedures for reciprocal recognition, dialogue and mediation.

In turn, the sociological perspective is articulated mainly in two frameworks. The first framework is environmental justice (Capek, 1993), which systematically connects social injustices with exposure to hazards that result in either accidents or long-term risks; it is systematic in that it is precisely the weaker status of social groups that makes them the typical addressees of health and environmental risks, either in their workplace or at home.

The other framework is the sociology of science. The basic outcome of decades of studies in this field is that, in a broad sense, science is a social enterprise. Not only is it made by human beings, which means that it is not totally immune to error, misunderstanding, vested interests and dishonesty but, above all, it is also embedded with normative, disciplinary value assumptions that go deeply into the process of scientific inquiry. For example, it affects the perceived meaningfulness of research questions or what is to be regarded as *sufficient evidence* in controversial cases (Bradford-Hill, 1965; Pellizzoni, 2010). At the same time, science cannot be regarded as the only source of relevant knowledge, which often also resides in the contextual and experiential competence of workers and residents (Irwin, 1995; Wynne, 1996; Brown, 1997).

It is clear that the choice of framework leads to quite different research questions, designs, and (often) methods and techniques. For example, laboratory tests and structured questionnaires are typical tools of psychometric studies; sociological approaches often mix questionnaires and qualitative instruments (as in the present study); and qualitative designs are usually preferred by anthropological or cultural studies.

The relationship between social research on technological risks and reference communities has become more relevant in recent years. A number of scholars remark that, while scientific activities were once mainly self-organized and internally validated (by means of peer review), in the last few decades the organization of science has changed remarkably. It has changed not only because academic (or comparable) institutions no longer have a monopoly on research, which corporate organizations carry out today to a significant extent, but also because the interweaving of science, business and politics has become increasingly tighter, due to common needs: the need for money by increasingly technology-dependent science and the dependence of politics and business on science that is increasingly innovative (Pellizzoni, 2009). Nowotny, Scott & Gibbons (2001) explicitly talk of a new organizational structure of science (which they label Mode 2), where knowledge production is increasingly driven by context rather than curiosity – that is, by concerns that originate from political or business communities (and to a far lesser extent from civil society groups) rather than scientists themselves. In other words, research questions stem only partly from purely scientific concerns and instead, to a growing extent, respond to political or business needs and investments.

Thus, applying science to policy and regulation is fundamentally different from traditional research, in that the goals of inquiry are as complex as its fields of application. Among these goals are the maintenance of the scientific quality of results, the legitimacy of the process and public acceptance (Funtowicz et al., 2000).

This situation is especially relevant where public trust in science (or better, in policy-relevant science, as is the case with much of risk-related research) is declining (EC, 2000c).

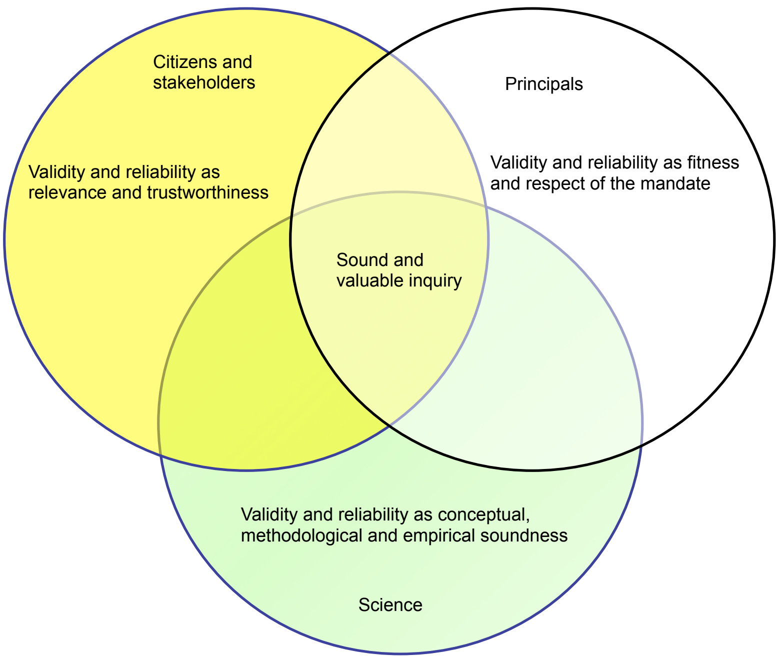
This means that, today, research on the social aspects of risks has to be accountable to three different types of communities: *citizens and stakeholders* – that is, public opinion, local residents, workers and groups affected by the risk, among others; *science* – that is, relevant peer communities of scientists and experts; and *principals* – that is, the actors who specify research mandates and provide the necessary funds. In all three types of communities, accountability means the ability to show that research designs and results are valid and reliable – that is, they actually address the demands and issues raised and do so in a sound, effective way.

Yet, validity and reliability have different meanings. From a scientific perspective, they mean conceptual, methodological and empirical soundness. Such soundness ensures correct, effective research design and implementation, in terms of the formulation of hypotheses, the choice of indicators, the operationalization of variables, the gathering of data and the interpretation of results. From the viewpoint of a citizen or stakeholder, validity means the ability to address concrete, sensitive, relevant problems, worries and concerns. From this same viewpoint, reliability means trustworthiness – that is, the confidence people put in experts and scholars (especially if, at the same time, they are the addressees and subjects of inquiry) should not be misplaced: declared research goals must correspond to actual ones, with no hidden aims and undisclosed uses of data.

From a research financer and principal perspective, validity means fitness and the capacity to address the questions specified, while reliability means respect of the mandate – that is, ensuring that work is actually focused on the matters indicated and is not diverted to other goals or topics.

Ensuring the balance of these three different meanings of validity and reliability is always difficult, since the reference communities differ in their constitution, interests, aims and language. This threefold accountability has no general recipe, and in practice a research project will easily lean towards one direction or another, being more sensitive to the requirements and viewpoints of people, science or the principals. Yet, for inquiry to be sound and valuable from a scientific, ethical and policy viewpoint, some balance needs to be found. A study must find a common region where the three different areas of social reference and meaning intersect (Fig. 58).

Fig. 58. Communities of reference and inquiry in policy-related social research on risk



Methods: general considerations

One of the few golden rules of the social sciences is: do not take for granted the meaning of words and constantly verify that their significance is shared by the audience (Cicourel, 1982). The term *risk*, when taking into consideration the scenarios in which it is usually employed, is probably among those that need more clarification, due to the possible meanings that may be derived from misunderstanding it.

Depending on the circumstances, qualitative research instruments are always refined, to limit misunderstanding and create correspondence between the different motives that drive researchers and social actors. Focus groups, in-depth interviews and participant observations are common tools that assume a particular function when used in areas of risk. Actually, work in a risky area implies a clear commitment to concerns about development, its relationship with the environment and well-being, and precise agreement on the meaning of the word risk. Often, research in these areas aims to produce changes in the environment in which people live, and (regardless of the aim of an actual intervention) this procedure always has political implications. A genuine democratic approach to knowledge and transforming existing relationships cannot disregard those who live in risky areas and must, therefore, be extremely sensitive to the aims and culture of residents, avoiding misunderstandings as much as possible.

Through an example of work and observation carried out in Gela, the present chapter will provide some useful clues for social scientists working in similar areas. This chapter seeks to address redevelopment and to analyse the socioeconomic impact of the petrochemical industry. First, it will describe how the general structure of the study developed (a combination of micro- and macro-information). Then, it will present, in detail, the field research conducted. In particular, it will discuss specific events, based on both the results of interviews and a review of scientific literature and other sources (such as newspapers and essays). All this information is fundamental to understanding the approach taken by the community to collectively orient itself to industry and local economic development (including the viewpoints of the firms operating in the area).

In Italian legislation, a territory can be defined "at high risk of environmental contamination" when major alterations in the ecological balances in water resources, air or soil constitute a risk to the populations and the environment (Parliament, 1986). During the last two decades, three areas of the Sicilian provinces of Syracuse, Caltanissetta and Messina were classified as being at high risk of environmental contamination, due to the environmental and health impact of the industrial activities present in them (for the most part, petrochemical). In consideration of these events, WHO (in 2007) decided to investigate the local populations' perception of health, environmental and technological risks. That meant, among other things, strongly focusing on the concept of risk, which is often taken for granted in both common and scientific language. Moreover, in areas with different levels of awareness, a lengthy discussion of risk often entails concentrating on the meaning of development, future and, in more general terms, issues related to economy and the politics of life. Considering all this led to the decision to proceed with a set of studies that would investigate the three high-risk areas of Sicily through multidisciplinary and diverse tools.

Since the 1990s, the rate at which researchers have integrated qualitative approaches into the techniques they use has been exponential. In one recent contribution, Skop (2006) noted, for example, that geographic research on population was increasingly characterized by methods and themes that are essentially qualitative, deploying methods and ways of questioning the reality of the situation studied that are borrowed from the social sciences, such as anthropology. Many things are changing, and various authors have agreed to use ethnographic analysis – which grasps differences in people's culture and pursues a thorough understanding of the individuals and groups studied – and critical literature in the fields of race and gender (McHugh, 2000; Boyle, 2002; Silvey, 2004). Interest in new methods and categories have clearly affected research practices and have led some researchers to use techniques that differ from traditional techniques based on structured questionnaires and sampling. If Skop's essay exemplifies the link between studies on race or gender and the geography of population, the present chapter exemplifies an attempt to demonstrate how focus groups, in-depth interviews, and participant observations may be used as auxiliaries to (or even substitutes for) traditional surveys.

It should be noted, before starting to discuss the points made above, that the populations' perceptions of their surrounding environment and risks should be considered to be something more than simple responses to stimuli and images spontaneously found in reality or artificially produced, for example, through public communication. Rather, they should be considered cognitive activities that take place day by day, often through pre-logical processes of thought, the contents of which are suggested by events external to individuals and the meaning of which is the result of both an individual and a collective process. If this definition is accepted, one can understand that a *dialogic approach* – for example, the one taken by focus groups – allows the socially constructed and shared nature of people's perceptions to be highlighted: and reveals the process of formation of common discourse in its making.[28] To better explain this issue, one should keep in mind that focus groups consist essentially of 6–12 people in a room who are encouraged to discuss (focus on) a list of points proposed by a moderator (Krueger, 1994). Essentially, the moderator is there to stimulate the group, and their task consists of starting a discussion of the topics in question and favouring the emergence of existing opinions. During these meetings, people aim to produce common definitions of the reality or to split into factions.

Apart from the individual or collective positions that arise during these discussions, it should be noted that a well-conducted focus group may show how social meanings and common sense are generated and, to a certain extent, replicate the dynamics that take place in the course of public interactions. Through increasingly precise specifications, individuals and groups start sharing so-called realities and building opinions that are not simply the sum of different points of view, but are *social* opinions – namely, a common discourse on a specific issue that the members of a community *construct together* or (sometimes) a socially acceptable discourse on the problems at hand (an agreement *process* that takes place over the course of the conversation and sheds light on the differences between individuals and individuals in a group).

Opponents of this and other qualitative techniques may argue that the same goal can be as easily achieved through structured questionnaires. Such questionnaires, if characterized by adequate sampling, present the advantage of offering the statistical significance of the results and a structure that facilitates the interpretation and collection of the viewpoints present in society. Despite this type of argument, the *methodological exclusivism* it implies (though quite imprecise, since questionnaires do not take into account the nuances of opinions and force the interviewees to choose among a restricted range of possibilities) is made obsolete largely by the spread of triangulation practices. Triangulation is a cross examination, which employs at least two methods for collecting and checking data.

For epistemologists, such as King, Keohane & Verba (1994), and authors, such as Phalet & Swyngedouw (2003) – who operate in a field seemingly different from ours (studies of perceived racial differences) – the frequent distinction between quantitative and qualitative research methods is considered to be somewhat artificial and ambiguous. Also, *interpretivism* (the ideational term for which a social actor's agency – that is, the capacity of individuals or groups to take action autonomously and to make their own free choices – depends on their ideas about the situation they experience) represents the ideal type of approach to qualitative research; it aims to create an internal and deep understanding of people's ways of defining situations. The survey, however, which is considered to be the prototype of quantitative approaches, aims to develop general statements about the association between variables. Nevertheless, in terms of the problems and needs of quantitative and qualitative approaches, they have more similarities than differences.

Moreover, since the 1980s, the social sciences have tended to combine techniques and methods. In this way, qualitative and quantitative techniques complement each other, allowing the typical limits of each instrument to be overcome. Problems with significance in many qualitative studies (Giddens, 1976; Schwartz & Jacobs, 1979) may be easily overcome by means of a structured questionnaire that addresses a representative sample of the population; this can be followed by in-depth interviews, so that the attitudes

28 The dialogic approach emphasizes: (a) conversation as a shared activity, with people focusing attention on their own points of view; (b) an open-ended, humorous attitude towards conversation, in contrast to thinking that it produces certainty, closure, and control; (c) a focus on what is happening between listeners, rather than each person focusing on what is going on in the other person's mind, thus co-creating a meaning; and (d) a focus on the present, rather than future goals or on past experiences. The dialogic approach is associated with: (a) encouraging each other to say more, to further explore and explicate their views and doubts; (b) using, extending, and sharing metaphors, which can help reveal new perspectives on an issue or situation; (c) paraphrasing one's statements; and (d) exploring the context of each other's claims.

that emerge during interviews can be measured. Similarly, obscure meanings of unusual associations between variables may be clarified by interviewing the subjects of the research.

Epistemological (methodological) pluralism, therefore, presents various advantages. On the one hand, it allows the development of more refined quantitative tools apt to track the social processes at the base of the *production of reality* – that is, the processes by which individuals interacting in a social system form concepts or mental representations of each other's actions and develop expectations, roles, institutions, collective behaviour, and personal strategies of evasion. Such tools work through horizontal (rather than a vertical) logic: the results of questionnaires become a sum of attitudes and languages that really exist in society (horizontal logic), rather than being the subjective expression of the researcher's interests and ways of wording problems (vertical logic). On the other hand, besides allowing the verification of the significance of certain opinions and experiences, methodological pluralism may shape the logic of the qualitative researcher. Their study will thus continue to analyse a few cases (less than a traditional survey) and adopt an in-depth perspective; but the principles that orient the researcher in the selection of the interviewees, the attention towards the features of the subjects and the attempt to balance different individual participation on the basis of certain characteristics will be highly conditioned by the classical rigorousness of quantitative approaches.

Furthermore, methodological pluralism may contribute to the transparency and validity of research results. Moreover, a comparison of data generated by different techniques (such as surveys and in-depth interviews, focus groups, and participant observations) may serve as internal tests for a research project, thus highlighting the contradictions that arise from data quantitatively generated, reducing the biases that stem from an uncritical acceptance of certain associations between variables, and calling attention to the presence of problems that need to be investigated.

However, the discussion of risk- and environment-related perceptions cannot be reduced to its technical and abstract aspects of data collection. It is more correct to insert methods and techniques in concrete frameworks, composed of goals, needs, ethical commitments and interests. Since studies always develop in a specific setting, it is important to be aware of this, so that it is possible to overcome technical ideas about research that assume the guise of neutrality and interest only in the production of knowledge. Some of these aspects will be analysed in what follows.

Methodology for studying environmental risk in Sicily

This section discusses a case study; but, above all, it shows how it is possible to investigate the present case study in accordance with the above-mentioned principles and methods.

The present study used a three-part or pluralistic approach that, for the study of different areas, followed three successive steps – (a) focus groups, (b) a survey and (c) focus groups – in the case of the Milazzo–Valle del Mela and Augusta–Priolo high-risk areas; and in that of the Gela high-risk area, it used in-depth interviews and focus groups. In high-risk areas similar to Milazzo–Valle del Mela and Augusta–Priolo, the three-step design is advisable when focus groups are employed for exploration – that is, to acquire knowledge of the field and of unknown dimensions of collective perception and to build up an informed questionnaire (Morgan, 1988). The same approach can also be implemented for different purposes: In particular, the present chapter distinguished between a *latere* focus groups (defined in the next paragraph) and validation focus groups.

To better define the above-mentioned points about focus groups employed for exploration, note that focus groups should preferably be carried out before a structured questionnaire is distributed. In the framework of our research, however, the first series of focus groups did not precede compilation of the questionnaire, but took place at about the same time. This was because a huge amount of literature on the subject of our study was available and also because many research institution and programmes employed similar questionnaires. In this situation the function of the focus groups was not so much that of exploring issues, but was that of adapting standardized questionnaires to the context of its new application. Therefore, we define the a *latere* focus group as one that performs the function of verifying whether pre-existing research tools match their new territorial application and are, therefore, refined enough to grasp the local reality as it is experienced by its inhabitants.

However, in view of their flexibility, focus groups may have a role other than the two already considered: validation and a *latere*. They may also perform a role in disproving a thesis. In accordance with a long-standing debate within social sciences on the substantially political nature of research results (Bourdieu, 1979; Latour & Woolgar, 1979; Knorr-Cetina & Mulkay, 1983; Van Maanen, 1988), the practice of *restitution* is slowly taking hold among qualitative researchers. Restitution – originally understood as an exchange between the researcher and the groups observed, which consists of delivering the results of a study to the groups targeted for their internal use – has gradually come to indicate the involvement of the subjects studied in the research, to assess their agreement with the opinions that result from the study (Whyte, 1983). The origin of this trend is the growing awareness of the political importance of any scientific description. Scholarly texts provide the viewpoints of individuals and groups. They can steer the choices of decision-makers and may have an impact on individual and collective lives. The inclusion of people and communities in the writing of a sociological text (or any other kind of text on a specific group) – and the comparison of the internal and external viewpoints of scholars and lay actors on a set of problems – contributes to the democratization of the scientific process.

Also, by using methodological pluralism, participation and restitution provide further benefits: they allow the results to be controlled, thus verifying their validity and dispelling possible doubts raised by the analysis about quantitatively generated data.

The approach used in the industrial sites of Milazzo–Valle del Mela and Augusta–Priolo, consisting of the integration of techniques, allowed us to understand much about the representations of the inhabitants, in relation to their gender, age, parental status and education. In particular, we understood that the array of fears and discontent related to their surrounding environment was broader than we thought and that industrial risk was not their main concern. The populations of those sites experienced apprehension about their economic future and a lack of trust in public institutions, local politicians and their fellow citizens; also, they were disgruntled about the general conditions of their cities – particularly, about their roads, infrastructure and public services (such as garbage collection and access to medical care).

Regardless of the quality of the information collected and in spite of taking such precautions as the use of focus groups with adaptive functions, we began to sense that, mostly, general notions were being applied to particular cases, thus, missing the real peculiarities of each site – that is, the way people produce meaning and dependence on the industry. In other words, we framed the interviewees within an obvious framework – that of the risk-based society – and did not think at all about the processes that lead communities to accept risk and pollution. All in all, we neglected a historical, and more critical, analysis of the context and role of power in allowing certain types of industrial production to be tolerated, in spite of manifest discontent.

The studies carried out in Milazzo–Valle del Mela and in Augusta–Priolo were the basis for the research carried out in Gela. For Gela, we decided to use different methods, based on the large set of data available on the area, the amount of social literature dedicated to this case, and the expected specific character of the city, such as it not being only an industrial area. Since the 1980s, the name of the city has also been associated with organized crime and mafia, and housing speculation (Ciappi & Bracalenti, 2006; Ciccarello & Nebiolo, 2007; Maffei & Merzagora Betsos, 2007). Expressly, the contradictions (consisting of modernization related only to the sphere of production and not to the civil and political sphere) and effects of sudden industrialization were more apparent in Gela than in any other place in Sicily and, probably, Italy. The speedy arrival of capital and investments may have attracted further illegal interests and activities.

At the same time, the new industrial salaries, the remittances from emigrants working in Northern Italy and abroad, the arrival of new people aspiring to be employed in the industrial facilities, and the political patronage of local elites produced a fast and disorderly expansion of the city. Around the historical centre, in a few years, a totally new city spontaneously – lacking services, sewers, roads and infrastructure – developed. Because Gela was an archetype – that is, a lieu, a place where these dynamics were extremely apparent – it became the central object of the present study.

In Gela, we interviewed 51 people who belonged to the following groups:

- institutional figures (politicians in charge);
- members of associations (devoted to environmental and health issues);
- businessmen (in the manufacturing, building and agricultural sectors);
- privileged witnesses (individuals that, for their position, age or status, are able to provide a detailed vision of historically important phases);
- industrial sector workers (employed in the petrochemical plant or in allied industries); and
- common citizens (men and women selected because of their place of residence, which is useful for understanding how such factors as class, education and proximity to the source of risk affect perception).

In addition to these in-depth interviews, we organized a focus group that consisted of nine retirees who worked in the Chlorinated Soda Production Unit, one of the most dangerous units in the petrochemical plant (it was closed in 1984). We must stress that it was impossible to assign a representative character or value to this meeting (Morgan, 1988; Krueger, 1994; Liamputtong & Ezzy, 2005) and that it was a very carefully chosen group: it consisted of a single category of worker associated with claiming compensation for the work conditions under which the group's members suffered for 20 years.

The meeting, however, was needed to collect as many details as possible about the working conditions in the critical units of the petrochemical plant and also about the phenomenon of the commuter workers, to consider the relationship between prolonged exposure and pathogenic factors and the presence of professional diseases (Signorino et al., 2011). The meeting also provided the opportunity to practice action-based research, since a forensic scientist, who advised the group on the plausibility of individual legal actions against the petrochemical plant, participated as an observer.

In addition to in-depth interviews and one focus group, we had a number of informal conversations, with different subjects under different circumstances, about everyday life. Moreover, for about two weeks, we also had the opportunity to visit the canteen of the Eni plant, occasionally speaking with workers and listening to them talk about family, football and cars, and work and safety conditions in the plant. Informal conversations and excerpts of lunch talks were recorded in an ethnographic diary, which was updated during the whole period of field research. This diary is where impressions, talks and events are recorded and in which the early elements of a theory related to the observed milieu develops.

Our qualitative study considered lay actors as qualified witnesses, and it refused to accept common hierarchies. Common people and individuals belonging to the local political and economic elites had the same chance of being heard about the same topics. In particular, our study aimed to investigate and discover:

- trends and ideas linked to redevelopment plans and, more generally, to the regeneration of the Gela area, starting from the needs and aspirations of the citizens: a collection of viewpoints and a bottom-up analyses;
- the developmental potential of the territory and possible agents of transformation – that is, the economic and social agents active in the city and their impact on city life;
- representations and perceptions linked to environmental risk – that is, the relevance of risk to (and its identification by) different social actors;
- perceptions of public health services – such as ease of access and compliance with citizen's needs – and suggestions for strengthening and improving the organization of such services;

- horizontal and vertical relationships of trust – that is, trust shared by institutional actors (horizontal) and citizens' trust in institutions (vertical);
- visions of development among citizens – that is, continuity or innovation of economic development based on the petrochemical industry; and
- transformation of the working class culture and relationships within the factory – that is, solidarity and cohesion.

Although we distinguished between common and privileged interviewees, we tried to minimize the importance of this and balanced the number of witnesses belonging to each category. Obviously, this research did not intend to obtain statistically representative results; rather, it intended to provide clues to solving the problems at hand and to investigate the viewpoints of the local actors In principle, we wanted all local actors to be treated as privileged actors. Local actors provide different representations and viewpoints, ultimately related to their position in society; but they are all equally entitled to contribute knowledge about (and discuss) the environment and space they inhabit. The adoption of this egalitarian outlook made the institutional actors and the workers of the petrochemical industry, and the common residents as well, all worthy of attention.

With regard to the methods employed in the interviews, we chose to submit a common, but nevertheless flexible, set of questions. To each category of interviewee, we posed both common and specific questions, depending on their position and expertise. Moreover, we were alert to unexpected ideas that could emerge from conversations and were ready to use the new knowledge gained in the course of each interview to improve the list of questions and better adapt it to the actors and circumstances. Those originally recruited fitted our criterion of relevance (in the case of institutional, environmental, health and business organizations) and then those recruited after fitted our reputational criterion, by asking the earlier interviewees to suggest actors who deserved to be heard because of their role or personal career (Hunter, 1963; Warner, 1963; Stone, 1988).

The results of this method of choosing interviewees – based on the recommendations of other interviewees – are open to criticism, because of the obvious risk of self-selection of interviewees (King, Keohane & Verba, 1994; Liamputtong & Ezzy, 2005). Nevertheless, the results do not seem overly affected by the limits inherent in the method. Many of those contacted according to this criterion often expressed views radically opposed to those of the person(s) who recommended them and had, in some cases, a semi-hostile relationship with the latter. A key role was also played by a mediator whose credibility and influence in the area proved to be a valuable passé-partout (master key) for access to many witnesses, facilitating contact with a large number of people in less than a month of work.

The development of Gela

In the words of one of the study witnesses, a local businessman who runs a medium-size engineering company and is a member of the Gela section of the Entrepreneurial Association (Confindustria):

> The executive of General Electric looked at the landscape outside the car. He was surprised at the beauty of the countryside, on the road from Catania to Gela. … Eventually, we reached that point on the road where, all of a sudden, you see the refinery and the city, spreading to the horizon. … Suddenly, the American executive asked me whether it was true that the allied forces arrived in Gela when the island was freed from the Nazis. I … said … he was right. "Ah", he said, "then those are the buildings that did not collapse under the bombs, right?" In that moment I understood. … This is how foreigners see Gela: as a bombed city…

In these words are all the key elements needed to introduce, even temporally, our case study. The country, the refinery, the development of an illegal subculture in the city, and apocalyptic urban aesthetics are the phases enclosed in the words of our witness. Yet, the mafia war of the 1980s and 1990s, the assault on the city hall against the laws passed by the Council against the construction of new illegal houses and neighbourhoods in 1983, and the 2002 riot in favour of petcoke are the most important events of the very erosive process that changed the social structure of Gela.

In particular, the story of Gela is not simply a local one and should not be considered a simple case study, because it embodies broader issues related to development and dependency. Its story combines social relations and power, which are universal in nature and are, in essence, connected to big money and peripheral areas. Discussing Gela means discussing the outcomes of centrally steered industrialization: underdevelopment (or industrialization without development) (Wallerstein, 1983; Gruzinski, 1988; Appadurai, 1996; Quijano, 2000), colonial relationships (in our opinion, a strong and pertinent tag – a way of defining the reality sociologically, cited frequently by local actors and many scholars) (Bordieri, 1966; Hytten & Marchioni, 1970; Amata, 1986), job blackmail, uncertain employment, health risks and the resistance it generates in small groups and, finally, a passive citizenry and crime as a resource.

