World Health Organization
REGIONAL OFFICE FOR Europe

Contaminated sites and health

Report of two WHO workshops:
Syracuse, Italy, 18 November 2011
Catania, Italy, 21–22 June 2012

Contaminated sites and health

Report of two WHO workshops:
Syracuse, Italy, 18 November 2011
Catania, Italy, 21–22 June 2012

World Health Organization
REGIONAL OFFICE FOR Europe

ABSTRACT

In Europe, earlier industrialization and poor environmental management practices have left a legacy of thousands of contaminated sites. Past and current activities can cause local and diffuse accumulation of environmental stressors to an extent that might threaten human health and the environment, by altering air quality, hampering soil functions, and polluting groundwater and surface water.

The WHO European Centre for Environment and Health organized two technical meetings – which included representatives of environmental and public health agencies (at the national and international levels) and research experts – to explore priorities, interests and needs and to review the state of the art, the current methodological options, and knowledge gaps in the domain of contaminated sites and health.

The assessment of the possible health impact of contaminated sites is a challenging exercise, especially in the case of industrially contaminated sites with ongoing multiple industrial activities and involving multiple human exposures. Notwithstanding these complexities, a variety of methods and tools for health impact assessment have been developed and applied to study contaminated sites, and a broad range of resources is available; these must be carefully selected and applied, depending on the needs, objectives and local feasibility.

Available assessments suggest that contaminated sites are an important public health issue at the national and international levels. Priority topics and goals for collaborative work on contaminated sites and health were identified at the two meetings.

Keywords

ENVIRONMENTAL EXPOSURE – adverse effects
ENVIRONMENTAL POLLUTION
EPIDEMIOLOGICAL STUDIES
INDUSTRIAL WASTE
PUBLIC HEALTH
RISK ASSESSMENT

Address requests about publications of the WHO Regional Office for Europe to:

Publications
WHO Regional Office for Europe
UN City, Marmorvej 51
DK-2100 Copenhagen Ø, Denmark

Alternatively, complete an online request form for documentation, health information, or for permission to quote or translate, on the Regional Office web site (http://www.euro.who.int/pubrequest).

CONTENTS

Executive summary

Europe has thousands of contaminated sites. They are the result of earlier industrialization and poor environmental management practices. Past and current activities can cause local and diffuse accumulation of environmental stressors to an extent that might threaten human health and the environment, by altering air quality, hampering soil functions, and polluting groundwater and surface water.

Among potentially contaminated sites are those hosting (or having hosted) production and processing plants and facilities for: chemicals, petrochemicals, manufacturing, waste disposal and/or treatment, cement, power generation, mining and metals. Scientific and policy concerns have been expressed about the well established or suspected impact on health of these sites. This is an important public health issue for several reasons: the large extent of contamination, documented in many contaminated sites; the coexistence of multiple environmental stressors; and the concurrence of several residential and/or occupational exposure pathways.

Furthermore, industrially contaminated sites are often located close to urban areas and/or socially deprived neighbourhoods; this makes exposure patterns more complex and results in interactions with other health determinants. It is therefore desirable to gather and compile existing evidence, to define the problem more precisely and identify methodological approaches useful in better characterizing the impacts on health of contaminated sites – as allowed by available data and resources. This information would be a determinant in formulating more effective public health actions and sound policy advice for populations affected by such sites.

Because of this situation, the WHO European Centre for Environment and Health has proposed a European network on contaminated sites and health – to bring together experts and institutions with common interests and duties on this topic – and engaged in providing information and advice on the health impact of contaminated sites and their remediation.

As a first step, the WHO European Centre for Environment and Health organized two technical meetings (Syracuse, 18 November 2011; and Catania, 21–22 June 2012): to review the state of the art, availability of data and current methodological options in the domain of contaminated sites and health; to explore priorities, interests, needs and knowledge gaps; and, finally, to identify topics and goals for collaborative work.

Possibly because contaminated sites are very heterogeneous, a common definition is not available, nor are common criteria to set up inventories of those sites at the local, national or European levels. There is concern, however, about areas hosting (or having hosted) human activities that have produced or might produce environmental contamination of soil, surface water or groundwater, air, and the food-chain, resulting (or being able to result) in human health impacts. For these instances, the existing legislative framework makes several provisions that address prevention and control of polluting activities in different fields, such as waste management, chemicals and industrial emissions.

The assessment of the possible health impacts of contaminated sites is challenging. Each site has its own characteristics, and it is difficult to describe typical or exemplary cases of exposure scenarios, especially for industrially contaminated sites with ongoing multiple industrial activities. Notwithstanding these complexities, a variety of methods and tools for characterizing impacts on health have been developed, and a broad range of resources are available. A suitable methodology and the data required for health assessments must be carefully selected and applied, depending on the needs, objectives and (local) feasibility.

To pursue better quantification of the overall health impact of contaminated sites, more systematic data are needed to improve the process of assessing human exposure. With respect to this, many initiatives at the European level have been developed, especially with soil as an entry point. Important initiatives have been undertaken by the European Commission – through DG Environment, the Joint Research Centre, and the European Environment Agency – to gather data on contaminated soils from many countries in Europe. According to the last data collection exercise, conducted in 2011, the number of potentially contaminated sites in European Environment Agency countries and west Balkan countries where potentially polluting activities are occurring (or have taken place in the past) are estimated at about 2.4 million, of which 190 000 have been designated contaminated sites and may need remediative action. Although the main polluting activities vary across Europe, industrial and commercial activities together with the disposal and treatment of waste are reported to be the most important sources of local contamination.