Environment: facts and perceptions

Before analysing the perceptions of social actors, the current characteristics of the Eni Refinery in Gela will be discussed briefly. The local petrochemical industry is a large complex now under the control of Gela Refinery, which includes Polimeri Europa, Syndial SpA (formerly EniChem SpA) and the former Agri-Isaf. The site has two plants for atmospheric distillation and vacuum distillation, a Gofiner unit (to break up heavy hydrocarbon molecules into lighter fractions using heat and catalysts), two coking plants (for processing heavy residual oils, such as tar and asphalt, into more valuable motor fuel blending stocks), an installation for catalytic cracking and alkylation (to produce high-octane hydrocarbons), and a Claus sulfur recovery unit. The Refinery has a refining capacity of about 6 million tonnes of crude oil and produces gasoline, diesel, liquefied petroleum gas and petcoke (a waste substance released during the cracking process). The refinery is powered by a 262-MW power plant that uses different kinds of fuel, such as fuel-oil lourd, high- and low-sulfur oil, coal tar, Algerian methane and petcoke. Gela is the only place in Italy that uses petcoke.

A SNOX process – to remove particulate matter, nitrogen oxides and sulfur oxides – treats the fumes emitted. The discharged water is treated in a sewage treatment plant Tas/CTE (wastewater treatment/thermal power station). A biological plant treats oil refinery wastewater and the municipal wastewater from Gela. The Eni Refinery uses 20 million m^3 of drinking-water from a desalination plant, built thanks to the financial support of the Fund for the South, *Cassa per il Mezzogiorno* (a special economic programme for the South of Italy implemented from 1950 to 1992) and operated by Agip Petroli SpA, while the population receives only 9 million m^3 of drinking-water (Legambiente, 2005; Musmeci et al., 2009). The Eni Refinery provides a set of public services, such as steam and electricity, desalination of sea water and the distribution of fluids. Chemicals handled and released by Gela's petrochemical industries include sulfur dioxide, nitrogen oxides, and particulate matter related to refining activities, as well as ammonia, fluorides, phosphoric acid, cyanide and dichloroethane (Parliament, 1995; Legambiente, 2005; Nardo, 2006; RTI et al., 2007a,b).

These characteristics of the Gela petrochemical complex do not reveal anything about pollution levels in various environmental matrices, but some criminal investigation have. Over the years, criminal investigations often ended up with convictions of senior managers of the complex. The most impressive investigation was carried out in 2003; it led to the seizure of 90 tanks, the contents of which seriously infiltrated the groundwater (Legambiente, 2005).

Also, it should be noted that "the available data show that the plant is a causal source of impact on air quality with particular reference to the relevant annual emissions of sulfur dioxide, nitrogen oxides and particulate matter" (President of the Republic, 1982). With regard to water pollution, it has been verified that for a long time 56% of the waste from the industrial area had "the sea as its receptor, while the remainder was discharged almost exclusively in the river mouth near Gela" (President of the Republic, 1982).

At this point in the present chapter, however, it is not very useful to pursue how much the Gela petrochemical complex polluted over the years. Instead, it would be better to reflect on the questions and tensions, some previously reported, that have emerged. In short, these tensions concern:

- the use of water resources
- the use of petcoke as a fuel for the plants
- the effectiveness of SNOX technology.

Also, the appropriateness of new technologies is currently a matter for specialists. The smoke abatement system – considered by most specialists to be a good tool for preventing pollution – is widely criticized by environmentalists for its doubtful effectiveness. This topic, however, is too technical to involve the general public, particularly in a period of more friendly relations between industry and society where – according to the tone of the public debate and our witnesses – everyone appreciates the financial efforts undertaken by the refinery to mitigate its environmental impact. Instead, other topics seem to involve the general public as a whole, because of the consequences they have on the daily life of the community.

The water issue

Tackling the social problems of Gela begins with the issue of water. This issue arose first in the history of the relations between the city and the petrochemical industry and symbolizes the knot of power. A brief history of the problem follows.

The industry uses groundwater, while the population uses desalinated water – that is, water that is not drinkable and is used only for flushing toilets and washing. This is because industrial plants could be damaged by desalinated water (Ministry of the Environment, Land and Sea, unpublished document, 2007).

During the period between 1963 and the 1990s, 50% of the good quality groundwater flow reaching Gela from the Dirillo River arrived by means of an aqueduct built by Anic – one of the first Italian oil companies, controlled by Eni, to which the Gela complex originally belonged. This water, which was further treated in the refinery plant, was not used for industrial purposes, but was used for civilian needs. However, the population to which the groundwater was distributed was not the one living in Gela, but was that of the residents of the Macchitella Village – an entirely new city built for the workers of the industry in the surroundings of the older city (Vasta, 1998:47–48).

By the mid-1970s and funded by the Fund for the South, a desalination plant was constructed and managed by petrochemical complex technicians. The water produced was sold to the Sicilian Aqueduct Company (EAS) for all civil purposes.

This desalination plant takes its own water from in front of the plant, near the long dock used for berthing oil tankers, and takes water to be used as drinking-water from where the plant discharges liquid contaminated with mercury and other substances (Legambiente, 2005). It is the same area where tankers operate, with frequent spills into the sea of oily substances (Legambiente, 2005). Also, the desalination and water purification processes resulted in water deprived of essential mineral substances, as well as water that was warm. It was inadvisable to drink this water, as stated by a number of city by-laws that forbid its use (City By-law No. 312, 25 July 2003; City By-law No. 110, 3 March 2004; City By-law No. 707, 14 December 2006).

In addition, dirty water coming from old pipes easily infiltrated by soil is a problem. The limited flow of this water is insufficient to meet the needs of the city dwellers, and it leaves large areas of the city without water for most of the day or for several days. This situation induces people to buy tanks, often very large, equipped with pumps to draw water. It results in a race that reduces the water supply, which amplifies the basic technical problems and makes the precious liquid difficult to acquire, even if it is not so scarce.

Finally, at the beginning of the year 2000, the water was officially declared undrinkable. Citizens now avoid drinking-water from taps and buy bottles of mineral water. Such water is also used for cooking and, often, for brushing teeth. During a month, water expenses are huge (more than €100 in some cases and during summers), accompanied by the inconvenience of transporting water bottles from supermarkets to homes, often on the upper floors of buildings with no elevators. The situation is aggravated by taxes on running water, which remain unchanged and increase the feeling of being cheated.

People take very different approaches to tackling the water situation. On the one hand, most of the people who do not know how to oppose the situation accept it, but not without resentment and disagreement. On the other hand, a minority of people are judicial activists, such as those belonging to the Association of Victims of a Miscarriage of Justice.

The water situation has resulted in the circulation of harsh hypotheses and suspicions among the general public. It has also evoked absurd responses. For example, some people in the health sector argue that it is not true that the water is undrinkable and, in fact, drink it regularly (as we verified personally at several lunch invitations). One of the witnesses – a medical doctor playing an important role in the local health system – recalled that Local Health Unit No. 2 of Caltanissetta declared Gela's water drinkable, and he considers the formula used by the regional government an absurdity. The formula defines the water distributed in the city as "potable but not drinkable", and it is difficult to understand. For example, according to local activists working on this issue, it was probably invented to support the struggle aimed at reducing the bills paid to Caltaqua, which replaced EAS and now manages the whole water supply system for the population. In the opinion of the doctor interviewed, the alarm about the drinkability of the water is used as a tool by politicians with no scruples. According to him, the same forces that years ago pressed for water to be declared undrinkable did so to obtain control of the commissionership for water,[29] thus achieving a power higher than that of the local government.

Finally, the interviewees claim that the difficulty of continuing to sustain the use of non-potable water led to more moderate tones in discussions, starting from the use of such formulas as the one quoted above. This formula, in sum, would be a precondition for the recognition of water potability in Gela, as indeed it has partially occurred from the end of 2007. This hypothesis, charming but confused, has to be reported because it shows the climate of local public life and the kind of rumours, suspicions and strains generated by a situation of relative deprivation over an extended period of time.

Such unavoidable suspicions and strains, as the ones just noted, are thus associated with an impenetrable curtain that makes it difficult to establish facts and responsibilities: The attempt to establish a simple definition of the status of drinking-water reveals itself to be a delicate social process, in which rival parties each contest the criteria and methods used by the other for the analyses. Similarly, looking for objective responsibility for inadequate water provision and the malfunctioning of the water system soon results in a maze of institutions and agencies involved in the service, such as Gela Refinery SpA, EAS, Optimal Territorial Authorithy (ATO) of Caltanissetta, Siciliacque Spa, Caltaqua, the municipal administration and the Regional Commissioner for the Water Crisis.

When considering this situation, it is not surprising that some civil society actors and environmentalists chose judiciary hyperactivity, emphasizing the existence of frauds enacted by different parties. Such frauds are related to the management of the plants, to failures to comply with agreements on the relationships between the institutions involved in the management of the service, and so on, in a crescendo of complaints and suspicions that divide the community and spread the belief that the commitment to the public interest is non-existent.

29 In Italy, a commissioner (*commissario*) is an officer temporarily appointed by the government to tackle specific problems. The powers of these officers are then comparable to that of the government or its local representative – the prefect – and are thus extremely vast.

The riot in favour of petcoke

The challenges that involve Gela's water do not exhaust the range of issues that divide the community. The story that best exemplifies the social structure and order of the territory is one that is simply called the riot in favour of petcoke. It exemplifies the dominance of a more powerful group over a subordinate group in Gela's collective mental and cultural forms (Gramsci, 1975; Gruppi, 1977). In this story, as noted by others (Ciccarello & Nebiolo, 2007:44–46), many issues of dependence converge. In our research, these issues are frequently encountered and appear disconnected. In this particular story, however, they are synchronized.

In the case of Gela, dependency means the unconscious adoption of the idea that the factory plays a central role in a person's life and in that of the community and that the survival of the city depends on it. From this stems the idea that the factory must be supported and that any action considered essential to its survival and expansion should not be hampered. In this manipulated ideological framework, it is immaterial that the stability of the factory is obtained at high social costs. Social costs are the necessary trade-off for the maintenance of the social and industrial body. This body is almost metaphysical, but it is very real in that it represents the fusion of the local society's desire for income with the capital that generates profits.

The riot in favour of petcoke was a large demonstration that took place the day after the court-ordered seizure of the petrochemical complex. The decision of the local court, after an investigation that followed the provisions of the Ronchi Decree (Parliament, 1997), defined industrial waste as the coal oil (or petcoke) employed in firing the plants and, subsequently, declared its use in the plant illegal. Petcoke is the solid residue obtained from the refinery process called *coking*. Despite its high calorific value, its use as a fuel is not common in Europe due to the high content of sulfur, heavy metals and polycyclic aromatic hydrocarbons, and the resulting environmental impact. Petcoke, however, is an inexpensive and effective way to produce power for the refinery, and its use as a fuel is symbolic. The discards of the refinery process – comparable to those produced by the digestive system – are used to feed the same process.

That this practice is disturbing is confirmed by the unusual and abundant presence of arsenic and molybdenum in the territory of Gela, probably related to the use of petcoke (Bosco, Varrica & Dongarrà, 2005). In Gela, there are also heavy metals, dioxins and a large number of substances related to the combustion of petcoke that are likely to generate toxicity, cancer and malformations (see Nardo (2006) for a discussion of the social reactions to these data).

The residents reacted against the framework of an actual health and environmental crisis and a judiciary act intended to defend public health. In 2002, about 20 000 Gela inhabitants, affected by the slogan "better sick than unemployed", took to the streets in defence of the refinery and against the order of seizure. They erected barricades, stopped access to the city and fought the police.

In 2002, another southern drama occurred, one characterized by resistance to misery and the struggle for a job, any kind of job. That year, a *biopolitical representation* (Foucault, 2008) occurred; it was the apex of successfully disciplining local people to internalize the ethics of production, labour and profit, all at the expense of life. Although it is very likely that these terms accurately portray a large part of reality, it is not the sole interpretation. A correct interpretation should also consider the weight of misinformation, the role of trade unions and, finally, the pressure of a local senator, a member of the political party Forza Italia. This politician committed himself, in agreement with the staff of then Prime Minister Silvio Berlusconi, to enact a decree that would redefine the nature of petcoke, transforming it from a waste into a fuel (Ciccarello & Nebiolo, 2007:45–46).

Largely unable to thoroughly understand what was at stake and the relevance of the possible violations, the residents believed the misinformation. Certainly, one cannot believe that the residents were completely naive, ignorant, and insensitive. Because of the high rates of congenital malformations in Gela and because the public was acquainted with the illness and pain that characterized the life of the community, the majority of the population clearly understood the risks of industrialization. Most likely, however, they were simply ambivalent. Ambivalence is probably the main characteristic of this population, which is divided between legality and informality and between environmentalist feelings and loyalty to the industry. Among other things, their ambivalence was confirmed the following year by the ease with which the same population welcomed the seizure of 90 tanks, despite the problems that this act entailed for workers and corporate profits.

During the riot in favour of petcoke, the actions of some professional activists (perhaps the unions) might have helped to emphasize some aspects at the expense of others. With the exception of the main Italian union, the Italian General Confederation of Labour (CGIL), which proudly claimed an active role in the organization of the demonstration (Rassegna.it, 2002), trade union representatives, in general, stated that they joined the demonstration once it was spontaneously organized by people; and all the unions rejected any responsibility for the episodes of violence that occurred. However, many statements collected by us and other researchers (Ciccarello & Nebiolo, 2007:46–47) are claims that the three major unions (CGIL, the Italian Confederation of Workers Unions (CISL), and the Italian Labour Union (UIL)) played an important and not-so-hidden role in mobilizing demonstrators, controlling the space and talking with key players in the riot.

These claims seem plausible and are supported by the view that unionism in Gela during those years suffered the same structural constraints that already limited its action 50 years ago. Those embedded constraints, according to the interpretation given by Hytten and Marchioni (1970), were essentially derived from the so-called state company with which the unions interacted. The state company was historically entrusted with the role of countering the oligopoly of large, mostly foreign private companies and the traditional land organization in Southern Italy. The company also pursued capitalist objectives, but did so with the view of producing *social profit* – that is, the supply of jobs and welfare. In Gela, the local unions and the rest of society considered the petrochemical establishment to be a public property – or a friend – and certainly not an alien entity.

Added to this socioeconomic trap is the role of the political sphere. Political parties and trade unions both represent collective and social demands imperfectly, dealing with industry on behalf of particular groups and special interests. As a result, many trade unionists inherited their jobs (the tradition of passage from father to son), reproducing what might be called the elementary forms of domination and contracting debts with the company since the very first contact with it. According to many of the trade unionists interviewed, the modern trade union should not be in conflict with employers; rather, it should always aim to negotiate and seek to merge with the interests of employers and employees. The individualistic methodological perspective (Boudon, 1986), however, suggests not indulging too much in structuralist criticism but instead questioning whether the unions, by organizing a great revolt against the closure of a company identified as the only real employer in the territory (providing jobs also to small entrepreneurs, the *padroncini*), were actually fulfilling their mission – that of defending employment, wages, and welfare.

If this is true, how can trade unions remove this contradiction: devotion to the ruling groups' ideology, which is also a defence of the unions' welfare? How can trade unionists leave a vision traditionally concentrated on the local oil industry and rid themselves of the view of the inevitability of the status quo? Above all, is there really an alternative to toxic substances and air pollutants from the plants?

The attempt to fully answer the questions about these dilemmas, however, would take us away from the specific historical events treated here. However, the above mentioned senator – who imposed relabelling petcoke as a fuel, instead a waste – provided an initial reply to some of these questions. Contrary to scientific evidence and the principle of caution, he asked his political community to transform a highly toxic substance into an innocuous one (an endeavour that eventually resulted in Legislative Decree No. 22 of 7 March 2002 (Parliament, 2002), which laid down urgent provisions for regulation of the use of petcoke in combustion plants).

This transformation, however, did not settle the issue and it was necessary for ENI to invest €200 million, to be spent on the environment, together with the use of SNOX technology to eliminate the fumes (a best available technology, as required by the EU). A novel communication strategy, focusing on large investments and social responsibility, allowed the company to gain much wider approval among the population than in the past. This move might have ended the age of disagreement.

The trade unions appear to be major backers and sustainers of the new corporate course. This position is spread among different layers of population. Even among those who do not hesitate to call themselves critics, it is very common to find agreement on the progress and efforts that the Gela Refinery has made in recent years. It would seem that the city is witnessing relative peace – one that continues to rely on its earlier shortcomings. It is a situation that relies on realism and the awareness of the shortage of alternative choices.

Resistance: environmentalists' arguments and tactics

Despite the extensive communication campaign conducted by Eni, some of the company's opponents do not accept uncritically the rhetoric of change and insist on substantial adjustments. The opponents include such environmental (green) groups as Legambiente, Aria Nuova and Amici della Terra. Criticisms raised by these groups stressed the fundamental conservatism of the oil company in choosing to use petcoke. They stress the limits of the technologies deployed and their management and operation under the ordinary conditions of production. The local Legambiente branch reported that, for years, lawful compulsory controls have not been carried out. In 2006, four years after the enactment of Legislative Decree No. 22 of 7 March 2002, the omission of compulsory control according to this legislation resulted in the company being convicted (Nardo, 2006:10). Based on an analysis of documents produced by Eni, Legambiente's report notes that the technologies currently on the market are unable to obtain a real conversion of heavy oil loads. None of them can eliminate or at least significantly reduce the production of oil and petcoke.

From an environmental impact perspective, the use of residues from the refinery process is a major issue, because contaminants concentrated in the heavier fractions of oil (in particular, heavy metals, sulfur and nitrogen) lead to the release of highly polluting substances. However, research conducted by Eni has identified a new set of technologies, called Eni slurry technologies (EST), which are intended to overcome the problems currently inherent in the utilization of available fuels. These new technologies, already used in Taranto and to be applied in a plant in Sorrazzana, are supposed to provide almost complete conversion of heavy crude oil and offer significant advantages in outcomes and quality of products, thus supporting the claim of excellent removal of heavy metals and sulfur.

Green groups, however, are not monolithic, and there are major differences between local groups. In particular, we have seen that the set of actions carried out by Eni has increased the scepticism of local environmentalists as a whole. Interviews with its leaders show that Legambiente, which may perhaps be considered the more technical and pragmatic group in the city, decided to follow Eni on its own ground, seeking alternative technical solutions (already developed by Eni, which is investing heavily in research) and requiring structural changes and increased investments to radically transform the technological philosophy of this large corporation. The same attitude is not found in other local environmental groups, due to lesser human resources and available skills and to the presence of an ideology that demands the closure of the petrochemical plant, rather than its improvement.

Aria Nuova, for example, as well as Legambiente, invests its limited resources in research. But rather than seeking technical alternatives, its activities have focused mainly on environmental monitoring, looking passionately at the signs of ecological disaster produced by the petrochemical establishment during its years of operation in Gela. Although its studies are poorly funded, they often result in remarkable judicial activity and the presentation of a large number of complaints. This hyper-activism has alienated many local actors, including those sensitive to environmental issues. In any case, this environmental group has identified many violations related to losses from tanks and pipelines.

Aria Nuova carries out investigations, employing methods that, by its own admission, have limitations. Its investigations include fieldwork, taking samples of soil or water and sending them for analysis to private laboratories or universities. For this, it uses personal networks, to ensure acceptable quality and cost–effectiveness of the analyses. Following the outcome of these investigations, it then tries to influence judicial activities. It takes the outcome of its activities to the judicial system, entrusting to the court and its experts the task of ascertaining the facts. It also lobbies for the case, establishes itself as an injured party, and tries to involve the media, albeit with little success.

Consideration of Aria Nuova leads, almost inevitably, to consideration of Amici della Terra. Locally, the presence of the two groups is the result of a split that occurred at the beginning of the new millennium, due to different interests, ambitions and courses of action. One fundamental difference between the two groups is that Amici della Terra focuses on the relationship between health and the environment. With regard to this, it may be useful to consider the concept of popular epidemiology (Brown & Mikkelsen, 1990), which can be broadly tracked in Gela's society.

Popular epidemiology is bottom-up epidemiology that arises from uncertainty, from anecdotal and unsystematic observations of the abnormal spread of certain diseases, and from the dissemination of a kind of popular medicine, conveyed by the media and spreading bursts of information – for example, the possible relationship between hair loss and exposure to mercury. It is popular science, essentially positivist in nature – as it is confident in the possibility of producing sound knowledge and detecting incontrovertible associations between the presence of harmful factors and the onset of a disease. It is so-called science that has a fundamentally different character than much of contemporary science, which is more engaged in casting doubts rather than creating certainties. One could even say that popular epidemiology is an extraordinary catalyst of insecurity and a vehicle for spreading often unsustainable theses, for which the only effect is multiplying the fears and anxieties of vulnerable people. However, if from an academic and political perspective these characteristics sound negative, it should be kept in mind that popular epidemiology is also a form of resistance that can raise subdued issues and fill relevant information gaps, often providing outstanding insights.

Interviews with older leaders of the local environmental movement are, in this sense, exemplary. Analysis of the individual and collective processes that guided their political involvement shows how certain practices arose from the (sometimes extreme) need to make sense of their own pain and from the difficulty of placing the loss of loved ones in the order of nature.

This was particularly evident when a witness made, for example, a reference to their 94-year-old grandfather's death from cancer. It may appear to be a natural death from the perspective of any observer, but it was felt as unnatural by the witness interviewed.

In other parts of the interview, it was hypothesized that uterine cancer may be related to the water used for hygienic practices. This suggests strong elements of irrationality behind the practices of this kind of movement. Yet, this type of thinking also contains the extraordinary ability to perceive trends, since the sensitivity of these witnesses to an abnormal cancer rate was confirmed by subsequent research, carried out also on the basis of their reports (Pasetto, Comba & Pirastu, 2008; see also Chapter 9). The same type of thinking structured the method used to highlight the number of deaths attributable to inaccuracies in death certificates, which consists of analysing the so-called exemptions – that is, the number of people exempted from the payment of drugs needed for curing certain diseases. Certainly, it reflects epidemiological imagination.

Our analysis would not be complete without reflecting on the lack of trust displayed by many witnesses. In particular, we need to address the widespread view that doctors are corrupted by Eni. Some witnesses had misgivings that the data on the deaths from cancer and other diseases attributable to environmental pollution had long been unavailable because of deliberate omission. The view expressed by some was that for years doctors intentionally filed false certificates of death to hide the effects of pollution, to protect the petrochemical establishment.

The plausibility of this hypothesis will not be discussed here, but it is worthwhile to reflect on the impact produced by bad management of information on similar topics and certain micro-practices in the field of health. In line with this, the construction of reality made by social actors seems to consist of apparently tiny pieces that have the power to create great distance between institutions and the public, thus enhancing the culture of suspicion. Also, some medical practices in use for decades have not only caused a substantial loss of objective information for studying pathological phenomena, but have also discredited health institutions and increased distrust in these institutions. These occurrences demonstrate the strategic role of communication in improving the relationship between public institutions and the general public, and they also provide important indications of local distrust. Anyone interested in improving the relationship between institutions and the general public in the Gela area, or similar places, should consider the practices that determine a serious crisis in trust.

Redevelopment plans and territorial scenarios

Any discussion of the permanent projects proposed for the area has to address the issues of land remediation and redevelopment. While it is possible to discuss the redevelopment plans as primarily ecological and needed for a healthy environment, it must also be kept in mind that the reclaimed areas are often abandoned areas, which have lost polluting activities and other economically valuable ones. It is crucial to keep this in mind because, as noted by Iaccarino (2005), abandonment is an event at the end of a life-cycle that cannot be considered merely industrial. Often, a spontaneous process of territorial and social degradation follows the abandonment of a site; if extended over time, this process complicates the possibilities and actions needed for rehabilitation. Besides being an intervention in the local social and working conditions, rehabilitation involves remediation. According to Iaccarino, abandonment should thus be considered a potential anomic process (one that lacks social norms), which can cause significant and widespread forms of deprivation because of the development of social fractures – to wages and lifestyles, for example.

From this perspective, abandonment (and redevelopment) is a border between the present and past economic and social formations of a place. Therefore, any consideration of the social impact of an industry in a particular territory must deal with, at some point, the future of abandoned spaces and of those that will also be abandoned.

As representatives of Eni stated in the course of a meeting with Italian researchers, held in Gela in June 2008, the corporate vision sees oil as a core business for just the next 20 years. In this context, those now in their 20s and 30s could experience years of crisis in Gela local society, probably extended to all of Sicily, because of the strong presence of Eni and its associates all over the island. Such a crisis should, therefore, not be conceptualized exclusively in terms of lost jobs, with few chances of being absorbed by other activities within the city or the island – unless new enterprises develop and are able to employ an equivalent number of these future unemployed industrial workers. Instead, the concept of crisis must be interpreted territorially, since one should add to the problem of unemployment that of a compromised land that cannot easily be used for either economic or civil purposes.

In 1990, the Gela area was officially declared to be at high environmental risk. In 1995, the rehabilitation plan took form (President of the Republic, 1995). Later, by Law No. 426/98 (Parliament, 1998), the site in Gela was ranked among the top 15 sites of the National Remediation Plan. Funding for rehabilitation, the equivalent of more than €20 million, was allocated initially. This money, however, remained largely unused for over five years. The funds were supposed to be used to finance a total of 47 interventions, 14 of which were to be paid by companies (mainly belonging to Eni) and 33 by the state. With regard to the interventions hitherto carried out, Eni believes it has fulfilled its obligations: by using SNOX technology, performing maintenance activities, and performing some drainage inside the factory. With regard to interventions by public institutions, rather than focusing on remediating contaminated sites, they focused on characterizing and correcting the problems of a closed landfill, constructing sewers, doubling the capacity of a wastewater treatment plant, and creating an air pollution monitoring network. In 2000 the Plan was assigned to a commissioner and its implementation delegated to the Prefect of Caltanissetta, to whose authority Gela is subject (Legambiente, 2005).

To help portray the environmental situation, it should be noted that landfills affect the entire territory of Gela, with 47 individual areas identified. Also, some areas, located in protected sites, have been used for the illegal extraction of inert matter and eventually serve as uncontrolled landfills of all types. The effects of intensive greenhouse agriculture near the protected area of Biviere should also be noted. This industry, arbitrarily settled on state-owned lands, makes extensive use of pesticides and fertilizers that easily infiltrate the sandy soil and groundwater.

Ultimately, the range of remediative interventions is limited and substantially inadequate for the environmental conditions present in the Gela area. Over the past 15 years, many practical, political and financial obstacles have reduced the scope of (and slowed) the rehabilitation plan. Currently, the interventions appear to be stalled, even though new agreements have been signed and further interventions may take place in the long run. Although the intentions of many public actors are beyond suspicion, the slow progress of the rehabilitation plan has fuelled suspicion among outside observers, about the efficiency of the administrative system, and raised questions about possible conflicts of interest causing the slowdown in plan activity (Commissione Rifiuti, 2007). In as much as responsibilities are distributed more or less evenly over the various administrative levels (local, regional and national) involved, it can be argued that solely blaming local politicians is quite unfair.

The interviewees, however, support the hypothesis that the local social organization should be interpreted in light of the particular interests, not always legitimate, held by small groups. It must be borne in mind that the economy of remediation plans is extremely vulnerable, and it has often proved to be a privileged field of action for so-called eco-mafias (Legambiente, 2003).

As already noted in the present chapter, a vast area of Caltanissetta Province is characterized not only by a widespread state of decay, but also by the presence of a dangerous form of organized crime that has penetrated a significant part of local enterprises and the public administration (Lalli, 2002; Bucca, Colussi & Urso, 2004). It is clear that the resources allocated for interventions are a major target for organized crime and that counteracting this process requires extreme care that, however, entails an increase in delays. Such delays must be added to the physiological slowness that stems from the conflicting relationships that characterize the social and political forces in the territory. Care is needed so that legitimate actions against organized crime do not become both an excuse for justifying delays and an excuse, in the eyes of the public, for rewarding small interest groups close to the administrations (regional, provincial, municipal and others): this is a perception shared by many interviewees, both privileged and common.

We argue that the rehabilitation plan and other environmental and public projects go beyond practical and technical impacts. Such plans have a symbolic and communicative value. Because environmental rehabilitation generates widespread social expectations – in a setting of widespread suspicion and distrust – it is interpreted by the community as being negative and even conspiratorial. In the context of the events that occurred in Gela, many political decisions made in the past ended up reinforcing the idea that law is a blurred concept open to continuous negotiation. This happened when decisions were made about construction, industrial development, water, petcoke, and greenhouse crops – with a complete lack of land-use and urban planning.

We therefore assert strongly that the themes and actions that relate to the environment lend themselves – better than in other areas – to the manipulation of symbols and values. The collective imagery, making up the perceptions hitherto discussed, is the result of the manipulation of symbols that occurred during the 50-year period when the relationships between local communities and industry developed. Therefore, the rehabilitation plan, beyond its effects on health, also constitutes a lieu where renovating the social order and its related imagery is possible. Failure to do this would damage public health, institutional trust and the economy of the area.

Discussion and conclusions

Our study highlights three critical aspects. The first concerns the issues that characterize the public debate in Gela. These issues – analytically discernible, albeit intertwined – are: (a) health and environmental risks; (b) employment and economic development; and (c) the broader social context (which includes power relations, social stratification, and occupational and land use patterns). In part, the emergence of these issues may be attributable to the way the study was carried out and the choice of research questions. Nevertheless, the topics addressed in the interviews and the focus group were diverse enough to provide a sufficiently robust picture.

The second critical aspect is timing. The development of each topic considered had its own timing, which the interviews and the documents examined confirmed. Moreover, the relationship between past and present (and, probably, future) is complex. Its character can be captured by the following categories.

1. **Continuity and change.** Sometimes the evolution of the issues is characterized by breaks and gaps in their features and the people involved, which allows the identification of actual phases. At other times the evolution is continuous, without gaps and breaks.
2. **Local and extra-local.** Sometimes evolutionary dynamics depend on events or decisions fully external to the sociopolitical and territorial context of Gela. At other times, such dynamics are influenced, instead, by factors or actors that relate to the Gela territory or to a more encompassing (yet directly related) geographical and political scale (province, region).

The third critical aspect concerns the interpretation of the results of the study, which (in our view) allows two opposed (yet complementary) readings.

1. **From particular to general.** Here, attention focuses on what the case studied shares with other cases. Our case can be easily compared in many respects with those of a number of industrial sites. Yet two points emerge. One concerns scientific matters. What does the Gela case teach us? What does it add or modify, confirm or disprove, compared with the knowledge and speculations available in the literature on technological risks and conflicts, economic development, social capital and other factors? The second point relates to policy. Do the similarities between this case and other cases provide evidence that measures implemented elsewhere might be usefully applied to Gela?
2. **From general to particular.** Here, attention focuses on what is peculiar and (maybe) unique about Gela – that is, the meaning that features characterizing other cases assume in this particular context. Again, the issue is twofold. First, from a scientific point of view, it is useful to inquire whether and which limitations stem from interpretations based on the general insights offered by the literature. Second, from a policy point of view, it is useful to inquire whether and which adaptations or creative solutions are needed to produce valuable and effective interventions that target the local problems.

Does Gela share a common fate with many other places affected by industrial modernization and have ambivalent feelings about its quality of life, or does its history contain some peculiarity from which a lesson can be drawn? As expected, the answer to these questions points to both these interpretations of the situation. Yet, much about the case of Gela depends on what one takes into consideration.

For instance, the issue of risk had no significant peculiarities. In the case of Gela, fundamentally, the ingredients were the same as those found in dozens or hundreds of other cases. Even the timing of social reactions – from uncritical reception to early doubts, from the rise of environmental consciousness to the development of popular epidemiology – looks remarkably like what was detected in other cases (Auyero & Swistun, 2008; Cable, Shriver & Mix, 2008).

Similarly, with regard to the economic, occupational and territorial aspects, the case of Gela is not much different from what one finds both in high- and medium-income countries and in low-income countries. Nevertheless, some specific aspects were singled out: they are obviously related to Gela's local history and are reflected in a compromise model of development – that is, in a particular association between novelty and continuity, modernization and permanence of traditional lifestyles and attitudes that characterize the social life of the area.

For many aspects, Gela shares the same fate as that of places that have suffered from, but also taken advantage of, industrial modernization. Its story, however, does not simply add a brush stroke to an already refined picture, but offers significant elements to a landscape still remarkably uncertain and incomplete. Our analysis draws attention to the capacity of capital – in particular, in its industrial and technological form – to shape Gela's operational context (which includes social stratification, power relations, and occupational and land-use patterns) and, at the same time, to adapt to this context, creating jobs and relative affluence, but also producing and re-producing marginalization, deprivation, dependence, and social and environmental degradation. Then, a historical perspective becomes crucial to understanding the current situation and planning for the future.

In other words, the past needs to be examined and a genealogy of the evolution of forms of power, consensus and subordination needs to be conducted, as they were produced locally in the course of time. In this respect, the most important lesson to be drawn from this research is that if Gela shares with other areas of the world, of Southern Italy and of Sicily itself, a history of delayed, partial or failed socioeconomic development, then purely economic or ecological interpretations might be incomplete and fundamentally biased. Economy, society, culture, territory, environment and technology intertwine and affect each other. Even though the ingredients are the same as those present elsewhere, their blend may be unique and should be analysed as such; one should also keep this in mind, to understand the capacity for environmental rehabilitation, which can only be obtained when combined with social renewal.

Despite the struggles and valuable efforts of many of its actors, Gela is degraded and its decline is environmental and psychological. Complementing this decline are clashing views of the stakeholders, the absence of a collaborative project, the scepticism of many, and the difficulty in identifying social forces capable of promoting significant changes. In short, the positive indicators, although present, are contradicted and apparently outweighed by negative indicators or are (at least) tarnished by a confused and uncertain situation.

However, a genealogical approach – that is, a reconstruction of power relations and consensus building in their historical evolution and, more generally, of the intertwining of the economy, society, culture, territory, environment and technology peculiar to Gela – offers some clues. As noted above, our study shows the existence of a structural relationship between the petrochemical plant, the territory and society. Every action of the first element in the relationship inevitably affects (and cannot be neglected by) the latter two elements (and vice versa). From this perspective, one can likely draw interesting policy indications for change. Such indications, however, cannot be properly elaborated here. Yet we think they are related to the following points, which we suggest as a possible starting point for further reflection and inquiry.

1. Because of the complexity of the factors that affect the situation in Gela and their interconnectedness, a simple and optimal solution to the socioeconomic and environmental problems of Gela is unlikely to exist. Multidirectional and reversible solutions, which can be modified according to their effects, seem then (with other things being equal) preferable to policies that result in unidirectional and irreversible solutions, because of their economic scope, technological characteristics, and social and environmental impacts.
2. Whatever policy is adopted, it cannot rely merely on theoretical considerations. Rather, it should be based on a thorough knowledge and analysis of the dynamics and characteristics of the sociocultural, political, economic and territorial features of Gela. Rather than singling out and implementing some theoretically winning model, an exercise in humility and creativity is preferable. Such an exercise aims to improve one's learning capacity through what can be described as strengthened reflexiveness – with severe examination of past mistakes on one side and constant verification of current actions on the other side.

Unless major changes come from the outside – which is possible, given the instability of global markets and energy policies – the most easily predictable and enforceable policies in Gela are adaptive and incremental (Lindblom, 1965). The difference between a good and a bad policy (good meaning a policy capable of improving the quality of life, work and the environment and of strengthening not only the incomes of Gela's inhabitants, but also their sense of community) depends, in our view, on the adoption of the substantive and methodological criteria noted above: a preference for multidirectional and reversible solutions and an attitude of constant, critical review of one's own behaviour. Such insights, we hope, may also prove useful in other contexts, where communities are affected by complex environmental and social problems.

17. PERSPECTIVES FOR SUSTAINABLE LOCAL DEVELOPMENT: INTERVIEWS IN THE AUGUSTA–PRIOLO AREA

Daniela Stuto and Luca Pezzullo

Introduction

This chapter addresses the issue of risk perception in a population living close to a large industrial area. It aims to define the feasibility of integrating qualitative approaches with the more common methods used in environmental research. Also, it will discuss methodological guidelines that are useful for research in industrial areas, as well as the analysis of specific results from a case study.

The chapter has the following four-part structure:

1. a short introduction of risk perception of industrial sites;
2. the methodological issues in environmental qualitative research, based on grounded theory approaches (with the use of software for qualitative data analysis) and the use of a SWOT analysis – the two major approaches used in this work;
3. an analysis of the results of a case study and further discussion of methodological and operational aspects; and
4. conclusions and suggestions about possible methodological generalizations for research in similar contexts.

Environmental risk associated with industrial sites

The scientific study of environmental risks associated with industrial sites has a long tradition: studies in environmental science, industrial and safety engineering, toxicology, epidemiology and land use have contributed to understanding and defining it. In recent years, this field of study has displayed significant growth, following the international development of environmental regulations and the wider recognition of the social implications of industrial risks and their sociocultural impacts. Environmental sociology and psychology have contributed to this recognition. Following major accidents, such as the Flixborough disaster in the United Kingdom in 1974 and the Seveso disaster in Italy in 1976, European legislation related to high-risk industrial sites has progressed in dealing with the prevention of such accidents. These accidents share similar characteristics: local authorities lacked specific knowledge about the substances used; local populations lacked information about emergency procedures; and there was a lack of emergency plans.

In Europe, some of these problems were addressed by the Seveso directives: Seveso I, Seveso II and their normative interpolation in different national laws (see also Chapter 13). The Seveso directives established clear normative indications about risk management, informing populations, and emergency planning for inside and outside the plant. Following these directives, many surveys investigated the perception of risk and the information needs of concerned populations. This was done to help plan risk-related events that communicate the social, environmental and health problems related to industrial activities.

Risk perception

Thinking about development means thinking about territory. The concept of territory includes not only the evaluation of geophysical characteristics, but also includes the processes that occur within its boundaries, such as the possibilities offered by urban settlements, by the promotion of economic evolution (Gelosi, 2004) and, above all, by the consideration of *contexts* and *representations* – the depiction or portrayal of the territory in a particular way. Risk perception analysis often identifies processes characterized by the fragmentation of representations. Here, fragmentation refers to the different representations different local actors have about the same territory; at the same time, it refers to the fields of research and the different and somewhat fragmented methods used to study territorial processes. A complete risk perception analysis that supports a development plan needs to overcome the fragmented perception of territory. This fragmentation is split between physical and emotional elements, which include the cognitive and social representation of risk.

The current literature on research, and also international guidelines, increasingly stresses that the success of a local development programme depends largely on the ability to involve local actors in its implementation, taking into account their representations, their needs and their problems. This clearly means mapping a territory's needs and the positive trends that sustain it and its competitive advantages, and also the weaknesses in need of eventual management. To aid this mapping, the psychosocial and psychological sciences can make useful and constructive contributions, both to greater knowledge of local processes and to the organization of operational responses.

In the 1980s, procedures for assessing and managing environmental risks began to evolve institutionally, politically and normatively. During this period, the concept of risk began to spread widely in society, the media and among decision-makers; at the same time, the institutional governance of risk began to show increasing consciousness of the concept of stakeholders, thus involving the general public more actively in the management of risk situations. Risk was transformed from a mere technical problem to a complex social issue. Also, the old technology-oriented risk management logic – based on the positivistic management of risk (that is, based on the view that sensory experiences and their logical treatment are the exclusive sources of worthwhile information) and interventions centred on the use of machines – developed in complexity and articulation. Moreover, risk governance evolved from a technological matter to a social process. For comprehensive analysis, engineering-type knowledge alone was insufficient or inadequate, and stakeholders' perceptions, local actors' actions, and local knowledge began, slowly to be included in risk management processes.

The perception of risk is not always influenced by so-called real risk. Risk has its own real existence, which is linked to evaluations performed by different disciplines – for example, environmental geology, engineering and epidemiology. Its impact and functional characteristics, however, are mediated by the perceptions and representations of individuals and groups and by social, cultural and symbolic factors. Several factors influence a person's decision to accept or reject a risk: different people perceive the same risk differently, and this may depend on age, gender, cultural background and educational level (see Chapter 15). The debate about risk cannot be restricted to the scientific correctness of mental representations; it is often a matter of how the interpretations frame the behaviour, not just the scientific correctness of particular behaviour. Therefore, if a researcher wants to initiate effective preventive campaigns to reduce risk exposure, he or she should, first of all, understand which social representation local actors and stakeholders have about their relationship with the territory.

Even today, some communication and education programmes for populations are prepared by experts who, in good faith, believe that their own mental model of the risk is the only real and objective one. In this way, recognition of different ways of constructing the meaning of the territory and its risks is unduly neglected. These implicit mental models generate the risk-related behaviours and attitudes; therefore, understanding their complexity and multidimensionality is a key step in any approach to risk mitigation, risk communication and risk management (Granger Morgan et al., 2002).

Risk research

The current tradition of research on risk perception was developed in the 1970s, with a programme of psychometric research on cognitive factors related to the perception of risk. These factors were associated with various functional elements of natural or technological risk – that is, the psychometric paradigm, which focuses on the roles played by emotion and feeling in influencing risk perception and examines how much risk people state they are willing to accept. To complement this approach, other theories and methods of risk perception were proposed, such as the Douglas–Wildawsky Cultural Theory and other qualitative approaches. For Douglas and Wildavsky (1982), risk is culturally constructed, which explains why different cultures choose to deal with certain hazards while ignoring others. Thus, according to the cultural perspective, risk is a socially constructed response to facing a real danger that exists objectively, even if knowledge of it is mediated by psychological and cultural processes.

Constructivist-type and qualitative psychosocial research approaches seem to show significant results on the subject of risk.[30] The critical appraisal of cultural, phenomenological and constructivist theories undoubtedly enhances our perspective on how people represent and react to situations that present risk. During the 1990s, within the cognitive evaluation of the risk framework, mental models studies were applied with excellent results to the study of representative forms of natural hazards and man-made risks; from an organizational and functional point of view, these studies were anticipated by Turner and Pidgeon's seminal work (Turner, 1978; Turner & Pidgeon, 1997).

In recent years, some of these approaches were synthesized within the social amplification of risk framework, which tried to unify the various aspects of social representation and social communication of risk (Pidgeon, Kasperson & Slovic, 2003). Psychological approaches are also diffuse and proved to be useful for understanding social representations of risk (for an overview of these approaches, see Slovic, 2000).

Risk perception: experts, laypeople and trust

In the scientific literature, many researchers have addressed the different ways experts and laypeople represent risk. These different views and ways of processing risk-related cognitive and affective information (related to moods, feelings and attitudes about a given situation that provide cues for information) have been studied by the United States Environmental Protection Agency (EPA, 1987) and, more recently, by Sjöberg (1999) and Slovic et al. (1995) and their research groups, among others. In recent years, some researchers have demonstrated that the risk assessment processes experts and laypeople follow are fairly similar (Rowe & Wright, 2001; Sjöberg, 2002). Nevertheless, there seem to be some functional differences (De Marchi, Pellizzoni & Ungaro, 2001): experts tend to conceptualize risk in a way that is more quantitative, impersonal and oriented to theory, while laypeople tend to conceptualize risk more in terms of personal impact, using more affective-information-based processing and basing it on local knowledge. Also, the connection between expert status and trust in institutional actors is functional, and this connection helps explain the different perceptions of laypeople and experts (Sjöberg & Drottz-Sjöberg, 1994).

Since the early 1990s, in studies of risk perception and communication, a promising line of research has focused on the theme of trust – that is, the social trust that stakeholders, both the general public and specific local actors, place in institutional communicators of risk. Trust in institutions was estimated to be a significant factor in risk communication, one that was relevant to the general public when receiving information and communication generated by institutional actors. Trust, or lack of it, in local institutions or other social actors, is a central issue in research on local risk perception and communication (Covello, 1992). Several studies have shown that cultural, institutional and social variables can be important mediators of social trust and the positive acceptance of risk-related messages (Viklund, 2003). Also, studies show different results for the role of trust in processing communication about health- and industry-related types of risks and for the way in which the psychosocial components of trust are modelled (Renn & Levine, 1991; Kasperson, Golding & Tuler, 1992).

What are the components of trust? Is there only one type of social trust or are there different types of it? Peters, Covello & McCallum (1997) have verified different hypothesis about the components of trust and about the relationship between trust and *expertise*. In their research, a tri-component trust model – based on (a) knowledge and expertise, (b) openness and honesty, and (c) concern and care – was strongly sup-

30 In the social sciences, qualitative research is a method of investigation that emphasizes comprehension of social phenomena through direct observation, communication with participants, biographical analysis or analysis of texts. Traditionally, qualitative researchers are interested in meaning and they investigate the why and how of social experiences, preferring smaller (but focused) samples over large statistical analysis. Social constructivism is a sociological theory of knowledge focused on the ways in which individuals and groups participate in (and express conflicting views about) the construction of their perceived social reality and their knowledge of one another.

ported by empirical data. They also verified that different factors were relevant to the act of communicating environmental risk: concern and care about industry-related risk, commitment to government-related risk, and knowledge of activist-related risk (Peters, Covello & McCallum, 1997).[31]

The analysis of a case study on perception and communication of health and environmental risk in Italy has allowed us to take into consideration some methodological tools that may also be of use in similar high-risk areas.

Methods for investigating risk perception and local development: suggestions and guidelines

According to qualitative and explorative research, the aim of a survey is to discover an area's main problems, from the perspective of the meaning (that is, expressions, messages, content, interpretations, intentions and understanding) and social representation of local witnesses, rather than from statistically representative results (Yin, 2009). To plan and conduct effective qualitative analysis of stakeholders' cognitive representations of high-risk areas, on the basis of scientific literature and empirical experiences, we propose some operational steps and make some suggestions that can be adapted to different settings and needs.

Integrate the qualitative methods from the beginning

From the beginning, it is necessary to plan and integrate the qualitative issues in a research master plan. In this way, the general implementation of the research, the data collection and/or analysis phases, and the distribution of tasks among researchers can be optimized (Burgess, 1989).

It is necessary to define and develop a sound research methodology, with a clear definition of:

- research objectives;
- data collection methods;
- data analysis methods; and
- the common framework used to integrate the qualitative results with the results from other aspects – such as socioeconomical, epidemiological and geographical – of territorial research.

Use care in identifying local witnesses

It is necessary to identify a small group of people with highly relevant information, so that their information can be integrated with that drawn from larger social surveys of the general public (see Chapter 16). The key stakeholders are living repositories of highly focused representations, knowledge and territorial information and of the powers of territorial decision-making and social influence (Marshall, 1996a,b). These variables are not spread randomly in the general population (territorial awareness and decision-making powers are processes that do not follow a random distribution); thus, a focused and well-selected sample can at times produce more useful information than a more general survey.

It could be useful to categorize local witnesses as:

- decision-makers, politicians and administrators (people with political power, land-use technical knowledge and influence);
- economic leaders and stakeholders (people with economic power); and
- highly involved citizens (people with social and territorial knowledge).

31 For industry, an increase in public perceptions of concern and care results in a larger increase in perceptions of trust and credibility than any other variable under consideration. For government, an increase in public perceptions of commitment results in a larger increase in perceptions of trust and credibility than any other variable under consideration. For citizen groups, an increase in public perceptions of knowledge and expertise results in a larger increase in perceptions of trust and credibility than any other variable under consideration.

Good differentiation is essential to provide a wide and useful spectrum of representation of risk. It is then very important to be careful about the roles of stakeholders and local witnesses by:

- planning ahead and conducting short pre-interview meetings, to present and share with the key stakeholders the research aims, its purposes and structure; and
- clarifying the so-called neutral and technical role of the researcher, to avoid having various stakeholders link it indirectly to other social actors involved in the land-management institutional system.

Use a snowball sampling

Snowball sampling is a non-random type of sampling widely used in qualitative research settings. It is helpful in making effective use of the stakeholders' own knowledge of the functional and relational system of which they are a part. As noted previously in this chapter (see section on "Risk perception: experts, laypeople and trust"), the stakeholder's *who's who* relational map – of perceived knowledge of the power, influence and specific information possessed by the other social actors in the territorial system – is precious knowledge that should be used to facilitate and refine the identification and selection of the main stakeholders to be contacted.

Data collection: interviews are powerful, if you allow them to be so

Semistructured interviews are one of the most flexible and frequently used tools in qualitative research that involves *key informants*. Such interviews are optimal for the analysis of cultural and social differences and are less binding and reductive than other highly standardized tools, such as questionnaires (Liamputtong & Ezzy, 2005). Semistructured interviews allow direct exploration of complex social representations in a more active and articulate way than a questionnaire, and therefore they are more suitable for qualitative research that takes the fewer subjects, more in-depth approach. The semistructured interview format allows more degrees of freedom for the interviewee. In the interviews, the researcher does not have to focus directly on the theme, but can focus on it indirectly. Since their pre-representations of the theme could frame, in a dysfunctional way, the exploration of the interviewee's own representations, the researcher's representation has to minimize judgments about what is within the theme and what is outside it.

Interviews are inter-views, where the interviewer (researcher) and interviewee (subject) share a view together: they do not have to be an interrogation or a question–reply type of interaction (Kvale, 1996). The objective of an interview is to construct shared representations. In this sense, the interview is also an exploration for the researcher. It can provide surprises and the need to review some assumptions about the theme explored with the subjects (Rubin & Rubin, 2005). To be effective and to have a good degree of validity, these qualitative methods need to be integrated into a well-structured data analysis phase (Ricolfi, 2001).

The interviews with local witnesses allow the interviewer to:

- draw operational conclusions (that is, conclusions that can be translated into actions) about and make recommendations for territorial planning policies, such as the consequences of implementing local development plans;
- investigate strengths and weaknesses of local territorial systems as a whole; and
- analyse strategic issues, such as the potential of the economic system, critical environmental concerns and opportunities for local development – also for less productive sectors and services.

Data analysis: using computer-assisted qualitative data analysis software

The use of third-generation computer-assisted qualitative data analysis software can help manage the varied sets of unstructured data derived from gathering qualitative information from stakeholders (MacMillan, 2005). The data analysis phase needs to be developed within the methodological framework of international best practices and the broadest scientific guidelines in this field (Mantovani & Spagnolli, 2003). Data analysis has two relevant processes: discovery and synthesis. Discovery allows researchers to freely explore the stakeholders' social meanings and representations, without influencing them too much with the interviewer's own preconceived mental models; and synthesis allows the researcher to categorize the main themes, representations and social meanings in a clear and organized way. Through these two processes, the broad and unstructured phrases, concepts and attitudes expressed in the interviews could be gradually unified and structured through a conceptual categorization process, from which emerges the main representations of the key stakeholders.

For the synthesis process, it is possible to follow different theoretical and methodological approaches. A good basic understanding of qualitative methodology issues is essential to conduct this process productively and effectively. For this process, grounded theory approaches seem to be effective and useful (Glaser, 1992; Charmaz, 2006).

Methodological triangulation

It is important to evaluate the possibility of conducting a quantitative survey alongside the qualitative analysis, to better frame the context of both (see also Chapter 16). The use of mixed approaches to get two or three viewpoints of the thing being studied, called methodological triangulation, seems to produce better results than using a single methodological approach, in terms of reliability and validity of qualitative data (Cohen, Manion & Morrison, 2000).

Role and function of interviews with local witnesses and SWOT analysis

Semistructured interviews with local witnesses can show aspects that statistical analyses do not – above all, about perceptions about economic, environmental and health aspects. The data obtained from semistructured interviews represent a privileged point of view for the researcher and offer an exploratory key composed of memories, opinions and feelings, which can be used to observe and analyse the present and the past. In this way, it is possible to explore interviewee representations in terms of the perceived strengths and weaknesses of the local territory or in relation to the opportunities of local development and people's opinions about the future of such opportunities.

SWOT analysis is an interpretative scheme usually used in local development plans and, in general, in the implementation of land use policies. Created as an application for business administration – to help firms define their strategies in fluctuating and competitive environments – this analysis requires the strengths and weaknesses of the firm and the opportunities and threats of the market. The strength and weakness components of SWOT provide evidence on internal mechanisms, such as the working model of a particular unit, on which to intervene. The opportunity and threat components deal with external factors that may influence system behaviour and the achievement of objectives. In the manual of the European Commission that covers MEANS Collection (EC, 2012), SWOT analysis is defined as a useful tool for supporting the objectives of a programme, identifying more precisely the effects that must be achieved, and identifying the most appropriate interventions to achieve them.

SWOT analysis is presently used to investigate the strategies of public institutions and of social and economic organizations; in this context, it is used to assess the perspectives of local development and the implementation of alternative policies. The aim of SWOT analysis is to incorporate the intrinsic characteristics of the territory involved into a socioeconomic programme and to outline the factors needed to carry out the programme (EC, 2012).

A case study in Sicily: strategy and methods

This section describes the results of a qualitative analysis used to investigate risk-perception related to living conditions in a complex industrial area. It is based on a series of interviews of local witnesses in the Augusta–Priolo area.

Objectives

The main objectives of the present research in Sicily were to:

- describe the socioeconomic situation;
- analyse the needs of the territory and the development hypothesis;
- examine the training needs, communication needs and needs of several stakeholders; and
- survey the current availability of social actors to discuss a possible change in the use of the territory.

To organize the large volume of information obtained, the following categories were used to structure the research material:

- territorial system
- economic system
- social system
- health system
- future scenarios.

The analysis of the survey tried to disclose, for example, how local survey participants consider the present developmental phase of the territory: in discontinuity, partial agreement or continuity with the past local development model.

Research steps

The theoretical and operative course of the survey was subdivided into six phases. These phases represent an operative guideline that can be adapted to similar situations, such as those where it is necessary to produce a global analysis of the territory and the territorial representations of stakeholders. The six phases were as follows:

1. exploration devoted to bibliographic research, as well as to the definition of interviews and the selection of the social actors needed;
2. defining the work planned: its general methods, data analysis methods and the approach to semi-structured interviews;
3. administering 39 interviews, which took several months, with the same researcher attending and conducting all the interviews, which were recorded in outside premises or (more frequently) in the office or workplace of the interviewees;
4. transcribing the interviews, to input them in a digital format that can be used for further analysis and to verify data;
5. the long process of reading and interpreting the qualitative data, through SWOT analysis and grounded theory approaches; and
6. reporting the results of the study.

Interviews: actors involved and working method

Thirty-nine interviews of local witnesses were gathered and subdivided into four categories (see Table 96). This subdivision was an attempt to track any differences in the vision of the territory that depended on the role the interviewee played.

Competence and role were the main requirements chosen for identifying the so-called local witnesses, as well as their likely knowledge of political, social and environmental issues. After a careful evaluation, an initial list of people to contact was compiled. It included local representatives of several sectors – economic, business, nongovernmental organization – and actors involved in the management of activities and projects of particular relevance to the local territory, as well as various stakeholders. The complete list of local witnesses (see Table 97) was built up step by step, with the first interviewees providing the perception that each of them could contribute to local *stakeholder geography*, which contributed to completing the list.

Table 96. Total number of interviewees

Interviewees	Number of witnesses	Code
Decision-makers	15	1
Population 1 (activists)	8	2
Industry representatives	3	3
Population 2 (non-activists)	13	4
Total	39	--

The interviews were conducted from June 2008 to November 2009. They had an average duration of about an hour and were semistructured. The intermediate level of structure and standardization of these interviews provided a series of specific questions, similar for everyone, that did not constrict the interviewee's answers or their freedom to respond with insight or anticipation (Rubin & Rubin, 2005).[32] Analysing such abundant and complex narrative data – the result of qualitative research that seeks to explain the experiences and interactions of a complex society – is time consuming (Patton, 2002).

For this reason, we chose to automate the analysis phase, using CAQDAS software for qualitative data analysis of texts. It facilitated the formal organization of data and the summary results, based on our research guidelines. The software allows encoding, retrieval and comparison of quotations to be performed quickly; above all, it saves time and increases the ability to manipulate the data. Through such software, the analysis process becomes systematic and rigorous. In any case, researchers can always decide: whether to use this type of support; the type of software to suit the needs of the research; and whether to follow every moment of the process, to guide its interpretation (König, 2011).

In consideration of the general objectives of the research and its methods, the thematic order of the questions was defined in the following format:

Part 1: risk representation;

Part 2: communication and territorial risk sharing – that is, experiencing the same risk and sharing an exposure to the risks of the area where they live;

Part 3: territory; and

Part 4: protagonists (relevant and central figures) of the territory and their systemic relationships.

The interview questions were also designed for SWOT analysis and were divided into four broad sections, organized as follows:

1. descriptions of the existing socioeconomic situation (their strengths and weaknesses) by the key players operating in the territory;
2. effects of economic activity;
3. the credibility of other survey participants, such as administrators and associations, in finding common solutions; and
4. description of the perimeter of the area at risk (in a few words, according to the viewpoint of the survey participant).

The comparison of analyses derived from the grounded theory approach with those derived from the SWOT analysis approach allowed us to derive an indirect indicator of the consistency or inconsistency in the representations related to the role and/or weight of industrial risks and, more generally, related to socioeconomic development.

32 Anticipation is a category used in psychology to describe a model of the world that includes everything, from small details (such as which shoe you put on first) to complex things (such as how you feel about yourself and your life). This model is used to anticipate – expect or predict – what will happen, for example, in the next moment or in the next ten years.

Table 97. Social actors interviewed

Position	Gender	Age (years)	Code	City of residence
Mayor	Male	45	1	Augusta
Professor – University of Catania	Male	48	1	Catania
Deputy Mayor for Environmental Issues	Male	54	1	Floridia
Mayor	Male	67	1	Floridia
Deputy Mayor for Environmental Issues	Male	54	1	Melilli
Civil protection	Male	49	1	Priolo
Mayor	Male	45	1	Priolo
Former Mayor	Male	50	1	Priolo
Chief of the Sicilian Office in Charge of Areas at Risk	Male	48	1	Syracuse
City councillor	Male	58	1	Syracuse
Director of Local Health Council	Male	48	1	Syracuse
ARPA technical officer	Female	49	1	Syracuse
ARPA technical officer	Male	52	1	Syracuse
Mayor	Male	52	1	Solarino
Mayor	Male	51	1	Sortino
Environmentalist	Male	50	2	Augusta
Activist and artist	Male	37	2	Augusta
Local activist against industrial contamination	Male	67	2	Augusta
Priest	Male	54	2	Augusta
Local activist against industrial contamination	Male	71	2	Augusta
Activist	Female	53	2	Augusta
Local nongovernmental organization representative	Female	34	2	Melilli
Environmentalist	Male	50	2	Priolo
Director of the Industrial Air Quality Monitoring System	Male	59	3	Priolo
Representative of small industries	Female	41	3	Syracuse
Representative of industries of all sizes	Male	70	3	Syracuse
Engineer	Male	33	4	Catania
Engineer	Male	30	4	Catania
Engineer	Male	39	4	Priolo
Bookkeeper	Female	29	4	Priolo
Clerk	Male	46	4	Priolo
Entrepreneur	Female	40	4	Priolo
Retiree	Male	57	4	Priolo
Clerk	Female	45	4	Syracuse
Unemployed	Female	26	4	Syracuse
Accountant	Male	56	4	Syracuse
Housewife	Female	52	4	Syracuse
Architect	Male	54	4	Syracuse
Housewife	Female	39	4	Syracuse

Grounded theory approach

The grounded theory approach to analysis started with the digital input of the transcripts of the interviews and the reading and careful study of the text; it was followed by the selection of words, sentences or paragraphs (quotation) to be connected to a conceptual category (semantic code). The codes were later formatted in families and represented in more or less complex conceptual frameworks; the use of a graph represents a considerable help in creating logical connections, the so-called links between codes. The frequency of a quotation belonging to a code can be further analysed with graphic representations, and the main themes elicited from subjects were analysed and discussed, to get a comprehensive view of the cognitive structure underlying the conceptual model of their social representations. In the current survey, on the basis of 39 interviews, 2538 quotations and 1838 codes were produced.

In the next section, some examples of this type of conceptual framework analysis will be provided.

SWOT analysis

From the semistructured interviews, we first ran a detailed computer analysis on representations related to the different environmental, economic and social plans. In the second phase, we analysed the perceived dynamics of future trends in medium-term territorial evolution, specifically linked to the industrial risk.

Results: narratives

The information obtained from interviews cannot, in any way, be considered exhaustive and complete. Although questions were formulated in a general way, the interviewees reported information and specific views that were mostly related to their field or area of expertise. This study was intended as a starting point for discussion, from which regional good practices may arise in the near future. We integrated the information obtained from the SWOT analysis with the cognitive representations produced by social actors. This objective of the integration was to provide a comprehensive framework for the area of Augusta–Priolo, which might offer useful indications of future local developments for the municipalities involved in this study.

The area should be analysed in its entirety. Because the interviewees produced multiple geographical subjectivities – that is, judgments based on personal impressions, feelings and opinions, rather than external facts – it is necessary to account for their different perceptions and, therefore, representations (Gravagno & Messina, 2008).

Before introducing a clearer analysis, based on grounded theory and SWOT analysis, it is worth reading the basic material of the interviews[33]. To present it, we will use excerpts from interviews, with the important premise that the purpose is not a text analysis, but is rather the need to share the depicted social scenery through the words of the inhabitants.

Narratives on rehabilitation plans

In the context of this study, we need to understand how social actors perceived remediative actions and if they had knowledge of the works carried out or planned by the authorities. We will see that this knowledge is often superficial and that the rehabilitation plan document is considered too long and confusing and the plan itself inflexible in its approach.

- (30) Decision-maker: “It is a rigid plan, once you have presented that project it has to be that one; time goes by and now you have to arrange it.”
- (12) Population 1: “It is part of a good literature … I don’t remember well though.”

33 The extracts from the interviews are preceded by the identification number of the subjects (within parentheses) and the general code specifying his or her role. The identification number does not correspond to the sequence in the list in Table 97 and is used just to show the different opinions collected. The excerpts of interviews presented here represent just a small part of the 39 made.

We know that a rehabilitation plan includes a coherent set of actions for an area with complex environmental challenges. Such a plan aims to prevent an environmental emergency subject to chance and to become the focal point of a real permanent management system. The plan can be considered a very rational model of integrated land management. Many social actors, even among institutional ones, responded that they did not know it.

- (15) Population 1: "I don't know it well, but I know a few things have been done."
- (20) Population 2: "I have only heard about these plans. I have also read something in newspapers.
- (23) Decision-maker: "I don't know the plan in detail."

A resigned attitude and a strong feeling of mistrust are apparent. The rehabilitation plan is not only considered utopian, but is also considered a failure that allowed only a few to gain.

- (33) Population 2: "The rehabilitation is a Utopia. We don't even know what it is."
- (29) Population 1: "We have talked about reclamation for such a long time! ... Twenty-five years have gone. We still talk about it, but nothing has been done."
- (28) Industry representative: "You should know that rehabilitation plans were a great failure in their application."
- (19) Decision-maker: "Rehabilitation plans are only demagogic and illusory measures."

Environmental rehabilitation plans are therefore considered a failure by a majority of social actors and a way to silence those who ask for the implementation of interventions. For some interviewees, the present WHO study is just something done to improve the image of the rehabilitation plans.

- (38) Decision-maker: "I believe that the WHO survey is only a way to carry on with poor government that has managed environmental pollution for its mere economic advantage."

On the contrary, some actors believe that through the rehabilitation plans a change in the vocational composition of the territory is possible – for example, towards tourism. The rehabilitation is seen, therefore, as a resource that can provide work and enhance the development of the territory.

- (9) Decision-maker: "The reduction of damage caused by industries is necessary, as it will bring wellness to the whole territory, and for this reason an environmental sensibility will have to be reactivated."
- (39) Decision-maker: "Today a lot is going on around rehabilitation plans. In fact, they created jobs in the past and will do so in the next few years."
- (15) Population 1: "Rehabilitation, modernization of establishments, production of goods in this area. This means the creation of a lot of jobs".

We also tried to investigate the views of social actors, addressing a specific question on mapping risk areas (see also the Questionnaire in the Annex): "Can you draw on the following paper one or more points or areas or streets that characterized risk zones according to you, in the Augusta–Priolo area?"

- (25) Decision-maker "With regard to the areas at risk, I would limit myself to those areas already identified. I would define as areas at risk Augusta, Melilli, Priolo and Syracuse. It is clear and undoubted that those who mainly suffer the pollution are the nearest ones to the industries and it is on those that the interventions must be concentrated."
- (22) Population 2: "This is an industrial area born in the 1960s; if I could I would close it down today, because as an employee and as a worker I can say it is not safe and also because there is no chance to create free areas among the establishments; there is also the railway which runs across the refinery."
- (7) Population 1: "Can I make a round sign as big as a house?"
- (19) Decision-maker: "In Priolo there isn't a risk linked to a particular emission or to a single establishment, but a risk linked to many different emissions in the atmosphere."

The need for different definitions of risk areas was revealed in the interviews, creating an area, that might be called red (at higher risk), in Priolo, Melilli and Augusta, and a lower risk area in the remaining municipalities, Floridia, Solarino and Sortino.

Continuing with the analysis of risk mapping, some local actors believe the risk is exhausted within the industrial plants, whereas the definition of risk areas is approached with no real scientific basis.

- (28) Industry representative: "The risk finishes and exhausts itself within the establishments. Following the rules, everything there is controlled, everything."
- (22) Population 2: "I believe that the areas at risk are always linked to the industrial area; therefore, also the railway section that crosses the refinery and the interior of the refinery."

Many of social actors are aware of the current situation in the area, and they express many aspects of concern for the environment. So, we asked what a good rehabilitation plan for the area around Augusta–Priolo should provide.

- (8) Decision-maker: "Census of the area at risk, inspections of the present factories and removal of the highly polluting ones."
- (25) Decision-maker: "We need the construction of a desalting establishment, because we have problems with the water-bearing stratum and with desertification due to the salinity of the water stratum. [We also need] the arrangement of a system to abolish the use of combustible oils; the installation in refineries of filters that eliminate the impact of substances introduced in the atmosphere through fumes like nickel, vanadium, which are highly carcinogenic."
- (22) Population 2: "Above all, there is the need to clean up the areas with abandoned establishments."
- (27) Population 1: "We do not have to wait for a solution coming from above. It should be the population that indicates what they feel is most urgent regarding the reclamation of the land. This can be done, for example, with the support of Agenda 21."

Furthermore, according to the people interviewed, almost every privately managed remediation work was completed, while the public projects were delayed or stopped.

- (27) Population 1: "The private part of remediation works was almost completed, while the public one was not, as there are 100 billion liras [about half a million euros] left to be spent. Almost nothing has been spent yet."
- (17) Industry representative: "On the public side, there were considerable difficulties caused by funding issues or by political circumstances."
- (25) Decision-maker: "Almost all works planned by private actors have been made, except for a couple; regarding the public part of work, almost nothing has been done."

The distrust in the execution of remediation works is accompanied by the knowledge that an intervention in the territory, considering its complexity, should develop in a multilevel way; the damage caused by the main activities requires not only a technical, but also a comprehensive and general, approach.

It seems to be recognized that environmental policy should no longer assess risk by the occurrence of occasional events and the existence of particular facts or by sectoral analysis, but should assess it through planning and management able to involve all economic–sectoral policy choices for a territory.

- (21) Decision-maker: "Problems regarding environment and health have always been presented as distinct problems: the punctual [very limited space] risk problem, the diffuse risk problem, the health problem, the development model problem are always treated as if they were separated. Dividing the problems doesn't help the management of the community. The bureaucratic approach to the risk theme is the real problem in this territory."

Although in recent years significant advances have been made in the field of risk perception, social actors remain resigned and fatalistic, or even ignore the risk.

- (24) Decision-maker: "People don't even know what risk perception is. They don't even know the potential risks that exist."
- (1) Population 2: "The perception I have is fatalistic and pessimistic. I mean, in the end we have to die; in any case, we wouldn't move from here, because this is our area and that's all."
- (12) Population 1: "In the population, a tone of resignation can be noted. When in Augusta you ask, 'What did he die from?' They answer, 'From what do you expect he died?' There is mental resignation."

When a population's perception meets the everyday realities of life, the result is an unpredictable perception.

- (29) Population 1: "Perception is a sensation connected to the emotion of the moment.
- (19) Decision-maker: "It is a perception linked to the quality of daily life – that is, what one perceives with senses, the smells.

In Priolo, unlike the other municipalities, proximity to hazard exposure is much stronger, due to the conspicuous presence of industries. In Priolo, some interviewees express a strong perception that major problems are experienced in their city.

- (18) Population 1: "I must say that the problems we have in Priolo cannot be found anywhere else."
- (32) Decision-maker: "We citizens of Priolo are aware of the fact of living in an industrial triangle."

For many actors, this different way of experiencing risk perception depends on risk communication and on how it is managed. A decisive role is attributed to the information circulating, which is perceived as biased or distorted and unbalanced.

- (2) Population 2: "I believe it is a matter of communication."
- (30) Decision-maker: "There is, however, a difference of opinion: on one side, the environmentalists show the problem in one way; on the other side, the institutions show it in another way, and people are confronted with these aspects that sometimes may not be contrasting, but they seem as if they were."
- (17) Industry representative: "There is a problem here of disinformation being provided to the public and alarmism created by the press, which has never shown a balance in providing information."

Good information and communication seem to be attributable to the population participating and sharing in the issues dealt with.

- (27) Population 1: "Above all, any kind of discussion should be public, open to anyone; otherwise, the population will always have the perception that there are privileged debates to which they cannot take part and, therefore, that the information is always filtered."
- (11) Industry representative: "According to me, the flow of information should start at the company, reach the associations, and then the institutions – that is, the city or district, which then communicates with citizens."

We also tried to explore which perception of health was present.

- (30) Decision-maker: "A lot of people tie their problems more and more to the presence of the industrial area."
- (18) Population 1: "According to me, people think that the situation is very bad. In each family there have been health problems, like cancer or very serious illnesses."
- (31) Decision-maker: "When something happens within the family, the perception changes, it becomes heavier."
- (35) Population 2: "I mean, as long as nothing happens to me, it is alright."

As can be read from these excerpts, the health perception, in Priolo, Augusta and Melilli, seems to be related to the presence of disease in the family. The interviews show a different health perception in the territory of Augusta, somehow more alarmed, which seems to be related to the high percentage of malformations in newborns recorded in this area.

- (7) Population 1: "In Augusta, the main issues are industrial risk and malformations."
- (38) Decision-maker: "We still study the causes of these malformations in the Department of Obstetrics in the hospital of Augusta. But what do we study for? We have to intervene. There's nothing to joke about it. We have to act."

Narratives on the industrial presence in the territory

The presence of industry in Priolo and in Augusta and Melilli has certainly had an effect on people, which should not be underestimated. We will try to show how social actors feel industry's presence.

- (21) Decision-maker: "These factories didn't intend to integrate themselves with the territory, but only to locate themselves in it. This has caused a predatory attitude in the name of industrialization. Here, anything that could affect in any way this allocation is considered an attack on industry, as an attitude against industry. If the industrial culture does not change its relationship with the occupied and ravaged territory, if a dialogue will not be sought, there will be no possibility to build development, communication and safety policies."
- (35) Population 2: "The tertiary sector is nonexistent. Industry devours everything. It doesn't allow any other human activity to develop."
- (24) Decision-maker: "The management of territory is in the hands of powerful private groups that also affect political power. They are industrial groups."
- (7) Population 1: "The industrial area gives wellness to the population and, at the same time, takes it away, being the cause of malaise. It is as if you had to pay for what you receive."
- (25) Decision-maker: "The industrial area gives wellness, in terms of economy, and takes it away, in terms of health and environment."

Industry is regarded as providing economic prosperity and also sickness, for both health and the local economy, which is crushed by the overwhelming power of the industrial sector. But industry is clearly perceived as living in a time of economic crisis, and it represents the illusion of being the defender against job insecurity.

- (16) Population 2: "The industries are all closing down and are very confused, so they don't offer economic and employment benefits, as in the past."
- (21) Decision-maker: "Even the industries begin to have problems of employment and don't offer as many jobs as they used to."
- (14) Population 2: "People don't react because they are submissive to the so-called employment threat.
- (27) Population 1: "Here some people say 'better to die of cancer than to die of hunger'."

Despite the economic crisis, the threat of withdrawing employment, through which industry still maintains its economic power on the territory, goes on.

Narratives on future development

Social actors indicated potential development paths for their territory.

- (33) Population 2: "First of all, there should be tourism, because it'd involve all companies in the territory."
- (12) Population 1: "This is a land that could develop its artistic and touristic heritage seriously."
- (9) Decision-maker: "I think it is necessary to join cultural and environmental assets, because this is the only way to have development in this territory. Investing in tourism means creating accommodations and also seeking the development of a university and scholarship, because if your country is nicer you are glad to stay and live there."
- (1) Population 2: "The territory of Syracuse should focus exclusively on tourism, because it has all the characteristics to do it."
- (21) Decision-maker: "A fundamental matter to deal with should be compensation – that is, an attempt to achieve a minimum balance between environment and industrial planning."
- (29) Population 1: "We need another kind of development; instead of the cement industry, why not make solar panels?"

The local witnesses have recognized the unexpressed potential for the significant development of tourism in this area. The one-dimensional, undifferentiated local economy has created significant anxieties about its possible fragility and low resiliency. Also, the crisis situation that affected some industrial sectors is reflected in the population's negative feelings about its perceived work and employment opportunities. Avoiding the same mistakes and trying to make investments that defend the environment – for example, through the use of compensation mechanisms and interventions that improve the environment (such as the creation of green areas and investments in eco-sustainable energy) – are desired and needed.

The paragraphs that follow analyse the main results obtained through the grounded theory approach and SWOT analysis.

Results: an interpretation through a grounded theory approach

In terms of its quantitative representations, because of their small number, the group of industrial enterprises differs in the number of encodings produced. These differences have been tested methodologically with two different quantitative techniques. The first, typical of traditional text analysis, is the quantitative evaluation (word crunching) of the major occurrences of a particular terminology in previously established semantic subgroups of the four social actors. The second is the analysis of different occurrences of codes in the same four semantic subgroups, by evoking the semantic nuclei (that is, the core meanings of the interviewee's text) that refer to the distribution of interviews on the basis of the subgroup to which it belongs.

Code occurrences

The relative prevalence of semantic codes among the four subgroups of interviewees shows some important aspects of distribution. First, it is important to note some similarities that emerged between the various subgroups, by using code-frequency analysis and lexicographical analysis.

Code frequency analysis

Four groups – population (both activist and non-activist), industrial representatives, and decision-makers – are discussed.

1. Population (activist and/or non-activist)

In the general population (including Population 1 and Population 2), some similar constructs (representations) emerge. Among the most prevalent semantic representations (word meanings), in both groups, are those that relate to public information (11 and 13 recurrences, respectively, in Population 1 and Population 2) and those that relate to industry ill-being (that is, population ill-being related to the presence of industry) (5 and 9 recurrences, respectively). Also, the populations of both activists and non-activists frequently focused on issues related to alternative forms of economical and territorial development and on issues related to alternative modes of development. Moreover, they focused on the economic and environmental potential of the geographical area – for example, the Sea: 4 recurrences in non-activists and 7 in activists.

The two groups, however, have specific differences. Among the semantic codes that only the group of activists elicited was that relating to the theme of civil protection exercises. Also, it made many references to the associations working in the area. Moreover, it focused on the codes related to the weaknesses of the territory, from an environmental perspective. Furthermore, the perception of industrial risk and military risk had a frequency of 3 and 4, respectively. The group of non-activists, compared with the activists, are much more sensitive to the economic aspects of the environment and its relationship with industry, with medium frequency references to concerns about the economic weakness and economic strength of industry (6 recurrences).

2. Industry representatives

The core semantic representations in this group (albeit, in a population of only 3 subjects and thus merely indicative) are related to themes strictly oriented to economically productive areas and integrating these areas with the population. The most prevalent semantic codes focused on the role of major economic players in territorial development (6 recurrences), agreements on planning and programme issues (4 recurrences), the problems of entrepreneurship and future investments (3 recurrences), economic strength (3 recurrences), the positive role of industry (3 recurrences), and some consideration of communicating risk and planning remediation (3 recurrences).

Even in the analysis of recurrences in the terminology used, the lexical references to *industry* are over-represented – given the size of the sample – on average in twice as many recurrences per subject than all other groups. Also, the lexical references to *development* were represented much less frequently in other groups.

3. Decision-makers

The group of decision-makers has a much more heterogeneous composition than that of the other thematic groups. The decision-makers, are not stakeholders in the classic sense (as is the resident population or industry); rather, they often find themselves playing a role in managing, mediating and resolving the conflicts of diverse interests and proposals of the various actors involved in territorial management.

Among the most significant semantic codes is the widespread use of the two opposing concepts: *industry-related well-being* (8 recurrences) and, in particular, *industry-related ill-being* (26 recurrences). Some references are made to: *recovery plan*, in which decision-makers often have an important functional role (8 recurrences); *regasification* (24 recurrences); *land management* as a whole (6 recurrences), and the *key stakeholders*, with whom decision-makers often need to interact (6 recurrences).

Lexicographical analysis

In general, with regard to distributions derived from the so-called word-crunching lexicographical procedures used on the different groups, the prevalence of terms (words) relating to certain topics is fairly similar among these four groups of interviewees.

Among the more common terms used by the different groups, *territory* emerges as the one most widely used by all four groups of interviewees, followed by *risk*. The group of industry representatives is an exception, as the topic of risk has a slightly higher frequency – largely because one group member made extensive use of the term in his interview. The wide use of the terms risk and territory is probably indicative of a widespread view of the problems related to them, as also shown by lexical frequency analysis (word counts). In detail, the relative frequency of these terms is as follows.

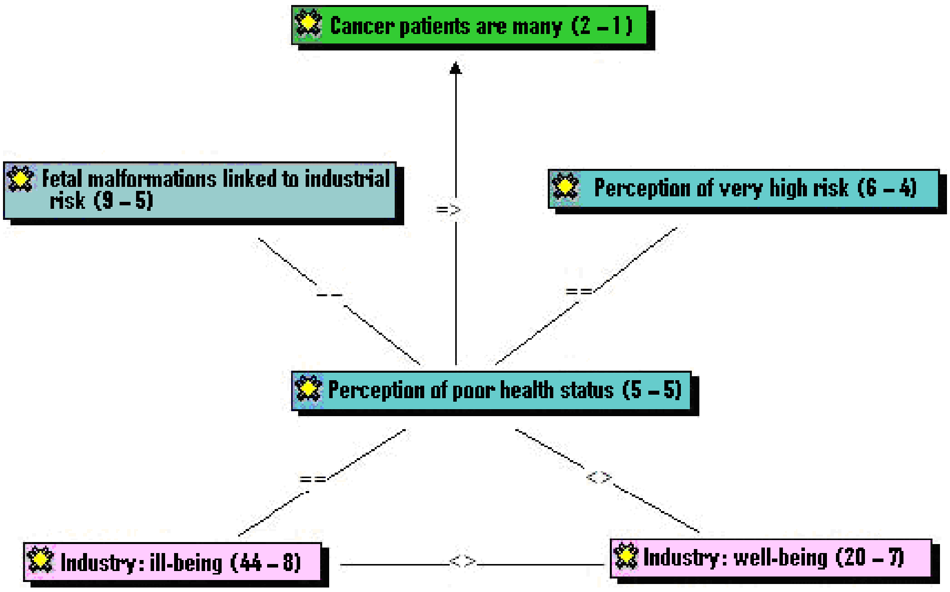
- **Territory.** The term occurred with a relative frequency of 30.33 times in the group of industry representatives, 29.12 times in the group of activists, 22.38 times in the group of non-activists and 19.8 times in the group of decision-makers. The prevalence of this citation among industrial representatives and activists is related to the high-relevance of the topic.
- **Risk.** The pattern of differences is stronger when we consider the distribution of the term risk. Its relative frequency was 12.46 in the group of non-activists, 16.73 in the group of decision-makers, 22.62 in the group of activists and 31.33 in the group of industry representatives. From these quantitative data, it is possible to deduce that the group least concerned (or willing to worry about) the concept of risk is the one with non-activists, while the highest level of attention is found in the group of activists (and with the caveat of the small sample size for the group of industry representatives).
- **Industry or industrial.** These terms are frequently used by everyone (with a relative frequency of 9.23 times for non-activists and 12.12 times for activists); however, it is more frequently cited by decision-makers and industry representatives (14.8 and 14.0 times, respectively).

As stated previously, we conducted a conceptual framework analysis on the basis of these data. Through a useful network mapping, CAQDAS software allowed the representation and analysis of the conceptual relationships among semantic codes. In the subsection that follows, we provide some examples of risk-perception and public-information mental models, to clarify the conceptual structure of these phases of the analysis.

Risk perception issues

The concepts of perception of risk and environmental area recurred frequently among interviewees. Their focus often seemed to be on health-related issues. The two functional networks represented in Fig. 59 and 60 provide a meaningful synthesis. As shown in Fig. 59, the construct of poor health perception is central in a number of correlations with the perception of a high general risk (perception of very high risk) and the complex problem of fetal malformation, which are perceived in interviews as related to industrial risk. This construct is also present as a semantic connection with the other major theme in health perception issues, the incidence of cancer.

Fig. 59. Mental model of the risk or health perception issues



Note. The numbers that appear in parentheses refer to *groundedness* and *density*. Groundedness is defined as the amount of data coded by the specific code – that is, how many times the code was assigned to describe the semantic meaning of elements in a text. Density is defined as the interconnectedness index of a code – that is, how many times the code was functionally linked to other codes.

The theme of the perception of health-related risk is developed in the more general context of the relationships between population and the industrial system, in its negative connotation (ill-being and industry). In contrast, constructs related to positive effects of industrialization were mainly expressed in relation to issues of economic well-being (well-being and industry).

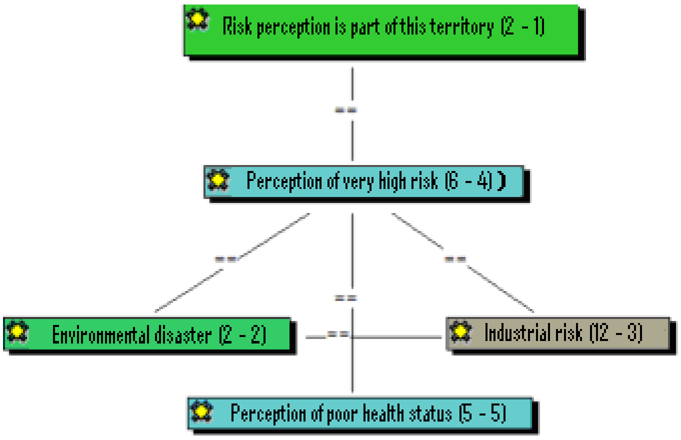
As shown in Fig. 60, the perception of a high level of risk is a conceptual construct that links together worries about environmental disasters, industrial risk and poor health.

Public information issues

On the basis of the responses of the interviewees, the theme of contingency plans and communication or information sharing with the population about industrial hazard is characterized by findings of deep concern and mistrust. As shown in Fig. 61, the information directed to the general public is widely perceived as inadequate (inadequate information provided to people).

From the mental model depicted in Fig. 61, a contradiction emerges between ideal instances of citizen involvement, the need for participatory communication practices, local involvement in such initiatives as Agenda 21, and those issues emerging from the poor involvement of local social actors in the processes of risk communication and risk management. Overall, the general public shows a lack of empowerment in managing processes with strong social and operational relevance.

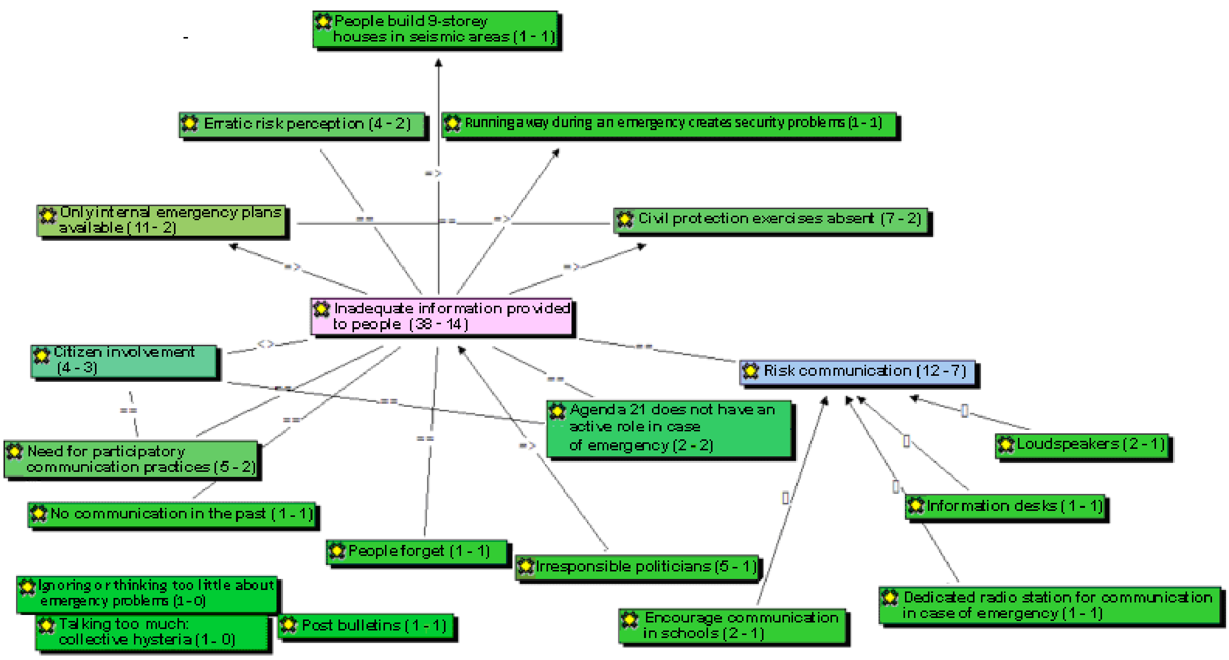
Fig. 60. Risk perception models



Note. The numbers that appear in parentheses refer to *groundedness* and *density*. Groundedness is defined as the amount of data coded by a specific code – that is, how many times the code was assigned to describe the semantic meaning of elements in a text. Density is defined as the interconnectedness index of a code – that is, how many times the code was functionally linked to other codes.

Also, an adequate safety culture is lacking, and the responses show that even knowledge of emergency or contingency plans is limited and fragmented, and mostly contained within the industrial complex. The absence of emergency exercises outside the industrial complex that involve the general public and the lack of provision of appropriate risk information are critical points (only internal emergency plans are available and exercises of civil protection are absent). These processes seem to have a strong social impact, and the local population seems to be ambivalent to or avoiding the risk (erratic risk perception) – and also harbouring attitudes of denial or fatalism. Some people, however, criticized politicians for being irresponsible in managing these safety processes. On the topic of risk communication, a fair number of interviewees expressed a general representation of fragmentation of efforts. They were also quite distrustful of the effectiveness and efficiency of communication systems and saw a need to implement the most effective and best structured way of risk communication.

Fig. 61. Public information and emergency management mental model



Note. The numbers that appear in parentheses refer to *groundedness* and *density*. Groundedness is defined as the amount of data coded by a specific code – that is, how many times the code was assigned to describe the semantic meaning of elements in a text. Density is defined as the interconnectedness index of a code – that is, how many times the code was functionally linked to other codes.

Results: an interpretation using SWOT analysis

In a traditional SWOT framework, Tables 98 and 99 show four categories of points (strengths and weaknesses and opportunities and threats) that emerged from the interviews. As is evident from these tables, because very heterogeneous elements and conflicting issues were elicited in the different areas, the representations of social actors display ambivalence and fragmentation.

Table 98. SWOT analysis: strengths and weaknesses

System	Points	
	Strengths	Weaknesses
Environmental	Climate Territorial history The coast and Climiti Mounts Sea Historical and geographical heritage Natural gas Protected natural areas Archaeological sites Control structures	Validation of controls Weak road system Pollution (atmospheric, hydrogeological) Augusta Bay pollution Urban areas No sewage treatment system (Augusta) Lack of roads for evacuation Rehabilitation plan not applied Industrial sites Territory "here and now"[a] Water issue Aquifer vulnerability Seismic zone
Economic	Agriculture Archimede Central (solar power plant in Priolo) Metallurgy and manufacture of machinery and equipment sector Job-producing Industries ARPA investments Specialized infrastructure and workforce Fishing Industrial site Chemical and mechanical specialization Local products Tourism	No tertiary sector Unemployment Lack of investment in archaeological jobs Few jobs produced by industry Overwhelming industrial presence No cooperative management Economic resources not reinvested locally Overpowering influence of industries on the territory
Social	Competent local workforce Resilience and strength of local population Adaptability of local population Open-minded population Creation of high-level educational institutions	Lack of civic involvement Individualism Lack of environmental concern Low-level access to health system Need for informal connections (to relatives or friends) to obtain services Workers' unions satisfied by the status quo Narrow vision (content with the current situation) Lack of communication between politicians and the population Disaffection with the territory

[a]This is a slogan that means take immediate care of the territory in which you live.

Careful evaluation of emerging opportunities is a fundamental analysis, since these opportunities do not always reveal themselves as such when examined in depth. The main perceived territorial resource, in addition to the industrial sites, is associated with the environmental and cultural wealth of the territory, seen as having great touristic potential. Properly developed and protected – using remediation, environmental protection and promotion of employment – the territory could represent an important alternative to recent development. Rehabilitation plans are also seen as a resource and opportunity that can provide jobs and enhance the development of the territory.

The opportunities and threats identified, in relation to the strengths and weaknesses linked to the territory, are organized as follows, starting with development opportunities:

- reclassification of territory
- diversification of investments
- reforestation

- enhancing tourism
- investing in agriculture and green energy
- implementing a rehabilitation plan.

Table 99. SWOT analysis: opportunities and threats

System	Points	
	Opportunities	Threats
Environmental	Investment in the development of Climiti Mounts Investment in tourism at Fontane Bianche Religion-, agriculture- and craft-oriented tourism Agenda 21 Alternative energy (solar) Port investment (commercial or touristic) Improvement of environmental protection culture Rehabilitation of the territory Re-evaluation of the territory Cleaning up the territory	Lack of investment in tourism Malls Remaining on the same management track Viewing the territory as a waste repository Continuing to build industrial facilities Incinerators Work-related migration Slow territorial management Loss of old crafts
Socioeconomic	Touristic and cultural activities Port rehabilitation and strengthening against pollution Rehabilitation of the cultural heritage Programme agreement for petrochemical rehabilitation Creation of committees Development of a university site Regasification plant Tertiary development Investment diversification Syracuse as a port for tourism Use of local raw materials Energy savings Strengthened higher education	Dependence of the current economic system Increasingly scattered institutional framework for land use Low-level development of tertiary sector Regasification plant Incinerators Lack of territorial culture No plant modernization No territorial rehabilitation Growth of distrust Lack of communication Apathy Plant automation No economic alternative to industry

The main perceived territorial resources are as follows:

- industrial sites – dominant; and
- environmental and cultural potential of the territory, in the form of:
  - touristic, cultural and artistic opportunities; and
  - important alternative ways for territorial development – both from rehabilitation and environmental-protection perspectives and from an economic and employment-related perspective.

The possible elements of conflict include industrial investments and regasification plants (incinerators).

Industrial investments. An element of strong conflict is the presence of industrial sites – that is, they are a weakness or threat to the environment and a strength to the economy. Failed diversification remains a threat to an economy perceived as totally dependent on industrial activities. While the petrochemical industry has become the scapegoat for all illnesses, the rest of industrial activities still seem to represent, collectively, the possibility of jobs. This perception does not match the present work situation: local industries linked to petrochemical sites have reduced jobs from 20 000 to 6000 units (see the section on "Effects of industrialization on employment" in Chapter 8). The industrial crisis is seen as a potential threat; and in this crisis, it appears difficult to imagine alternatives capable of providing economic well-being.

Regasification plants. The regasification plants planned for the area represent an element of environmental conflict. They are viewed as a threat and were rejected by the local people. The question about these planned regasification plants deserves more consideration. Local actors present it as an opportunity, but it is also a threat, so that prevailing security concerns, and some doubts about the actual impact on job levels, alternate with moderate optimism about its potential economic benefit. Also, critics greeted the adequacy of the safety profiles – if properly constructed – with a minimum of conviction.

In general, the environmental areas of critical urgency are:

- waste management
- water protection
- natural heritage protection
- industrial risk of major accident
- the Augusta harbour area.

Conclusions

From the present case study, it is possible not only to derive some general conclusions about (and guidelines for) similar situations and research needs, but it is also possible to derive some concrete results that can be used for further action in the territory examined.

Risk perception and implications for the environment

Environmental risk perception is a frequent theme discussed with interviewees. This risk is considered to have both industrial and anthropogenic sources. In response to the risk, resignation and fatalism arise, which can lead to psychological removal or denial of the risk. The topic of risk often seems to be related to health issues; some social actors perceive community health to be poor and link this situation to the presence of industry.

The theme of perceived health appears to be one of the main intermediary factors in the dichotomy of the perceptions of industry as a source of discomfort and as a source of wealth. This dichotomy is central to understanding the dynamics of risk perception and the relationships between the general population and industry.

Important improvements in the present situation necessitate the following actions:

- interconnected epidemiological and environmental analysis
- improvement of local health services
- appropriate promotion of a health culture in the territory
- distribution to the public of well-structured and accurate information about health issues
- operational synergies among the different entities involved.

Study implications for information and risk communication

Emergency plans and communication or sharing issues that relate to these plans with the general public have problems and are greeted with mistrust. Public information is widely perceived as inadequate, due to local civic actors' low involvement in the risk communication and risk management processes. A culture of safety is largely lacking, and the interview responses show that knowledge of emergency plans is limited, fragmented and confined to the industries. It appears as if, even for those who have organizational responsibilities, an emergency is perceived as only happening inside the industrial plants, without any extension to the geographical territory outside; thus representing an artificial dividing line between industry and the greater territory.

To meet the challenge of low trust in institutions, which emerged in the survey, it appears necessary to develop:

- a high degree of transparency about the training on safety and risk management and decision-making processes;
- greater direct public involvement;
- better balanced communication of scientific evidence and environmental and health risks; and
- greater sharing of emergency plans for the area and people outside the industrial plants and of civil protection activities.

A communication plan to reduce environmental and health risks must be clearly defined, to encourage active participation of the population, who should be acquainted with the features and purpose of safety interventions (Fischhoff, 1995; Leiss, 1996). The way to implement these recommendations may include:

- improving Agenda 21 meetings or local forums – for example, by considering the views of citizens' associations directly involved with environment and health problems; and
- building pathways to mobilizing the population in a new way – for example, by gathering experiences with communication, participation and problem solving in similar circumstances in other countries (Ravazzi, 2008).

Study implications for environmental rehabilitation plans

Exploring knowledge of plans for environmental rehabilitation was not an easy task. Many institutional social actors responded that they do not know the plans thoroughly. This response also emerges in references to the lack of updated environmental rehabilitation plans, which leads to a gap between current reality and the reality predicted by the plan. Also, in this case, environmental rehabilitation is considered to be a failure in the majority of the interviews, because these interventions are often not implemented, even if necessary.

At the operational level, the actions recommended should:

- ensure regular updating of rehabilitation plans and their connection with real territorial dynamics and issues;
- optimize the efficiency of public interventions, through closer coordination of the political actors involved; and
- support environmental remediation as an important step towards rehabilitation and as a first step towards the transformation of land use, as well as an opportunity to improve the local employment situation.

Industrial system and risk: implications for policies

An evident and common theme in most interviews is the importance of representations that refer to the petrochemical industry. Specifically, the semantic representations that sustain the social feelings of comfort or discomfort with industrial processes have the greatest importance (both in terms of groundedness and density, expressed in the terms of computer-assisted qualitative data analysis – see the note at the bottom of Fig. 60 for a definition of these terms) in the present study. A significant part of these complex representations is the theme of strengths and weaknesses of industry-related economics, in terms of issues that relate to the general industrial economy and its impact on local industries linked to the large petrochemical establishment and to employment.

The industry-based economy appears to be rigid and one dimensional, with few opportunities for developing aspects other than those connected to the petrochemical industry; therefore, an adequate differentiation of the socioeconomic development of the territory is not possible, and even land planning seems to be a satellite of industry. Because of the heavy influence of the industrial economy, territorial management is often perceived to be outsourced – that is, beyond the control of the community. Industry is considered to be the source of economic prosperity; at the same time, it is considered to be the bearer of ill-being, both for health and the economy, which is monopolized by the power of a big industry that seems to leave no room for local economic alternatives. It is worth noting that, in interviews, semantic associations between industry and ill-being exceed those that refer to industry and well-being.

The theme of economic and social development is strictly connected to that of territorial and risk management. The rehabilitation of the road system as a whole is of primary importance to economic development and civil protection, given the complex combination of risk factors related to the presence of the industrial area and the geological characteristics of the territory (high seismic risk).

Local witnesses (interviewees) seemed to ascribe major power roles to external economic actors (operating from outside the local context) who exert a major influence on the socioeconomic dynamics of the territory, resulting in an external locus of control and lack of empowerment of local actors.[34]

Often, some politicians and decision-makers are viewed as insufficiently present in the active management of the territory – with the exception of the mayors; and the intermediate level of regional political actors is perceived as playing a less convincing role. Overall, the major source of influence is regularly ascribed to the key economic and industrial stakeholders, even if they are perceived as external to the local social context; in terms of perceived local power, they are followed by politicians, who play their part in mediations and negotiations.

The positive assets, in social representations, appear not only when expressing a general assessment of economic opportunity, but also appear when expressing a strong conviction about the development of the territory's potential. Having identified four major categories that relate to the functional social actors involved in the territory (industrial, population activists, population non-activists and decision-makers), we provide a summary of their different perspectives. The perspectives that emerge are guided by the propensity of each category to focus mainly on its own identity issues as a cognitive anchor in its representations of territorial issues. Although expected, this marked behaviour could result in a rather diverse perceived importance, among different categories, of various issues.

Of the four major categories, population activists showed a greater focus on environmental concerns, risk perception, and industrial and similar constructs; for non-activists, these issues, although present, were moderated by economic concerns. Decision-makers seemed to maintain a more structured role, with recognition and mediation of different and sometimes conflicting requirements, and they focused more on issues of planning and managing the territory.

Industry representatives – although too few to draw conclusions that can be generalized – seemed to be more focused on production issues and on the consequences that the prospects of development of the area may have on them. They were also aware of the territorial risk.

In terms of policies, useful actions could be directed at:

- supporting, at the political and administrative level, the partial diversification of industries linked to the whole industrial area;
- supporting new ways of development – more oriented to touristic and/ or environmental and historical planning;
- actuating significant investments, to exploit and enhance the specific environmental characteristics of the area (such as archeological remains, landscape and natural parks), both on the coast and in the hinterland;
- implementing significant investments in transport infrastructure, health care, and local services, which are important job and development opportunities;
- promoting the culture of safety and health through the involvement of the schools; and
- gathering examples of communication, participation and problem solving in similar circumstances from other countries.

Considerations of methods

The research methods employed, based on qualitative models and semistructured interviews, proved to be useful in facilitating the exploration of representations of various stakeholders, with respect to the functional links between environment, health and policies of land management. Therefore, the results of these types of investigations (achievable with resources that are also efficient) seem to be particularly useful as input to an integrated mix of approaches for territorial analysis: they allow

34 *Locus of control* refers to the theory investigating the extent to which people assume they can control actions and events that affect them. Such a locus can either be internal (when a person believes they control their life) or external (when they believe their environment, chance, or other people determine events and control their decisions and life).

a more detailed definition of social representations that directly affect attitudes, participation and co-management of local communities, with respect to the complex territorial issues that affect these communities.

It is important to emphasize the need for a set of actions – potentially useful in similar situations – that aim to:

- establish plans for integrated analysis that – besides the classic socioeconomic, geo-environmental, urban and epidemiological factors – would provide structured forms of qualitative research on social representations distributed among different stakeholders;
- facilitate the collection and structured analysis of qualitative data drawn from different types of stakeholders, to analyse the different representational forms of environmental factors;
- consider the role and importance of social processes that act as mediators (influencing factors) of collective behaviour and attitudes derived from psychological–environmental analysis; and
- re-evaluate and emphasize the collection and analysis of data on local knowledge, as an essential component of environmental and epidemiological research.

In terms of policies, the organization of meetings for public expression of views and information could help to partially reduce the differences in attitudes among different groups of social actors. An integrated methodological approach – that uses qualitative methods, as well as quantitative ones, and connects classical SWOT analysis with stakeholders' representational models (based on computer-assisted qualitative data analysis) – could produce sophisticated knowledge that aids in the synthesis of the main territorial issues. Through qualitative interviews, we believe it is possible, according to a semiotic and cultural model, to analyse risk.[35] This can also be supported by an interpretation that takes into account the meaning of the symbolic aspects and social representations of the population in contaminated areas. The analysis of risk has to take into consideration the internal formation and the causes of specific local contexts of co-constructing meaning, where social actors are involved in interpreting, preserving and reproducing the structure of their cultural and social links. Moreover, the psychosocial approach to these issues is not interested only in individuals or disease, or other fixed categories, but is interested in the interactions between individuals and their contexts, fully reduced to their sociocultural and historical processes.

35 Semiotics is the study of signs in a broad sense, including symbolisms, indications, designations, likenesses, analogies, metaphors, the conveyance of meaning, and communication. Semiotics is strongly related to linguistics   that is, studies of the structure and meaning of language.

18. DISCUSSION: LESSONS FROM THE SICILIAN EXPERIENCE

Pierpaolo Mudu, Benedetto Terracini and Marco Martuzzi

Consequences of industrial contamination

For decades, the environmental and health consequences of industrial operations have created public concern worldwide. This is the case in the three Sicilian areas described in the present book and in many other contaminated sites – the characterization of which requires thorough investigation. The present book adopted a broad view of environment and health, including the social consequences of industrialization and a survey of perceptions and attitudes of residents in industrially contaminated areas. The contaminated high-risk areas of Augusta–Priolo, Gela and Milazzo–Valle del Mela are an example of the need for such a broad, complex, and multifaceted approach to the study of the consequences of industrial contamination.

In these three areas of Sicily, contamination of water, soil and air is well documented, while epidemiological data show excess mortality and morbidity for several conditions. For some specific substances, such as 1,2-dichloroethane, levels of pollution in soil and groundwater exceed all official national and international limits. Over the years, through different modes of transport (wind, diffusion along surfaces and groundwater), contamination expanded from its point sources to distant areas. For example, the contamination of deep levels of the marine sediment in the area of Augusta suggests that pollution in the sea started some decades ago. Although pollution limits for many substances were already in force in the 1980s, many types of data – for example, those for lead and other metals in air – were not collected. Such omissions have presented an obstacle to the creation of a detailed, consistent and comprehensive picture of the extent of the contamination. The air quality monitoring systems available, however, showed critical aspects and the excess of several pollutants (sulfur dioxide, PM_{10}, nitrogen dioxide and ozone) regulated by national legislation. Monitoring organic micropollutants (polychlorinated dibenzo-*p*-dioxins and dibenzofurans and dioxin-like polychlorinated biphenyls) and polycyclic aromatic hydrocarbons was planned by regional authorities in the mid-1990s, but data from monitoring campaigns are not available.

With very few exceptions, present and past contaminants cannot be firmly linked with excesses of diseases. This limitation is due to difficulties in characterizing individual past and present exposures and to incomplete knowledge of the effects of long-term exposure to single and mixed contaminants. Also, available health statistics have limited power to detect and show causal relationships, except for asbestos-related pleural cancer and deaths and hospital admissions for acute respiratory diseases due to air pollution. In the Milazzo–Valle del Mela area, the latter association was confirmed by a specific study of children.

Frequently, causal inferences are also problematic for other reasons. One reason is that most health outcomes suggested by current statistics are multifactorial in origin, and risk factors of a different nature (such as those related to lifestyle) can overshadow the effects of environmental pollution. Also, the effects of environmental contaminants may occur many years after initial exposure, and even after removal of these contaminants. This has important implications for assessing the health impact of contamination and for identifying suitable remedial action.

In spite of these limitations, current health statistics in the three Sicilian areas provide some insights. Overall, the data available indicate that exposure of residents to contaminants occurred over a long period of time. Total mortality provides an approximate, but informative, picture of the population health profile and of the most significant pressures to which the population was exposed. The most notable results include a significant excess in mortality among the residents of the Gela area. During the period 1995–2002, the excess over the neighbouring populations, in terms of SMR (including 95% CI) for all causes of death, was 109 (106–113) for men and 108 (104–112) for women, corresponding to more than 20 extra men and more than 15 extra women dying every year.

Mortality analyses in the other areas, however, provide a mixed picture. For instance, in the area of Augusta–Priolo, the lower mortality among women living within the contaminated area compared with those living in the local reference area might reflect better access to medical services, but it is not clear why the phenomenon was limited to women. The only statistically significant result in the analysis of mortality trends for birth cohorts is the decreasing trend of lower SMRs in younger generations of women in Augusta–Priolo and in Syracuse: again, why this occurred only for women is not clear. In the Milazzo–Valle del Mela area, only deaths from laryngeal cancer in men appear to exceed expectations. In the same high-risk area, comparisons with the regional population have also detected statistically significant fewer deaths from respiratory diseases in men.

Congenital malformations are a matter of concern in the Gela and Augusta–Priolo areas. Although overreporting cannot be excluded, it is unlikely that flaws in the registration mechanisms have led to artefactual twofold excesses in a variety of categories of malformations. In particular, the high prevalence of hypospadias found in Gela and in Augusta is consistent with the possible role of endocrine disrupting chemicals, as hypothesized in the literature.

The assessment of the risk of cancer is informative, but can be very challenging. Traditionally, it was assumed that each environmental carcinogen acts on a limited number of target organs through a specific biological mechanism. The idea has been recently challenged by the hypothesis that epigenetic mechanisms play a role in environmental carcinogenesis; this has widened the concept of cancer promotion. In assessing the relevance of epidemiological findings of excesses of cancer (or other diseases), both the consistency of the results of studies carried out elsewhere and knowledge of mechanisms of action should be taken into account. In the Augusta–Priolo and Syracuse areas and in the Gela area, deaths from mesothelioma explain only a minor part of the excess deaths due to cancer. Such an occurrence, however, confirms the presence of exposure to asbestos in the workplace. However, in the absence of individual exposure histories, para-occupational exposures via a third party cannot be investigated. Nevertheless, the incomplete remediation of asbestos – not only in the workplace, but also in the general environment – raises concern.

The human biomonitoring study carried out in Gela showed high levels of arsenic in urine and/or blood in some residents throughout the local community, with no tendency to cluster spatially. This suggests exposures due possibly to the ingestion of contaminated food or water, rather than exposures linked to the proximity of the city's petrochemical plant. This is critical to understanding how the population has been exposed over time and how exposure distributions and adverse effects on health develop.

Environmental pollution and socioeconomic status

To understand the patterns of mortality and morbidity observed, it is important to characterize the social profile of residents. This characterization is critical, given the difficulty in epidemiology of standardizing poverty, the lack of hygienic measures and deprivation – that is, removing the adverse effects on health of these factors and focusing on the strictly environmental ones. Residents in highly polluted areas tend to belong to the socioeconomically disadvantaged strata of society. Therefore, patterns in mortality may reflect a mix of environmental exposures, including occupational ones, as well as other determinants, such as lifestyle and limited access to medical services.

In the Augusta–Priolo, Syracuse and Milazzo–Valle del Mela areas, particularly in men, standardizing SMRs for socioeconomic status resulted in estimating a stronger role for environmental contamination. The opposite occurred in Gela, the most deprived among the contaminated Sicilian areas. In this area, partly unregulated housing developments and deprivation contribute, in all likelihood, to the excess of mortality observed. When estimating SMRs adjusted for an indicator of poverty, data limitation and dilution may result in incomplete removal of the confounding effect, if any. Moreover, standardization is based on the assumption that deprivation acts as a confounding factor, whereas there is a strong possibility that social circumstances can also act as modifiers of effects. Ad hoc studies, requiring high-resolution data, would be needed to address the crucial question of the joint effect of environmental contamination and social factors, with the latter having a possible role as a modulator of the effect.

Vulnerable groups: children's health

Children's health, in particular, is a priority in the formulation of policies in polluted areas. Two aspects of the experience in Milazzo–Valle del Mela illustrate this need for formulating policies. One is the finding of an association between contamination levels and respiratory symptoms in schoolchildren. The other is a demonstration of the feasibility of identifying children at high risk of developing respiratory disease. These illustrations highlight the need to implement the guidelines for respiratory diseases in children according to the WHO Children's Environment and Health Action Plan for Europe. More specifically, we recommend that local (and when relevant, regional and national) authorities:

- undertake actions to reduce air pollution;
- support doctors and paediatricians in disseminating and implementing the WHO Children's Environment and Health Action Plan for Europe guidelines for children – a priority for ensuring access to consultation services and the prevention and treatment of children's respiratory diseases;
- ensure that the health system provides adequate attention to respiratory disorders in children that are very common, may be overlooked, and may go undetected or be underdiagnosed; and
- monitor the use of bronchodilators and corticosteroids.

Bronchodilators and corticosteroids are safe and effective drugs for asthma-like symptoms. However, when the distinction between asthma and other respiratory diseases is not adequate, such prescriptions may be inappropriate and may present a risk.

Environmental authorities' response

Environmental authorities are responsible for identifying and implementing environmental rehabilitation, thus maximizing the elimination of sources to which populations are exposed. High-risk areas present serious environmental contamination challenges, where pollutants can persist for decades in the soil or sediments – for example, mercury in the Augusta–Priolo area. The life-cycle of contaminating substances involves all environmental matrices. Such substances may end up polluting the food-chain – an understudied vehicle of human exposure in contaminated sites for which specific data (such as food quality and consumption) are rarely available. Implementing the best available techniques and indicating quality objectives is also the responsibility of environmental authorities.

Although the legislation on pollution limits for many substances was already in force in the 1980s, many data (for example, for air pollution) were not collected in Sicily. Thus, it can be difficult to establish where and when legal limits were exceeded.

In Sicily and elsewhere, delays in completing remediation procedures can be deleterious. Comprehensive remediation programmes should: be based on scientific validity; have adequate financial support, which can be obtained by applying the polluter pays principle; and be developed through a publicly accessible process. This requires the publication of regular reports on the progress of remediation, which would allow verifying deviations from the original plans. Bioremediation techniques, when available and accessible, ought to receive adequate consideration.

In general, existing legislation needs to be strictly complied with, keeping in mind that legal limits do not provide full assurance of safety, given that most limits are established for single substances and do not consider possible interactions. Within European legislation, the effects of mixtures of (and interactions between) different substances are rarely covered. Thus, compliance with legislation and standards should go hand in hand with the adoption of a precautionary approach.

When developing remediation policies, due consideration should be given to the need for incorporating interventions aimed at reducing other sources of environmental pressure – for example, sea ports and road traffic.

Finally, the framework of studies and surveys that have been undertaken also indicate that environmental and public health authorities could improve the decision-making process, by incorporating the assessment of environmental, health and social impacts.

Filling the knowledge gaps

Findings in Sicily also indicate a knowledge gap in the data and methods needed to understand the environmental health profile of the areas studied. The number of chemicals with possible toxic properties present in these areas is impressive. The risk from the simultaneous presence of different agents from different sources is likely to involve interactions between agents and synergistic effects. As mentioned above, such interactions are rarely taken into account in studying adverse effects on health and in determining risks, standards and legal limits. Thus, in such areas as those the present book focuses on, it is important to consider options for systematic data collection, such as:

- monitoring pollutants relevant to respiratory health – for example, $PM_{2.5}$ – with particular attention to the circumstances in which exposure affects such sensitive subgroups as children;
- measuring all relevant pollutants, depending on local characteristics and long-term levels of contamination – for example, through in-depth measurement of sediments – including organic pollutants (such as polychlorinated dibenzodioxins and dibenzofurans, polychlorinated biphenyls and polycyclic aromatic hydrocarbons) and inorganic pollutants (such as heavy metals) in petrochemical areas;
- investigating environmental matrices that may play a role in the diffusion of pollutants – for example, agricultural soils and pastures – and indicators of absorption and accumulation in animals grown for human consumption, which implies setting up a monitoring programme in local food production and distribution, with the involvement of veterinarian institutions;
- identifying a zero point – that is, a specific reference time after which measurement methods are consistent and results are comparable;
- planning environmental monitoring through a census of all emissions in the areas and specific measures of pollutants at smokestacks, with a system that includes:
  - recording data on the management of the chimney torches,
  - effective dissemination of air quality data – for example, information on the measured parameters available in real time to the public, with warnings in case of infringements of limits, and
  - relocating and strengthening monitoring networks wherever possible; and
- having independent scientific institutions carry out a continuous review of environmental and health literature – given the complexity of the issue and the increasing bulk of publications – and considering the construction and maintenance of dedicated databases.

In terms of methods for understanding the joint effects of temporal changes in the social structure and the environmental exposure of the population, all-cause mortality is an informative indicator of the health status of the population, and birth cohort and time trend mortality analyses may also contribute. Overall mortality, in any case, should always be investigated while attempting to distinguish between the effects of the environment and the effects of socioeconomic factors.

However, the studies carried out in the high-risk areas of Augusta–Priolo, Gela and Milazzo–Valle del Mela also provide recommendations for improving epidemiological surveillance in highly polluted areas – in particular:

- a preliminary assessment of the quality and reliability of existing health information systems and of the opportunities for their optimization;
- any proposal for new information systems (such as registries of malformations and registries of hospital emergency department attendance) should be carefully evaluated in terms of feasibility and cost–benefit ratio; and
- analytical epidemiological studies carried out only if based on robust hypotheses and only when statistical power is adequate.

The reliability of exposure assessment is crucial in analytical epidemiological studies. Estimates based on simple distance from sources reduce the sensitivity of epidemiological studies. Thus, more reliable models for the construction of the space of contamination and exposure are needed.

Biomonitoring is also a key method for studying contaminated sites. It may shed light on actual exposures to specific agents and their mechanisms of action. Population exposure patterns traceable by surveys on space-time activity patterns and pollutant diffusion are best validated through biomonitoring in an appropriate sample of the population. Biomonitoring estimates individual exposures to environmental chemicals more precisely than do questionnaires. The abnormal presence of heavy metals or other toxic substances in bodily tissues are a sign of contaminants circulating through different pathways, and this exposure is a predictor of adverse effects on health. Although biomonitoring is promising, it raises ethical issues that have to be considered during study planning. For example, among the things to be considered are: giving subjects the choice to be (or not to be) informed about the results of their analysis; having the possibility of guaranteeing a medical follow-up in case an unusual concentration of a chemical agent is found in their body; and dealing with the situation where these subjects are asymptomatic and it is uncertain whether any of them will subsequently develop any disease.

Risk perception and risk management

In polluted areas, decisions about remediation and health surveillance must be made when outcomes are uncertain and univocal scientific findings are absent. Sometimes, uncertainty in identifying precise causal effects is used to justify delaying or cancelling remedial action. This procrastination contributes to lingering social conflicts and to litigation as a way to solve environmental and health problems.

In Sicily, the net benefit local communities derive from extensive industrial development is unclear. Although the initial offer of work was substantial, the demand was insufficient to absorb the workforce that abandoned agricultural areas and thus to restrain emigration. In contrast to the benefits, industrial development has entailed (and still entails) adverse impacts, as documented in several chapters of the present book, with environmental degradation adversely affecting health and well-being. As is often common, part of the population is unaware of the risks and impacts.

The coexistence of relatively high risks and indifference, both influenced by gender and age, suggests the need for greater communication of scientific thought that clarifies both established causal relationships and areas of scientific uncertainty. To this end, the dialogue between institutions and the general public must take into account the relationship between different cultural models and the socioeconomic characteristics of the population and its perception of risk. In Sicily, the perception of (and attitudes towards) health risk and the perception of the need for remediation were found to be influenced by age, gender, education, working conditions, and parenthood. These risk perception patterns suggest the need for a reproducible standard for comparative evaluations of risk perception between populations. When defining an action plan, the active participation of the population should be sought. Such participation is achievable through appropriate communication, and it can be effective if the population (as a direct recipient) is recognized as being a central and active contributor to the decision-making process.

Some conditions are essential to overcome the lack of trust the public has in institutions, which may hamper public consultations and policy action. These conditions are as follows:

- direct involvement of the population, with a programme of public events at various levels, taking into account the views of citizens' associations that are directly involved in environment and health issues;
- a highly transparent decision-making processes, informing the population about the rationale of the decisions being made, with adequate explanations given when decisions are at odds with the expectations of the population – for example, when people support the creation of new hospitals, which may be unnecessary; and
- full availability of relevant scientific evidence and information on risks to the environment and health.

Tools for implementing these recommendations include strengthening the work of Agenda 21 and local forums and taking stock of and critically evaluating the communication experiences, participation and problem solving utilized in similar circumstances elsewhere.

The set of studies described in the present book led to the collection and compilation of a variety of data and information produced from different sources in contaminated areas. This information, and the results of the analyses, was returned to the population, thus enabling it to have a more informed say in land use policies and remediation. Local coordination councils were set up as part of the technical assistance provided by WHO to Sicilian authorities. These councils have also had a role in building consensus on additional political actions to improve environmental and health conditions. The remit of these councils extended beyond contaminated sites: they became forums for the discussion of broader topics about environmental health. These councils, however, are not sustainable in the long run; thus, it is important to establish permanent mechanisms and independent agencies to address environmental health issues.

Conclusions

Understanding the health implications of pollution and the social changes caused by the petrochemical industry is complex, but knowledge of these areas has increased significantly in recent years. Methodological progress for investigating environmental health in contaminated areas is documented in the literature, and the present book's project in Sicily provides additional insights. The three-year project considered various options and identified the most relevant studies and research activities to be undertaken; it did so through discussions between experts and peer review during the design of the studies, their implementation and the interpretation of results. In parallel, citizens, health authorities, municipalities, stakeholders and environmental agencies were involved. The experience in Sicily described in the present book has a variety of political implications, both at the local level and in general. The three high-risk industrial sites share characteristics relevant to the population, the health system and medical doctors, environmental authorities and the industrial system, and local authorities.

The studies in this book have led to realistic suggestions for both policy responses and methodological approaches. The whole case study thus provides a model for integrated environmental health assessment as a basis for allocating investments and resources planned for local rehabilitation and development policies. The same model is useful for evaluating the extent to which the development of local communities is affected by risk factors over which the resident population has virtually no control. The model can be extrapolated to other circumstances for which routine environmental monitoring systems are too weak to provide the information needed to control highly contaminated territories.

The economic vision that accompanied Sicilian industrialization 50 years ago lacked the necessary foresight to consider the implications for local human development and sustainability: the historical pattern of the three industrial areas shows that rapid industrialization was quickly followed by unplanned urban growth. Among other things, this also prevented the development of tourism in places within the three high-risk areas that were similar to others outside these areas. Such areas enjoyed a prosperous growth through tourism, in a booming postwar Europe. In hindsight, it seems unbelievable that the decision was made to create large petrochemical and industrial complexes in areas of archaeological interest, high touristic value, high seismic risk and prone to flooding, as repeatedly shown by recent and old earthquakes (in 1908 Messina was destroyed by an earthquake and a tsunami).

It is hoped that the lessons learned from this project in Sicily, the methodological developments and the policy implications will contribute to establishing a firmer basis for studying and managing industrially contaminated areas in both Sicily and elsewhere.

ANNEX

Focal point experience in Milazzo–Valle del Mela

Pasquale Andaloro

Valle del Mela lies in a hilly terrain north-east of Sicily and has at its centre the City of Milazzo – the embarkation point for the Aeolian Islands. Historically, the area has been mainly agricultural, specializing in early fruits and vegetables. In the 1960s the Gulf of Milazzo was identified as a suitable place to establish a refinery, a thermoelectric power plant and a factory that produced fibre-cement sheets containing asbestos.

The early promise of jobs for all proved to be illusory, and the area became prone to emigration. Agriculture no longer provides income, and any possibility of alternative development is substantially inhibited by the presence of large hazardous industries that occupy large areas while employing a small number of workers. This concentration of hazardous settlements (three plants are classified as at risk of a major accident) displays an obvious consumption of land and resources – in some respects irreversible.

Since 1999, after news of an imminent siting of a waste incinerator in Pace del Mela, the population formed the Association for the Protection of Public Health, chaired by Don Giuseppe Trifiró (the parish priest) and me (a doctor). The Association requested the Sicilian Region government to declare the Milazzo area at high risk of environmental contamination. This request was the cornerstone of a popular protest. At the end of 2002, the Sicilian Region government in Palermo passed the declaration that officially made it an area at high risk of environmental contamination. Between 2002 and 2006, local politicians and regional authorities held a series of meetings and discussions about involving the WHO Regional Office for Europe in assessing the situation in the area. Due to delays caused by regional policy-makers and by ensuing protests by the population, it took four years to obtain an agreement between the Sicilian Region government (responsible for rehabilitation plans) and WHO. At the end of 2006, WHO began work in our area.

My acceptance of the informal role of focal point in 2002 led eventually to formalizing that role. The role involved maintaining a connection between people, associations and local and regional policy-makers and, occasionally, organizing public meetings. This role then expanded to include supporting the organization of scientific activities – in particular, the campaign to measure the breathing capacity of children. Institutional and public activities were complemented by an extensive series of informal meetings and by such informal activities as requests for personal information among the population and discussions during my working and leisure time. These informal meetings helped to obtain real results, which also meant that the population developed confidence in the work WHO coordinated.

It is important to note that the high-risk area is a composite territory, divided administratively into seven municipalities – some with land included in the industrial area (Milazzo, Pace del Mela and San Filippo del Mela) and some located in the predominantly agricultural hilly land (Condrò, Gualtieri Sicaminò, San Pier Niceto and Santa Lucia del Mela). Due to the presence of the industries, municipalities with land included in the industrial area enjoy some apparent advantages (such as taxes, funding and sponsorship), while municipalities located in the hilly land seem to have only the disadvantages of pollution. With regard to monitoring the industrial activity of these two different types of areas, local politicians behave differently: the policy of the municipalities close to the industrial plants is usually more moderate than that of the municipalities of the hilly land, which is often more aggressive when compared with the first group of municipalities' lack or inefficient control of the industries.

The air-quality monitoring network has always operated irregularly: the Province of Messina, instead of ARPA (the regional authority), managed some units. For several consecutive years over the past decade, the monitoring stations stopped operating several times, due to lack of funding and maintenance. Unfortunately, the operating monitoring stations have provided discontinuous measurements for a few pollutants, and the data were not made public immediately but, instead, were communicated months later, thus hampering any preventive activity.

In this context, clear signs of political attention to environmental and health problems of Valle del Mela are lacking and broad social welfare, as promised for decades, does not exist. Still we wait for a recovery plan and a clear path for sustainable development.

A troubling question remains: has the land use associated with industrial activities in Valle del Mela improved the living conditions and health of its inhabitants?

Focal point experience in Gela

Salvatore Migliore

When I was a boy, I always asked myself a simple question: why? Since primary school, my question has always been the same to every life phenomenon. When I was a child, it was a different time: people were not always prepared to explain everything or provide simple answers. This was because they did not want to question themselves or the work of their entire life. So, quite instinctively, I thought it would be amazing to be a doctor, not only because you could help relieve people of the burden of disease but, above all, because you could understand the reasons for many things. So I convinced my father – who wanted me to join the army or be a judge or (at least) a lawyer – to let me enrol in the faculty of medicine and surgery of the University of Catania.

Don't worry, I will not tell you my whole life story.

It is clear that to do research you need appropriate opportunities and also have to cope with everyday life, especially if you are not well off or you live in a country where scientific research is minor and, so, lacks adequate funding. It was my good fortune to be a student of Professor of Hygiene Giuseppe Giammanco at the University of Catania. His teachings helped me pass the medical officer's examination in the City of Gela at the age of 27. Continuing to be one his students, although I am a director of a public office, has allowed me to realize a minimum amount of scientific activity. Another good opportunity was meeting Dr Michele Faberi, Regional Adviser for Sustainable Development, of the WHO European Centre for Environment and Health. I cooperate with him in doing WHO-coordinated research in the Gela area.

Whenever a researcher asks for help, to realize some scientific activity, I am always prepared to do it. Over the years, I formed a group of operators (such as doctors, psychologists, technicians, nurses and experts) that is always prepared to help me whenever it is necessary to do research. The group's members all have the same desire I do: to know more about every single phenomenon of life. When Pierpaolo Mudu (Researcher of Environment and Health at the WHO European Centre for Environment and Health) asked me to write something about the SEBIOMAG experience, I thought about writing what I have just written.

For all of us, the SEBIOMAG study was an exciting experience from the start, when we tried to find an acronym for our study. Also, we soon understood the importance of having the population's support in realizing the study and worked to win their trust, so that people would spend time with us (20 minutes to provide a blood sample and useful information for completing the guided questionnaire). It is not easy to convince someone, who is not sick, to spend time replying to a questionnaire or even to give a blood sample. We were, however, able to do this, thanks to the trust of the population of Butera, Gela and Niscemi (gained through communication of our actions) and thanks to the first subjects interviewed and providing blood for testing. These first subjects were like an amplifier that boosted the interest of those undecided. They were pleasantly surprised by the welcome, the seriousness of the interview, the respect for their privacy and the professionalism shown during the blood test (which involves a complex technique).

The details of the analytical results were delivered to the study subjects. It was not a simple delivery: for each subject, we explained the data obtained, removed any possible doubt about the result of their blood test and, above all, a member of the scientific committee provided advice on very specific issues.

As already mentioned in the book, the SEBIOMAG biomonitoring survey enlisted the help of 262 adults (between 20 and 44 years of age) from the populations of Gela, Niscemi and Butera (see Chapter 10). In particular, the results showed critical widespread exposure to arsenic, consistently indicated by measurements in urine, blood and plasma. The average values were higher than values reported for unexposed populations in similar employment or accidental (unintentional fortuitous) circumstances.

In July 2009, during the official presentation of the data, we promised to repeat the blood test for everyone whose test showed high values for arsenic, especially to determine the speciation of organic (good) and inorganic (bad) arsenic. Due to a lack of funds, the research was discontinued, resulting in many inconveniences that stem from the betrayal of trust of those who believed in the SEBIOMAG study. I did my part and tried, with other operators, to find a solution to the problem. Every time I met a study subject with a positive result for high values of arsenic who asked me when we would repeat the blood sample and the analysis; I didn't know how to answer and felt guilty. For evident reasons, I don't want to talk about politicians.

On 8 April 2010, I was very pleased to receive funding from the City of Gela, which I had asked for years before and which was intended to study the impact of social diseases. The funding was unused, and I was able to recover it, thanks to the trust and help of the Director-General of Caltanissetta Province's Health Care Facility, Paolo Salvatore Cantaro. This funding (about €28 000) would allow us to continue our work and provide answers to those who had trusted us. When Fabrizio Bianchi (Scientific Director of SEBIOMAG) and Marco Martuzzi (Scientific Officer of the Health Impact Assessment Unit of the WHO European Centre for Environment and Health) confirmed that we could restart the study – also thanks to other funding – it was a great day for me and for those who worked on the SEBIOMAG study.

I hope that something will change in our country and that people and policy-makers will become aware of the need to adequately fund the scientific research needed.

Focal point experience in Augusta–Priolo

Anselmo Madeddu

The Department of Land and Environment (ARTA) of the Sicilian Region, through its Special Risk Areas Office, recently developed a programme to implement action plans for the three high-risk areas of Augusta–Priolo, Gela and Milazzo–Valle del Mela.

To define and implement a rehabilitation plan in Augusta–Priolo, ARTA asked the WHO European Centre for Environment and Health for technical and scientific support. In turn, the Centre asked for the assistance of the Provincial Health Agency of Syracuse, which also coordinates the Cancer Registry.

In 2007, as a preliminary step, two distinct phases were planned: a preparatory phase before taking remediative action and a second phase of monitoring and verifying such interventions. The first phase has been concluded and results are published in the present book. Other details are also worth circulating.

When the activities began, several public and private entities were informed and became involved in various ways. The list of these entities is quite long and includes: the municipalities of Augusta, Melissa, Priolo and Syracuse and their Agenda 21 offices; the Province of Syracuse; ARPA and its Syracuse department; the Epidemiological Monitoring Unit of the Regional Health Department; the National Institute of Health; the National Agency for Regional Health Services (AGENAS); the universities of Grenoble, Catania, Messina and Padua; the Italian National Research Council (CNR); the French National Center for Scientific Research in Strasbourg; the Sicilian Investigation on Congenital Malformations (ISMAC) Registry; CIPA; the Italian Federation of Family Physicians (FIMMG); the Italian College of General Practitioners (SIMG); and such environmental protection groups as Association AugustAmbiente, Legambiente and Decontaminazione Sicilia.

To consider the current state of the relationship between environment and health in the Augusta–Priolo area, a literature search was performed and relevant studies were thoroughly and meticulously collected. This collection includes both articles and books from the scientific literature and grey literature sources, such as the expert reports for the legal consultancy for the tribunal, which is used as evidence in tribunal judgements, and reports from specialized agencies or single experts, which offered invaluable information. With the help of my staff, we also provided assistance to the survey with a questionnaire conducted on the perception of risk (see Chapter 15). Finally, the results of most of the research on environment and health carried out in the Augusta–Priolo area by the different research groups involved were presented at a public meeting held in Syracuse, in November 2009.

To investigate the relationship between environment and health in the Augusta–Priolo area, studies on cancer epidemiology are extremely important. For trends in incidence, mortality and survival, the studies used were based on the Registry of Pathology produced by the Provincial Health Agency of Syracuse for the period 1999–2005 (see Chapter 5).

The epidemiological profile of cancer in Sicily is heterogeneous. In less than 50 years, large-scale industrial activity, imported to an area like Augusta, has generated an area entirely divorced from the character of the rest of Sicily – a region that displays completely the epidemiological profile of an industrial city in Northern Italy. Nevertheless, proximity to a vast industrial complex is not enough to generate a high incidence of cancer, which is the case in Melilli.

Important conclusions can be drawn from the update of the Cancer Registry of the Province of Syracuse for the period 2002–2005 (Madeddu et al., 2009). The number of tumours increased (the incidence of cancer cases per 100 000 inhabitants standardized against the Italian population increased in males (from 450.4 to 466.7 cases) and in females (from 356.0 to 362.3 cases)). In particular, increases in lung cancer occurred among females (38%) and also occurred for prostate cancer (25%). However, survival also increased in males (from 42.3% to 49.3%) and in females (from 52.1% to 58.2%). In brief, people get sick a little more and die a little less.

In the Augusta–Priolo area, the incidence of cancer varies significantly from north to south and from east to west, with the incidence significantly highest in the industrial area. The Province of Syracuse has a lower incidence of tumours than that observed during the same period in north-central Italian regions and an incidence similar to that shown in the cancer registers of Southern Italy. However, the high incidence of some cancers in particular areas of the Province of Syracuse – leukaemia in Lentini, liver cancer in Augusta and cancer of the thyroid in Syracuse – should be noted (Madeddu et al., 2009). Also, due to shortcomings of oncology assistance and an almost total lack of screening programmes in the Province of Syracuse, patients chose to use the health facilities of the Province of Catania instead.

The most difficult task in public health is to place things in their proper perspective, where both good and evil are honestly balanced. It is not true that industry is responsible for all the evil and that the environmentalists have done all that is good, and vice versa. As always, the truth lies somewhere in between. What we simply desire is industrial production that is compatible with the needs of the health and safety of the citizens of our province. But let us not forget that, fundamentally, the real wealth of Sicily (and Syracuse) is tourism, its history and the extraordinary artistic and cultural heritage our ancestors bequeathed us.

Questionnaire: multipurpose investigation of a population in an area at risk

WHO, UNIVERSITY OF MESSINA (DEPARTMENT OF ECONOMICS, STATISTICS, MATHEMATICS & SOCIOLOGY) and FRENCH NATIONAL CENTER FOR SCIENTIFIC RESEARCH

NOVEMBER 2007 – FEBRUARY 2008

VERSION A or B	
to be compiled before the interview:	
Date	
Hour	
ID *of interview: interviewer's initials plus the sequence number of the interview (e.g. John Smith, interview n.25 = JS25)*	
Municipality	

THE QUESTIONNAIRE IS DIVIDED INTO 6 SECTIONS:

- INTERVIEWEE CHARACTERISTICS
- RISK PERCEPTION
- HOUSING CHARACTERISTICS
- LOCATION AND TRAVEL
- FAMILY CHARACTERISTICS
- LIVING CONDITIONS

INSTRUCTIONS FOR THE INTERVIEWER

- MANY QUESTIONS ARE ANSWERED THROUGH TICKING WHICHEVER APPLIES.
- MANY QUESTIONS ARE ANSWERED BY INSERTING NUMBERS IN THE PROPER SPACE.
- SOME ANSWERS REQUIRE WRITING WORDS. PLEASE DO IT IN CAPITAL LETTERS.
- IF NOT OTHERWISE SPECIFIED, QUESTIONS WITH MULTIPLE ANSWERS ALLOW ONLY ONE CHOICE.
- NOTE THAT SOME QUESTIONS ARE RELATED, ACCORDING TO THE ANSWER, TO SUBSEQUENT QUESTIONS.
- IN CASE OF ERROR, CIRCLE THE WRONG ANSWER.

GOOD AFTERNOON/GOOD EVENING, I AM AN INTERVIEWER FROM THE UNIVERSITY OF MESSINA. WE ARE CARRYING OUT A MULTIPURPOSE INVESTIGATION ON THE ENVIRONMENTAL AND SOCIAL SITUATION OF THE AREA WHERE YOU LIVE. …

INTERVIEWER: Remember that families were previously contacted by letter/phone call.
I HAVE TO ADD THAT, ACCORDING TO THE CURRENT LAW ON PRIVACY PROTECTION, YOU ARE FREE TO ACCEPT THE INTERVIEW OR TO STOP IT WHENEVER YOU WANT. I GUARANTEE THAT ANY INFORMATION FROM YOUR SIDE WILL BE TREATED AS STRICTLY CONFIDENTIAL, WITHOUT YOUR NAME OR TELEPHONE NUMBER OR ANY OTHER PERSONAL INFORMATION. THANK YOU IN ADVANCE FOR YOUR COLLABORATION.

Authors: Pierpaolo Mudu, Arnaud Banos, Elise Beck, Emmanuel Bonnet, Michele Faberi, Elisa Gatto, Sandrine Glatron, Marina La Rocca, Massimo Mucciardi, Pietro Saitta and Guido Signorino.

I. CHARACTERISTICS OF THE INTERVIEWEE

QC 1. YEAR OF BIRTH |____|____|____|____|

QC 2. GENDER:

(1) Male	☐
(2) Female	☐

QC 3. MARITAL STATUS

(1) Single	☐	(4) Separated	☐
(2) Married	☐	(5) Divorced	☐
(3) Widowed	☐	(6) Cohabiting	☐

QC 4. CITIZENSHIP

(1) Italian	☐		
(2) Other country in the EU	☐	Specify	
(3) Other country outside the EU	☐	Specify	

QC 5. HIGHEST LEVEL OF EDUCATION COMPLETED

(1) Without	☐
(2) Primary school	☐
(3) Lower secondary education (Licenza media inferiore)	☐
(4) Secondary school	☐
(5) University (undergraduate, postgraduate, PhD)	☐

QC 6. PLACE OF BIRTH:____

II. RISK PERCEPTION

**QPR 1. PLEASE CONSIDER THE FOLLOWING LIST OF SOCIAL PROBLEMS.
FOR EACH ITEM, INDICATE TO WHAT EXTENT YOU FEEL WORRIED.**

Interviewer: show the list items separately.

	Extremely worried (1)	Quite worried (2)	A little worried (3)	Not at all worried (4)	Don't know	Order
(1) Road accidents	☐	☐	☐	☐	☐	☐
(2) Food risks (e.g. genetically modified organisms, spoilt food, "mad cow" disease)	☐	☐	☐	☐	☐	☐
(3) Drug addiction (tobacco, alcohol, heavy drugs)	☐	☐	☐	☐	☐	☐
(4) Deterioration of the environment (greenhouse effect, deforestation, acid rain) and pollution (air, water, soil)	☐	☐	☐	☐	☐	☐
(5) War	☐	☐	☐	☐	☐	☐
(6) Poverty and social exclusion	☐	☐	☐	☐	☐	☐
(7) Natural disasters (earthquake, tsunami)	☐	☐	☐	☐	☐	☐
(8) Terrorism	☐	☐	☐	☐	☐	☐
(9) Unemployment	☐	☐	☐	☐	☐	☐
(10) Serious illnesses (AIDS, cancer)	☐	☐	☐	☐	☐	☐
(11) Nuclear threats (reactor failure)	☐	☐	☐	☐	☐	☐
(12) Industrial risks	☐	☐	☐	☐	☐	☐
(13) Insecurity/precariousness (in job conditions and life's uncertainties)	☐	☐	☐	☐	☐	☐
(14) Extremely low-frequency electromagnetic fields (e.g. long-distance electric power transmission line)	☐	☐	☐	☐	☐	☐
(15) High-frequency electromagnetic fields (e.g. cell phone antennas)	☐	☐	☐	☐	☐	☐

QPR 2. CAN YOU RANK IN ORDER OF IMPORTANCE THE THREE MAIN RISKS YOU FEEL YOU ARE MOST EXPOSED TO?

The meaning of exposure, as mentioned in the questions, is related to proximity and contact with a potential source of damage to health.
FILL IN THE LAST COLUMN OF THE PREVIOUS TABLE (1: more important; 3: less important).

QPR 3. WHAT DOES RISK MEAN TO YOU? CAN YOU DEFINE IT USING 2 OR 3 WORDS THAT YOU ASSOCIATE WITH RISK?

Note all the words that are listed.

– ………………………………………………………………
– ……………………………………………………………… ☐ Don't know
– ………………………………………………………………

QPR 4. HOW MUCH DO YOU EITHER AGREE OR DISAGREE WITH EACH OF THE FOLLOWING STATEMENTS ABOUT RISK?

Statement	Strongly agree (4)	Moderately agree (3)	Slightly agree (2)	Strongly disagree (1)	Don't Know
Risk can mean the probability of an adverse outcome.	☐	☐	☐	☐	☐
Risk can mean a consequence of individual or collective behaviour.	☐	☐	☐	☐	☐
Risk cannot be precisely defined because it depends on the nature of the event (e.g. earthquake, accident, pollution).	☐	☐	☐	☐	☐
Risk is associated with a situation of financial loss.	☐	☐	☐	☐	☐

QPR 5. REGARDLESS OF THE LIST OF SOCIAL PROBLEMS PREVIOUSLY SHOWN, TO WHICH RISKS DO YOU PERSONALLY FEEL YOU ARE MOST EXPOSED?

This question refers to the risks that the interviewee feels to be most exposed to in the area where she/he lives (e.g. the area of Milazzo–Valle del Mela or the area of Augusta–Priolo).

The interviewer should collect, if possible, between 3 and 5 answers. For each risk indicated by the interviewee, ask if it is associated with home, work or "Other" (in this case, specify).

Risks	Home (1)	Work (2)	Other (3)	Specify
	☐	☐	☐	
	☐	☐	☐	
	☐	☐	☐	
	☐	☐	☐	
	☐	☐	☐	

QPR 6. PLEASE CONSIDER THE FOLLOWING LIST OF RISKS. FOR EACH ITEM, INDICATE TO WHAT EXTENT YOU FEEL EXPOSED.

Risk	Extent exposed					
	Extremely (1)	Quite a bit (2)	Moderately (3)	Not at all (4)	Don't know	Order
(1) Flooding	☐	☐	☐	☐	☐	☐
(2) Noise	☐	☐	☐	☐	☐	☐
(3) Transport of dangerous materials	☐	☐	☐	☐	☐	☐
(4) Hazardous waste (chemical, radioactive)	☐	☐	☐	☐	☐	☐
(5) Air pollution	☐	☐	☐	☐	☐	☐
(6) Extreme weather events (hurricanes, flooding, tornadoes)	☐	☐	☐	☐	☐	☐
(7) Fire (of any kind)	☐	☐	☐	☐	☐	☐
(8) Water pollution (sea, river, water table, lake …)	☐	☐	☐	☐	☐	☐
(9) Dangerous industries	☐	☐	☐	☐	☐	☐
(10) Earthquakes	☐	☐	☐	☐	☐	☐
(11) Landslides/mudslides	☐	☐	☐	☐	☐	☐

QPR 7. CAN YOU RANK THE THREE MAIN RISKS TO WHICH YOU FEEL YOU ARE MOST EXPOSED?

FILL IN THE LAST COLUMN OF THE PREVIOUS TABLE.

I will pose some questions that are related to a particular category of risk that can be defined as a great collective risk. This kind of risk relates to a rare event, with severe consequences and the involvement of a large number of people and can potentially produce a catastrophe.

QPR 8. IF A CATASTROPHE HAPPENED IN THE AREA OF [MILAZZO–VALLE DEL MELA]/[AUGUSTA–PRIOLO], WHICH ONE MIGHT YOU THINK OF?

Only one answer! Note the first answer mentioned.

………………………………………………………………………………

QPR 9. WHY DID YOU THINK OF THIS PARTICULAR EVENT?

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

QPR 10. IF YOU COULD KEEP ONE THING, IN CASE OF CATASTROPHE, WHAT WOULD YOUR PRIORITY BE?

You can mention three objects.

Note the order of priority given by the interviewee.

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………………………………

QPR 11. WHO/WHAT DO YOU THINK WILL BE MORE AFFECTED BY THE CONSEQUENCES OF THE EVENT YOU HAVE INDICATED?

(This question is related to the consequences of the event mentioned in the answer to question QPR 8.) Three possible answers, ranked by importance (1: more important; 3: less important), are allowed.

(1) People (including you)	☐
(2) Buildings	☐
(3) Environment	☐

QPR 12. WHICH CONSEQUENCES ARE YOU THINKING OF?

Three possible answers, ranked by importance (1: more important: 3: less important) are allowed.

(1) Death	☐	(5) Material and financial losses	☐
(2) Diseases	☐	(6) Destruction	☐
(3) Serious injuries	☐	(7) Heavy pollution	☐
(4) Psychological effects	☐	(8) Other (specify):	☐

QPG 1. CAN YOU DRAW ON THE MAP ONE OR MORE AREAS, OR POINTS OR STREETS THAT YOU THINK CHARACTERIZE THE RISK AREAS IN [MILAZZO–VALLE DEL MELA]/[AUGUSTA–PRIOLO]? Show Map 1.

(1) Interviewee has answered ☐ Refused to answer ☐ Don’t know ☐

QPR 13. DO YOU HAVE PERSONAL EXPERIENCE WITH A SERIOUS ENVIRONMENTAL/INDUSTRIAL ACCIDENT IN THE RISK AREAS YOU INDICATED?

(1) Yes	☐	(2) No	☐

If “No”, move to question QPR 17.

QPR 14. IF YES, TO WHICH ACCIDENT ARE YOU REFERRING? *Specify also the year.*

……………………………………………………………………………………………..…

QPR 15. IN THAT SPECIFIC ACCIDENT, WHO DID YOU RELY ON?

(1) Family at home	☐	(5) Civil protection/firemen/forest rangers	☐
(2) Relatives	☐	(6) Police	☐
(3) Neighbours	☐	(7) Other (specify) ………..………………….	☐
(4) Friends	☐	Don’t know	☐

QPR 16. WHAT MEASURES DO YOU CONSIDER FEASIBLE IN THAT CASE?

The question is with reference to the case mentioned in QPR 14.
No more than three answers.

………
………
………

QPR 17. DO YOU KNOW HOW THE POPULATION SHOULD BE ALERTED IN CASE OF AN INDUSTRIAL ACCIDENT? No more than three answers.

(1) Sirens	☐	(5) Telephone	☐
(2) Loudspeakers	☐	(6) Other (specify):	☐
(3) Bells	☐	Don't know	☐
(4) Radio and TV	☐		

QPR 18. HOW DO YOU FEEL ABOUT THE INFORMATION ON ENVIRONMENTAL RISKS IN THE AREA WHERE YOU LIVE?

(1) Very satisfied	☐	(4) Dissatisfied	☐
(2) Satisfied	☐	Don't know	☐
(3) Not too satisfied	☐		

QPR 19. WHICH MEDIA DO YOU PREFER AND DO YOU USUALLY CONSULT?

Please show the order of importance (1: more important; 3: less important), following the order of importance indicated by the interviewee.

(1) National TV	☐	(6) Internet	☐
(2) Local TV	☐	(7) Information from local grassroots organizations	☐
(3) National newspapers	☐	(8) Family	☐
(4) Local newspapers	☐	(9) Other (specify):	☐
(5) Radio	☐		

QPR 20. IN GENERAL, WHICH TYPE OF MEDIA WOULD YOU PREFER TO INFORM YOU ABOUT RISKS?

No more than three answers. Please show the order of importance (1: more important; 3: less important), following the order of importance indicated by the interviewee.

(1) National TV	☐	(5) Radio	☐
(2) Local TV	☐	(6) Internet	☐
(3) National newspapers	☐	(7) Information from local grassroots organizations	☐
(4) Local newspapers	☐	(8) Other (specify):	☐

QPR 21. AT PRESENT, WHO/WHAT DO YOU RELY ON FOR INFORMATION ON THE RISKS THAT YOU ARE EXPOSED TO?

Multiple answers are allowed, up to a maximum of 5. Please tick the proper cell, following the order of importance indicated by the interviewee (1: more important; 5: less important).

(1) National media (TV, newspapers, radio)	☐	(10) Local grassroots organizations	☐
(2) Local media (TV, newspapers, radio)	☐	(11) Management of the industries	☐
(3) Municipality	☐	(12) Workers from the industries	☐
(4) Local politicians (e.g. city councillors)	☐	(13) Environmental organizations (e.g. Legambiente, World Wildlife Fund)	☐
(5) Prefecture or other government institutions (e.g. civil protection)	☐	(14) Trade unions	☐
(6) Firemen	☐	(15) Parish church	☐
(7) Police	☐	(16) Other (specify):	☐
(8) Doctors	☐	(17) A particular person (specify):	☐
(9) Scientists (e.g. experts, engineers)	☐	Don't know	☐

QPR 22. THE ENVIRONMENTAL SITUATION IN YOUR MUNICIPALITY IS:

(1) Excellent	☐	(3) Serious, but solvable	☐	Don't know	☐
(2) Acceptable	☐	(4) Serious and irreversible	☐		

QPR 23. DO YOU THINK THAT SWIMMING ALONG THE COAST INDICATED ON THE MAP:

(1) Is not dangerous	☐	(3) Is dangerous, except in the zone of………………	☐	Don't know	☐
(2) Not very dangerous	☐	(4) Is dangerous in any case	☐		

QPR 24. DO YOU THINK THAT EATING FISH CAUGHT ALONG THE COAST INDICATED ON THE MAP:

(1) Is not dangerous	☐	(3) Is dangerous, except in the zone of………………	☐	Don't know	☐
(2) Not very dangerous	☐	(4) Is dangerous in any case	☐		

QPR 25. TO WHAT DEGREE DO YOU THINK IT IS PROBABLE FOR SOMEONE LIVING CLOSE TO A CONTAMINATED AREA TO CONTRACT:

(one answer for each row)

	It is certain (1)	Highly probable (2)	Less probable (3)	Impossible (4)	Don’t know
(1) Allergies	☐	☐	☐	☐	☐
(2) Temporary damage to respiratory tract	☐	☐	☐	☐	☐
(3) Permanent damage to respiratory tract	☐	☐	☐	☐	☐
(4) Temporary damage to different organs	☐	☐	☐	☐	☐
(5) Permanent damage to different organs	☐	☐	☐	☐	☐
(6) Damage to liver	☐	☐	☐	☐	☐
(7) Cancer	☐	☐	☐	☐	☐
(8) Leukaemia	☐	☐	☐	☐	☐
(9) Genetic malformations in children born to parents exposed to pollution	☐	☐	☐	☐	☐

QPR 26. HOW DO YOU FEEL ABOUT INVOLVING YOURSELF IN POLITICAL ACTIVITIES ON ENVIRONMENT AND HEALTH ISSUES?

(only one answer)

(1) I am involved actively (e.g. with groups, associations, demonstrations).	☐
(2) I was involved in the past, but not any more.	☐
(3) I would participate, but I don’t have the time.	☐
(4) I am sceptical about the real objectives of such initiatives.	☐
(5) Other (specify)	☐
Don’t know	☐

III. HOUSING CHARACTERISTICS

QAB 1. WHY DO YOU LIVE HERE?

No more than three answers. Please show the order of importance (1: more important; 3: less important).

(1) Have always lived here	☐	(6) Security of the neighbourhood	☐	Refused to answer	☐
(2) Good schools	☐	(7) Proximity to the sea	☐		
(3) Good air quality	☐	(8) Proximity to workplace	☐		
(4) Less expensive housing	☐	(9) No other possibility	☐		
(5) Proximity to shops and transport facilities	☐	(10) Other:	☐		

QAB 2. EXCLUDING KITCHEN, BATHROOM, CORRIDOR, CLOSET, PASSAGES, ETC., HOW MANY ROOMS ARE IN YOUR HOUSE?

|____|____|

QAB 3. YOUR HOUSE:

(1) Presence, in the bedroom(s) or living room (excluding kitchen and bathroom) of stains from damp, mould, mushrooms, …	☐	(3) Has an air-conditioning system	☐	Refused to answer	☐
(2) Has a heating system	☐	(4) Has regular maintenance	☐		

QAB 4. DO YOU OWN OR RENT YOUR HOME?

(1) Own property or usufruct	☐	Specify amount of mortgage in €	
(2) Rent paid to a private individual	☐	Specify amount of rental in €	
(3) Rent paid to a private firm	☐	Specify amount of rental in €	
(4) Rent paid to public local institution (e.g. popular municipal housing)	☐	Specify amount of rental in €	
(5) Rent paid to other public institution	☐	Specify amount of rental in €	
(6) Free of charge	☐		
(7) Other (specify):	☐	Refused to answer	☐

QAB 5. HOW LONG HAVE YOU BEEN LIVING AT THIS ADDRESS?

…………………………………………

QAB 6. WOULD YOU LEAVE THIS AREA IF YOU COULD?

(1) Yes	☐
(2) No	☐

If "No", skip next question.

QAB 7. IF YES, WHY?

(only 1 answer)

(1) To be closer to the workplace of one of my family	☐	(6) To live in a better neighbourhood	☐
(2) To be closer to my relatives	☐	(7) To have better facilities	☐
(3) To come back to my birthplace	☐	(8) For security reasons	☐
(4) To be away from urban "chaos"	☐	(9) Other (specify):	☐
(5) To be close to a historical centre	☐		

IV. LOCATION AND TRAVEL

QMO – INSTRUCTIONS:

- *Fill in the diary, specifying the activities carried out the day before (Saturday and Sunday excluded).*
- *Indicate the location where you were yesterday, from midnight of the previous day (e.g. HOME with **H**, WORK with **W**, SHOPPING with **X**) and indicate travels with **S** (at least one PLACE and the activity carried out) and the travel destinations in the proper cell.*
- *If within 15 minutes you stay in several locations or if more than one activity applies, tick all of them.*
- *If you stay for more than 15 minutes at the same location or activity, connect the bubbles with lines.*
- *Weekly frequency is referred to the days of the week not the weekends (e.g. put 2/7 in case of two day frequency or 3/30 in case of monthly frequency).*
- ***TRAVEL** (by foot (S1), car (S2), motorcycle (S3), bus (S4), taxi (S5), train (S6), bicycle (S7), other). If the travel is outside the map, specify the municipality of destination.*

QPG 2. CAN YOU SHOW ON THE MAP THE AREA WHERE YOU LIVE AND THE AREA WHERE YOU WORK?

Show Map (home with "H", work place with "W")

For the interviewer:

(1) Interviewee answered	☐	Refused to answer	☐
(2) Work outside the area (specify):_____________	☐	Don't know	☐

QMO 1. Show Diary Form

For the interviewer:

(1) Interviewee answered	☐	Refused to answer	☐
(2) Work outside the area (specify):_____________	☐	Don't know	☐

QUESTIONNAIRE ID AND CODE OF INTERVIEWER

HOUR	MINUTE	HOME/WORK/TRAVEL/OTHER (specify)	Cell	Frequency		HOUR	MINUTE	HOME/WORK/TRAVEL/OTHER (specify)	Cell	Frequency
0	0					12	0			
	15						15			
	30						30			
	45						45			
1	0					13	0			
	15						15			
	30						30			
	45						45			
2	0					14	0			
	15						15			
	30						30			
	45						45			
3	0					15	0			
	15						15			
	30						30			
	45						45			
4	0					16	0			
	15						15			
	30						30			
	45						45			
5	0					17	0			
	15						15			
	30						30			
	45						45			
6	0					18	0			
	15						15			
	30						30			
	45						45			
7	0					19	0			
	15						15			
	30						30			
	45						45			
8	0					20	0			
	15						15			
	30						30			
	45						45			
9	0					21	0			
	15						15			
	30						30			
	45						45			
10	0					22	0			
	15						15			
	30						30			
	45						45			
11	0					23	0			
	15						15			
	30						30			
	45						45			

V. FAMILY CHARACTERISTICS

QFA 1. WHAT IS YOUR OCCUPATIONAL STATUS?

(1) Employed (full time)	☐	Refused to answer	☐
(2) Employed (part time)	☐		
(3) Looking for a job	☐	**Go to QFA 5**	
(4) Unemployed (worked previously)	☐	**Go to QFA 5**	
(5) Retired	☐	**Go to QFA 5 if not working**	
(6) Inactive (not looking for a job)	☐		
(7) Unable to work	☐	**Go to QFA 5**	
(8) Student	☐	**Go to QFA 5 if not working**	
(9) Housekeeper	☐	**Go to QFA 5**	
(10) Other (specify, e.g. two part-time jobs; occasional work, seasonal work)	☐		

QFA 2. WHICH IS THE OCCUPATIONAL QUALIFICATION OF YOUR JOB?

Employed as:		(10) Professional	☐
(1) Executive	☐	(11) Self-employed (e.g. trader, artisan, farmer)	☐
(2) Management	☐	(12) Member of producers' cooperative	☐
(3) Employee	☐	(13) Contributing worker in family firm	☐
(4) Specialized worker	☐	(14) Other independent position	☐
(5) Non-specialized worker	☐	Work short term on daily/weekly/monthly basis (subordinate low-pay job):	☐
(6) Apprentice	☐	(15) Collaborate/job on project	☐
(7) Work at home on behalf of a firm	☐	(16) Occasional worker	☐
(8) Other employee condition	☐	(17) Other precarious position	☐
Independent/self-employed (those answering this section go to QFA. 4):		Refused to answer	☐
(9) Entrepreneur	☐		

If QFA 2 received answers between 9 and 14, skip question QFA 3 and go to QFA 4.

QFA 3. YOUR JOB IS REGULATED BY:

(1) Regular contract	☐	(3) Contract that does not correspond 100% with the actual work	☐
(2) Oral agreement with the employer	☐	Refused to answer	☐

QFA 4. WHICH SECTOR ARE YOU EMPLOYED IN?

(1) Agriculture, hunting, forestry	☐	(9) Transportation, warehousing and information	☐
(2) Fishing	☐	(10) Finance and insurance	☐
(3) Mining	☐	(11) Real estate and rental and leasing sector; scientific and technical services, research	☐
(4) Manufacturing	☐	(12) Public administration	☐
(5) Utilities	☐	(13) Education	☐
(6) Construction	☐	(14) Health care and social assistance	☐
(7) Wholesale and retail trade; cars, motorcycles, home repairs	☐	(15) Other public services	☐
(8) Hotel, food services	☐	(16) Other	☐
		Refused to answer	☐

QFA 5. INCLUDING YOU, HOW MANY PEOPLE LIVE IN YOUR HOUSE?

|__|__|

If 1, go to QFA 12.

QFA 6. CAN YOU LIST THE PEOPLE LIVING IN YOUR HOUSE, SPECIFYING THEIR RELATIONSHIP TO YOU?

(For answers 1 to 8, ask the age; for answers 7 to 11, specify the number.)

(1) Father	☐	Age |___|___|
(2) Mother	☐	Age |___|___|
(3) Father-in-law	☐	Age |___|___|
(4) Mother-in-law	☐	Age |___|___|
(5) Husband/wife	☐	Age |___|___|
(6) Partner	☐	Age |___|___|
(7) Children	☐	Number |____| Age |___|___| |___|___| |___|___|
(8) Children of husband/wife or cohabiting partner	☐	Number |____| Age |___|___| |___|___| |___|___|
(9) Brothers and sisters	☐	Number |____|
(10) Other relatives (e.g. nephews, cousins, uncles)	☐	Number |____|
(11) Other (non-relatives)	☐	Number |____|

QFA 7. IS YOUR WIFE/HUSBAND/PARTNER OR THE HEAD OF THE FAMILY AN ITALIAN CITIZEN?

(1) Yes, she/he is Italian	☐
(2) No, she/he is from another EU country	☐
(3) No, she/he is from a country outside the EU	☐

QFA 8. WHAT IS THE HIGHEST LEVEL OF EDUCATION YOUR SPOUSE/PARTNER HAS?

(1) Without	☐	(4) Secondary school	☐
(2) Primary school	☐	(5) University (undergraduate, postgraduate, PhD)	☐
(3) Middle school diploma	☐	Don't know	☐

QFA 9. WHAT IS THE OCCUPATIONAL STATUS OF YOUR WIFE/HUSBAND/PARTNER OR HEAD OF THE FAMILY?

(1) Employed (full time)	☐	
(2) Employed (part time)	☐	
(3) Looking for a job	☐	**Go to QFA 12**
(4) Unemployed (previously working)	☐	**Go to QFA 12**
(5) Retired	☐	**Go to QFA 12 if not working**
(6) Unable to work	☐	**Go to QFA 12**
(7) Inactive (not looking for a job)	☐	**Go to QFA 12**
(8) Student	☐	**Go to QFA 12**
(9) Housekeeper	☐	**Go to QFA 12 if not working**
(10) Other (specify, e.g. two part-time jobs; occasional work, seasonal work)	☐	
Don't know	☐	

QFA 10. WHAT IS THE OCCUPATIONAL QUALIFICATION OF YOUR WIFE/HUSBAND/PARTNER OR HEAD OF FAMILY?

Employed as:		(10) Professional	
(1) Executive	☐	(11) Self-employed worker (e.g. trader, artisan, farmer)	☐
(2) Management	☐	(12) Member of producers' cooperative	☐
(3) Employee	☐	(13) Contributing worker in family firm	☐
(4) Specialized worker	☐	(14) Other independent position	☐
(5) Non-specialized worker	☐	Work short term on daily/weekly/monthly basis (subordinate low-pay job):	
(6) Apprentice	☐	(15) Collaborate/job on project	☐
(7) Working at home on behalf of a firm	☐	(16) Occasional worker	☐
(8) Other employee condition	☐	(17) Other precarious position	☐
Independent/self-employed (those answering this section go to QFA 4):			
(9) Entrepreneur	☐	Refused to answer	☐

QFA 11. THE OCCUPATION OF YOUR WIFE/HUSBAND/PARTNER OR HEAD OF FAMILY IS REGULATED BY:

(1) Regular contract	☐	(3) Contract that does not correspond 100% with the actual job	☐
(2) Oral agreement with the employer	☐	Refused to answer	☐

QFA 12. HOW MANY PEOPLE IN YOUR FAMILY (INCLUDING YOU) WORK OR RECEIVE AN INCOME, EVEN OCCASIONALLY?

|____|____|　　Refused to answer ☐

VI. LIVING CONDITIONS

QPE 1. CONSIDERING THE TOTAL INCOME OF YOU AND YOUR FAMILY, THE ECONOMIC–FINANCIAL LEVEL OF YOUR FAMILY ALLOWS YOU TO LIVE:

(1) With many difficulties	☐	Refused to answer	☐
(2) With difficulties	☐		
(3) With few difficulties	☐		
(4) Easily	☐		

QPE 2. WAS YOUR FAMILY ABLE TO SAVE SOME MONEY IN THE LAST 12 MONTHS?

(1) Yes	☐	Refused to answer	☐
(2) No	☐		
Don't know	☐		

QPE 3. WHAT NET MONTHLY INCOME (IN EUROS) DO YOU THINK WOULD BE ADEQUATE TO SATISFY THE NEEDS OF A FAMILY SIMILAR TO YOURS?

(1) Up to 1000	☐	(11) From 5500 to 6000	☐	Don't know	☐
(2) From 1000 to 1500	☐	(12) From 6000 to 6500	☐	Refused to answer	☐
(3) From 1500 to 2000	☐	(13) From 6500 to 7000	☐		
(4) From 2000 to 2500	☐	(14) From 7000 to 7500	☐		
(5) From 2500 to 3000	☐	(15) From 7500 to 8000	☐		
(6) From 3000 to 3500	☐	(16) From 8000 to 8500	☐		
(7) From 3500 to 4000	☐	(17) From 8500 to 9000	☐		
(8) From 4000 to 4500	☐	(18) From 9000 to 9500	☐		
(9) From 4500 to 5000	☐	(19) From 9500 to 10 000	☐		
(10) From 5000 to 5500	☐	(20) More than 10 000	☐		

QPE 4. KINDLY INDICATE THE NET MONTHLY INCOME IN EUROS (ADDING THE INCOME OF ALL THE COMPONENTS) THAT YOUR FAMILY CURRENTLY RECEIVES?

(1) Up to 600	☐	(8) From 2400 to 3000	☐	Refused to answer	☐
(2) From 600 to 1000	☐	(9) From 3000 to 4000	☐		
(3) From 1000 to 1300	☐	(10) From 4000 to 5000	☐		
(4) From 1300 to 1600	☐	(11) From 5000 to 6000	☐		
(5) From 1600 to 1900	☐	(12) From 6000 to 7500	☐		
(6) From 1900 to 2100	☐	(13) From 7500 to 9000	☐		
(7) From 2100 to 2400	☐	(14) More than 9000	☐		

QPE 5. IN THE LAST THREE YEARS, DID YOU TAKE MEDICINE FOR ANY PARTICULAR DISEASE RELATED TO THE RESPIRATORY TRACT?

(1) Bronchitis	☐	(4) No	☐
(2) Pneumonia	☐	Refused to answer	☐
(3) Asthma	☐		

QPE 6. DO YOU CURRENTLY TAKE MEDICINE FOR CARDIOVASCULAR DISEASES?

(1) Yes (specify which disease)	☐		
(2) No	☐	Refused to answer	☐
Don't know	☐		

QPE 7. DO YOU THINK THAT, IN THE LAST FIVE YEARS, YOU (OR INDIVIDUALS BELONGING TO YOUR FAMILY) HAVE SUFFERED ANY DISEASE THAT CAN BE LINKED TO THE CONDITION OF THE ENVIRONMENT?

(1) Yes (specify which disease)	☐		
(2) No	☐	Refused to answer	☐
Don't know	☐		

QPE 8. IN THE EVENT OF A SERIOUS DISEASE, WHAT WOULD YOU DO?

(1) I would approach my family doctor.	☐	(4) I would approach health facilities outside the region.	☐
(2) I would approach a specialist and local health facilities.	☐	(5) Other (specify)	☐
(3) I would ask relatives and friends for advice.	☐	Don't know	☐
		Refused to answer	☐

AS PROVIDED FOR BY LAW NO. 675/96 ON THE PROCESSING OF PERSONAL DATA, I HAVE TO INFORM YOU THAT, FOR THE SHORT PERIOD IN WHICH WE WILL PROCESS YOUR ANSWERS, YOU CAN ASK TO CONSULT THE ANSWERS YOU GAVE US, MODIFY THEM OR NEGATE YOUR CONSENT TO OUR PROCESSISNG THEM. YOU CAN WRITE TO:

UNIVERSITY OF MESSINA – WHO – FRENCH NATIONAL CENTER FOR SCIENTIFIC RESEARCH

Would you be available to be contacted again for other investigations?
Yes ☐ No ☐

THANK YOU FOR YOUR KIND COLLABORATION. THE QUESTIONNAIRE IS FINISHED. THANKS FOR YOUR AVAILABILITY TO ANSWER ALL OUR QUESTIONS. HAVE A NICE DAY.

TO BE FILLED IN AFTER THE END OF THE INTERVIEW

QPE 9. ADDRESS OF THE INTERVIEWEE

____

QPE 10. CENSUS TRACT

|__________|

INT 1. ASSESSMENT OF THE RELIABILITY OF THE ANSWERS GIVEN BY THE INTERVIEWEE

Excellent (4)	Good (3)	Poor (2)	Unreliable (1)

INT 2. ASSESSMENT OF THE RELIABILITY OF THE ANSWERS GIVEN BY THE INTERVIEWEE WITH REGARD TO THE ECONOMIC CONDITIONS (available income)

Excellent (4)	Good (3)	Poor (2)	Unreliable (1)

INT 3. ASSESSMENT OF THE ATTENTION PAID BY THE INTERVIEWEE

Excellent (4)	Good (3)	Poor (2)	Not at all (1)

QAB 8. ASSESSMENT OF THE QUALITY OF HOUSING OF THE INTERVIEWEE

Apartment		Villa		Structural problems (e.g. crack in a wall, plaster peeling off the walls)	
(1) Luxury condominium	☐	(5) One-family villa	☐		
(2) Middle class condominium	☐	(6) More than one-family villa	☐	(1) Interior	☐
(3) Popular condominium	☐	(7) Country house	☐	(2) Outside	☐
(4) Independent apartment	☐				

Interviewer comments

Chronology of major accidents in the three Sicilian petrochemical areas

Federica Menichini, Pierpaolo Mudu, Sergio Bajardi

It is worth briefly discussing how the populations in Augusta–Priolo and Milazzo–Valle del Mela perceive the issue of accidents and potential catastrophic events, using five questions (see the questionnaire in this Annex: questions QPR 8, QPR 9, QPR 13, QPR 14 and QPR 15) from the survey conducted on a sample of adults (see Chapter 15). The answers contribute to a picture of great concern, both in Augusta–Priolo and Milazzo–Valle del Mela, about the risk of an earthquake (Table A1). Accidents in the industrial zones are a particular matter of concern in Augusta–Priolo, and personal experience is much higher in Augusta–Priolo than in Milazzo–Valle del Mela. The long record of accidents has a strong residue of memories, and authorities do not seem to be a reliable reference point.

Table A1. Augusta–Priolo and Milazzo–Valle del Mela: survey results on the risk perception of potential catastrophes

Question number	Survey responses	
	Augusta–Priolo	Milazzo–Valle del Mela
QPR 8: major potential catastrophes people imagined (first four listed, including per cent of respondents)	Earthquake (32.7%)	Earthquake (29.1%)
	Accident in the industrial zone (32.7%)	Explosion at the refinery (20.6%)
	Fire in the industrial area (11.2%)	Explosion in the industrial area (10.8%)
	Industrial disaster (8.4%)	Industrial disaster (7.3%)
QPR 9: reason to think about a catastrophe (first three listed, including per cent of respondents)	It has already happened (37.7%)	Proximity to industrial plants (22.9%)
	Earthquake zone (13.1%)	It has already happened (12.9%)
	Proximity to industrial plants (7.7%)	It is probable (9.8%)
QPR 13: personal experience with a serious accident in your area (per cent of respondents)	Yes (38.1%)	Yes (11.4%)
	No (61.9%)	No (88.6)
QPR 14: episode of a serious accident experienced (first three listed, including per cent of respondents)	Earthquake (41.6%)	Explosion (29.3%)
	Explosion (19.5%)	Toxic cloud (12.1)
	Fire (7.5%)	Fire (5.2)
QPR 15: in that specific episode, who was relied on? (first three listed, including per cent of respondents)	Family at home (64.4%)	Other (50.0%)
	Other (12.4%)	Civil protection (23.3%)
	Relatives (8.6%)	Family at home (11.7%)

Industrial areas are often victims of accidents (Sovakool, 2009). Sicily is not an exception. Once established in Sicily, the petrochemical industry has been involved in several major (and minor) accidents. To offer a picture of the difficult conditions of these industrial areas, it is critical to complement the contamination data with a list of accidents. Although the construction of the data for such accidents is very difficult, due to the lack of institutional coordination and lack of a systematic database collection, some of them are listed (see Table A2), to provide a glimpse of the situation. In 2006, according to a table published by the association Terranostra, nine accidents occurred in the three Sicilian areas, mostly reported in Gela, where five accidents occurred (Terranostra, 2008).

Table A2. A chronology of major accidents in the three Sicilian areas

Area	Date	Event	Known impacts
Augusta	Jan. 1959	Fire.	One worker died from burns suffered while doing maintenance work on a fractionating column.
Augusta	Feb. 1961	As a result of a fire, thousands of tonnes of oil burned, with flames as high as 100 m.	Two workers were injured.
Priolo	Sept. 1965	A tank of sulfuric acid exploded.	Two workers died.
Priolo	Aug. 1967	40 000 tonnes of fertilizer burned, creating a toxic cloud.	Priolo was alerted to evacuate.
Augusta	Aug. 1971	During loading at one company's pier, the petrol tankers caught fire and 4000 tonnes of gasoline burned.	Six people died, many were injured and a pier was destroyed.
Priolo	Sept. 1971	In the SG-14 plant, two tanks containing 5000 m^3 of acetaldehyde (each) and two tanks containing 1000 m^3 of acrylonitrile (each) burned.	Many firefighters were hospitalized from inhaling chemicals. An hour later, 80% of the inhabitants of Priolo left their homes. Many fish died, and fishing was banned for 15 days along the coast.
Augusta	Nov. 1971	While one company was doing reclamation work, six workers were poisoned by petrol fumes that contained tetraethyl lead.	Three workers died.
Priolo	Nov. 1971	Fire at the CR-11 plant.	Four workers were injured.
Priolo	Aug. 1973	Sulfuric acid leakage.	A young man died after inhaling the toxic fumes.
Priolo	Nov. 1979	Explosion at the AM-6 plant.	Three workers died and two were injured
Priolo	May 1985	One plant was destroyed by a series of explosions in two tanks of ethylene.	A woman died of a heart attack in Priolo and six workers were injured; one died from the accident after a year.
Priolo	May 1985	An accident occurred during the maintenance of a fractionating column.	One worker died from burns.
Priolo	Nov. 1987	Sulfuric acid spilt into the street and then into the sea.	No impact was reported.
Priolo	Jan. 1988	An ammonia leak occurred.	Nine railmen were hospitalized from inhaling chemicals.
Priolo	Jan. 1988	A nitrogen pipe exploded.	No impact was reported.
Priolo	Jan. 1988	Fire at the CR1/2 plant.	One worker died.
Priolo	Feb. 1988	Due to a malfunctioning of the electric services plant, several tonnes of fuel oil spilled into the sea, the third such occurrence within a month.	No impact was reported.
Augusta	Aug. 1988	One Greek ship lost several tonnes of crude oil in Augusta Harbour.	No impact was reported.
Priolo	Nov. 1988	A lightning strike ignited three tanks of crude oil.	No impact was reported.
Priolo	Jan. 1989	A fire occurred on an Egyptian ship while it was loaded with fertilizer at the company's pier.	The wind pushed the toxic cloud offshore.
Priolo	Mar. 1989	Legambiente denounced a loss of industrial sewage from a plant pipe.	No impact was reported.
Augusta	Aug. 1989	A fire occurred at the OXO–ALCOLI plant.	People disagreed on the seriousness of the fire, and workers contradicted the official statements of the factory and the union that sought to minimize the situation.

Table A2 (continued)

Area	Date	Event	Known impacts
Augusta	Sept. 1989	A fluid catalytic cracking plant had a dangerous failure and stopped work.	During the failure (according to unofficial comments), from 4 to 12 tonnes of bromine catalyst were released from the plant into the atmosphere.
Priolo	Sept. 1989	Stoppage at one plant; a high and dense column of black smoke was visible from many kilometres away.	Tonnes of heavy hydrocarbons and polynuclear aromatic hydrocarbons, known to be carcinogenic, were dispersed into the atmosphere.
Priolo	Sept. 1989	The power generator of one plant created security problems for which it was decided to stop it; workers were forbidden access to the plant for several days while firefighters kept the plant continuously under control.	No impact was reported.
Priolo	Sept. 1990	While being transferred, sulfuric acid broke down a rubber armoured hose.	Three workers were burned by the acid spill and hospitalized in Catania; due to the severity of the burns, one of them was transported to Barcelona (Spain).
Priolo	Oct. 1990	A violent storm caused a power outage in the industrial area, and many plants stopped working.	For about a week, factory torches and chimneys released an unknown amount of air pollutants. Thick columns of black smoke were seen rising for several days from various parts of the industrial zone, without the population receiving any communication about the situation.
Augusta	May 1991	A persistent odour came from the industrial area.	The citizens of Augusta protested.
Milazzo–Valle del Mela	June 1993	The Contrada Mangiavacca area, belonging to one refinery, had a large fire.	It resulted in 8 deaths and 20 injuries.
Milazzo–Valle del Mela	June 1993	Explosion.	Seven workers died from the explosion.
Priolo	Aug. 1993	Explosion.	No impact was reported.
Priolo	Aug. 1994	A pipe burst in the plant cracking unit.	A deafening roar was heard, followed by dense dark smoke and tall flames; nobody died or was injured.
Priolo	Oct. 1999	Gas leak from a safety valve of a ship in the pier.	The citizens of Augusta and Priolo protested.
Priolo	Nov. 1999	Fire.	Nobody died or was injured.
Priolo	June 2000	Gas leak and explosion.	Five workers intervened.
Milazzo–Valle del Mela	Apr. 2001	Industrial emissions west of Pace del Mela caused a huge black cloud in the atmosphere.	In the area of Archi, an unbearable odour affected the residents, and there were also cases of difficult breathing.
Milazzo–Valle del Mela	July 2001	Emission of pollutants from the refinery, including hydrogen sulfide: the monitoring station located within the refinery did not work, thereby causing a further delay in recognizing the excess emissions.	Some workers who breathed the gas were admitted to the infirmary and the hospital. The newspapers also reported that union sources mentioned the failure of emergency sirens.
Milazzo	Aug. 2001	Some workers, while intending to transfer fuel oil from a ship to pipes that go to the plant, mistakenly transferred it to a small tank in the refinery that is usually used for the storage of waste water.	Soil was polluted.

Table A2 (continued)

Area	Date	Event	Known impacts
Milazzo–Valle del Mela	Aug. 2001	Giammoro, Pace del Mela (Messina Province) industrial area: during the last week of the month, the monitoring stations of the Province reported anomalies, both within the oil industry plants and in the central plant where the previous weekend there was an out-of-service event that caused a leak of polluting substances.	Because of an intolerable odour, the environmental protection unit of the police checked the sewage treatment of the industrial area of Giammoro, in the municipality of Pace del Mela. The odour also affected the nearby villages of Monforte and San Pier Niceto. Environmentalists complained about the strong odour in the atmosphere that made life difficult for the inhabitants of the village of Gabbia, which is surrounded by industrial activities.
Milazzo–Valle del Mela	Sept. 2001	A black cloud appeared, due to a plant stoppage.	No impact was reported.
Milazzo–Valle del Mela	Mar. 2002	From the refinery, the power plant in San Filippo del Mela and in a plant producing energy from water vapour originated water pollution and an increase in the temperature of the water.	The water along the coast between Villafranca Tirrena and Milazzo was at risk of being polluted.
Gela	June 2002	Explosion in the topping plant of the petrochemical plant.	No one was injured, but the fire generated after the explosion destroyed parts of the topping plants of the refinery.
Milazzo–Valle del Mela	Sept. 2002	Milazzo (Cimitero area), seaside near the harbour and refinery plants – carcinogenic pollutants were found in the marine subsoil in thirteen places, along with very high concentrations of polycyclic aromatic hydrocarbons and organic compounds containing highly toxic benzene.	No impact was reported.
Milazzo–Valle del Mela	Oct. 2002	Pace del Mela industrial area – release of air pollutants	For several hours (early in the morning and late in the evening, on the last day of the month), the neighbourhoods adjacent to the industrial area suffered from a strong odour of gas that, at times, made breathing difficult for residents.
Milazzo–Valle del Mela	Feb. 2003	During a normal phase of transporting a tank containing oil polychlorinated biphenyls, highly toxic and carcinogenic, its contents spilled on the ground.	In March, the Province asked ARPA Sicily to inspect the accident site. The inspectors found that the remediation of polychlorinated biphenyls was attempted, but also found high rates of heavy oil in the ground.
Priolo	Feb. 2003	The monitoring stations in front of the plant measured the presence of mercury.	No impact was reported.
Milazzo–Valle del Mela	May 2003	Pace del Mela Industrial area – the Contrada Gabbia neighbourhood experienced nauseating putrid odours from the industrial consortium treatment system.	No impact was reported.
Priolo	June 2003	Petrol leaked from about 270 storage tanks in a refinery.	The waters of the area of Priolo, both surface and underground, were polluted by hydrocarbons. During the preceding month of April, an elderly farmer in Priolo, Sebastiano Cannamele (a former employee of Agip Petroleum), filed a public complaint, after finding gasoline emerging from his tap, instead of the drinking-water normally used for irrigation.
Milazzo–Valle del Mela	Oct. 2003	The oil refinery had an emergency, due to an electrical power outage that lasted an hour; the plants stopped working, causing the conveyance of a larger than normal amount of gas into the torch, whose flame increased, accompanied by a high column of black and yellow smoke.	Out of fear, the inhabitants of the area of Milazzo called the fire department.
Gela	Oct. 2003	Black smoke rose from the chimney of the refinery.	According to a newspaper, after covering the industrial area for hours the black cloud reached Palermo.

Table A2 (continued)

Area	Date	Event	Known impacts
Milazzo–Valle del Mela	Aug. 2004	Pace del Mela industrial zone – for a month, reports circulated about the intensification of intolerable odours, presumably linked to gas emissions of hydrocarbons from the surrounding industrial area, that annoyed the population residing in the Contrada Acqueviole neighbourhood (Municipality of Milazzo); the course of the phenomenon was related to meteorological conditions.	Urgent action against increasing emission levels was requested.
Milazzo–Valle del Mela	Oct. 2004	Pace del Mela Industrial zone – gaseous emissions.	In the area near Via Acqueviole, Via Gramsci and the Istituto Statale d'Arte, 70 people (students and teachers) sought medical aid for breathing problems.
Milazzo–Valle del Mela	Oct. 2004	In San Filippo del Mela, black dust propagated in the area surrounding the power station.	Several residents in the area of Archi (around the power station) reported that, for several months, a thick layer of black dust, coming from the power plants, was present daily on balconies, terraces, cars and even inside houses.
Milazzo–Valle del Mela	Nov. 2004	Gaseous emissions surrounded a school with a toxic cloud from a refinery.	For the third time in three weeks, about 100 students and teachers from the Istituto Statale d'Arte di Milazzo, had to seek medical aid for breathing problems.
Milazzo–Valle del Mela	Nov. 2004	A flare occurred during maintenance work when the refinery plants were closed.	A maintenance worker hit by the flare suffered serious burns to the face and body.
Milazzo–Valle del Mela	Nov. 2004	During loading, at the refinery pier, finished products (such as petrol and diesel oil) released gaseous emissions; emission-limiting measures for volatile organic compounds were inadequate or not available.	It was found that vacuum systems and conveying systems for capturing fumes in the air during the loading of ships were not installed in two docks, which led to controls being instituted.
Milazzo–Valle del Mela	Dec. 2004	Milazzo Industrial area – gaseous emissions reached the centre of Milazzo.	At times, in Milazzo, the air was unbreathable. As a result, some civil servants in the Piazza Caio Duilio and Via Crispi experienced slight illness, and numerous citizens, alarmed by the odour, called the police, fire department and environmentalists.
Gela	Dec. 2004	High voltage substation was functioning, instead of being turned off.	One worker was electrocuted by a 6000-volt jolt.
Milazzo–Valle del Mela	May 2005	A sudden fire spread in the western area of the power plants, near Archi; the flames quickly rose and spread to the instrumentation.	No impact was reported.
Priolo	Apr. 2006	Following an oil spill, a vast fire developed in the area of the northern plants.	Several firefighters were injured, and the public prosecutor of Syracuse seized the refinery, to investigate the cause of the fire.
Milazzo–Valle del Mela	June 2006	A fire produced a thick column of smoke.	Through the activation of the fixed extinguisher stations and the combined action of internal emergency team and the Fire Brigade from Milazzo, the fire was extinguished, avoiding serious potential effects.
Gela	July 2006	Power plant operation was interrupted.	No impact was reported.
Gela	Aug. 2006	Operation of the ethylene plant was interrupted.	No impact was reported.
Gela	Sept. 2006	The petrochemical plant emitted black (thick and odorous) smoke.	No impact was reported.
Gela	Oct. 2008	Fire developed from a loss of oil in a compressor plant that distills the aromatic cyclic products.	No impact was reported.
Milazzo–Valle del Mela	Mar. 2008	Fire.	No impact was reported.

Table A2 (concluded)

Area	Date	Event	Known impacts
Priolo Gargallo	Oct. 2008	An explosion occurred in the boiler of the gasifier (TG1); due to faulty operation during maintenance work, there was a gas leak that caused the explosion of a turbine, spreading shards and burning combustible materials over the area; the gas turbine, steam turbine, the alternator and the boiler were involved.	One worker was injured.
Gela	Nov. 2008	Gas leak.	No impact was reported.
Priolo	Nov. 2008	Sulfuric acid leaked from the plant for desulfurization.	Twenty workers engaged in shutting down the nearby ethylene plant within the Polymeri establishment were asphyxiated.
Priolo	Nov. 2008	Hundreds of litres of fuel oil spilt into the sea during the loading of a tanker.	No impact was reported.
Gela	Jan. 2009	The production unit for co-catalyst processes exploded.	One worker died, and the public prosecutor initiated an investigation and seized the plant.
Milazzo–Valle del Mela	Feb. 2009	A container of argon gas exploded.	One worker's hand was injured.
Gela	Apr. 2009	An explosion occurred in the plant for refining motor fuel.	No impact was reported.
Priolo	Nov. 2009	On a pier, during the final phases of loading a ship, the loading arm hit a sailor from Latvia.	The sailor was transported to the Syracuse hospital where he died.
Gela	May 2010	A tank for treating acid water of the sour water stripper (SWS) unit for the reduction of polluting sulfur compounds exploded, on Island 7 North.	The explosion displaced a column 70 m and a tank for several metres.

Sources: Terremoto dei silenzi (2009); Association for the Protection of the Health of Citizens (2012); ARPA Sicily (2012); Corriere della Sera (2012); Gazzetta del Sud (2011).

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INDEX

The WHO Regional Office for Europe

The World Health Organization (WHO) is a specialized agency of the United Nations created in 1948 with the primary responsibility for international health matters and public health. The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health conditions of the countries it serves.

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In recent years, increasing attention has been focused on the health effects of large industrial establishments. The aim of this book is to outline a framework for the integrated assessment of the effects of large industrial activities on health. The framework is supported by examples related to the effects on environment and health of the petrochemical industry, based on the results of a research project carried out in the Sicilian Region of Italy by the WHO European Centre for Environment and Health. The Sicilian case studies provide a method for estimating the health effects of petrochemical activities in highly contaminated areas and an instrument for integrating health impact assessment into the decision-making and influencing rehabilitation plans.

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