Other European sources of information relevant to human exposure assessment include the European Pollutant Release and Transfer Register (releases from industrial facilities to air, water or soil) and the WISE datasets on European water issues. Those datasets provide valuable information on the status of chemical pollution of water, air or soil, although with no direct reference to contaminated sites. Adding full georeferencing data to this type of information would represent an important improvement.

The possibility of using these datasets in human health exposure assessment at the European level requires still further work and a stronger and deeper collaboration between environment and public health professionals; with respect to these aims, more initiatives would be desirable, at the national or regional level, especially in countries or regions with limited resources for conducting analytical studies.

Priorities for further work will be defined, taking into account solicitations and requests from the governments of the 53 countries of the WHO Regional Office for Europe and giving particular consideration to those countries with limited experience in dealing with contaminated sites.

Topics and goals for collaborative work have been identified as follows:

- producing guidelines on: (a) strategies for studying environment and health in contaminated sites, focusing on methodology; and (b) communication strategies;
- developing resources, materials and training modules on: (a) approaches and methods to be applied in different sites and contexts; and (b) communication strategies;
- strengthening the methodology on exposure assessment – in particular, on biomonitoring and the food-chain;
- implementing health assessments that include the separate analysis of population subgroups – in particular, children; and
- planning a system to collect data and produce comparative analyses of the health impact of different sources of contamination within and among different countries of the WHO European Region, allowing for the inclusion of socioeconomic factors.

Contributors and editors

This report is the result of discussions held during the two WHO workshops and reflects the contribution of all the participants. Individual presentations are included in Annexes 1 and 2.

The report was edited by Roberto Pasetto (National Institute of Health, Italy), Piedad Martin-Olmedo (Andalusian School of Public Health, Spain), and Marco Martuzzi (WHO Regional Office for Europe).

Acknowledgements

The editors would like to thank all participants in the workshops for their contribution to the discussion and their support in preparing the report.

A special acknowledgment is due to Benedetto Terracini and Ivano Iavarone for coordinating the discussions and chairing, respectively, the fist and the second workshop.

The first workshop was funded by the Sicily Region, Assessorato Territorio e Ambiente, Sportello Unico per le Aree ad elevato Rischio di Crisi Ambientale – Agenda 21 – Amianto.

The second workshop was funded by the project Capacity building in Environment and Health (CBEH), co-funded by the European Commission Directorate-General for Health and Consumers (DG SANCO) and coordinated by the WHO Regional Office for Europe.

List of abbreviations

AIMA	Interactive Mortality Atlas for Andalusia
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	benzene, toluene, ethylbenzene and xylene
CABERNET	Concerted Action on Brownfield and Economic Regeneration Network
CF	Common Forum on Contaminated Land in Europe
CIPAIS	International Commission for the protection of Italian Swiss waters
CLEA	contaminated land exposure assessment (model/initiative)
CSI	core set indicator
DALYs	disability-adjusted life years
DG Environment	European Commission Directorate-General for the Environment
DYNAMO-HIA	Dynamic model for health impact assessment
EASP	Escuela Andaluza de Salud Pública (Andalusian School of Public Health)
EC	European Commission
EEA	European Environment Agency
Eionet	European Environment Information and Observation Network
EPER	European Pollutant Emission Register
E-PRTR	European Pollutant Release and Transfer Register
ESDAC	European Soil Data Centre
EU	European Union
Eurodemo+	European Coordination Action for Demonstration of Efficient Soil and Groundwater Remedation
FOREGS	Forum of European Geological Surveys
GIS	geographic information system
HEIMTSA	Health and Environment Integrated Methodology and Toolbox for Scenario Assessment
HI	Hazard Index
ICCL	International Committee on Contaminated Land
ICT	impact calculation tool
IMPEL	EU Network for the Implementation and Enforcement of Environmental Law
INTARESE	Integrated Assessment of Health Risks of Environmental Stressors in Europe
INSPIRE	Infrastructure for Spatial Information in the European Community
IPPC	integrated pollution prevention and control
IRBD	international river basin district
JRC	European Commission Joint Research Centre
LUCAS	land use/cover area frame statistical survey
NICOLE	Network for Industrially Contaminated Land in Europe

NPCS	national polluted contaminated site
NRS	national remediation site
PAH	polycyclic aromatic hydrocarbons
PCA	principal component analysis
PCBs	Polychlorinated biphenyls
PCDD/Fs	Polychlorinated dibenzo-p-dioxins and dibenzofurans
PCNs	Polychlorinated naphthalenes
PCS	potentially contaminated site
PHA	public health assessment
PLAINE	Plateforme intégrée pour l'Analyse des Inégalités d'Exposition environnementale
POPs	persistent organic pollutants
PRA.MS	Preliminary Risk Assessment Model for the identification and assessment of problem areas for Soil contamination in Europe
RIF	Rapid Inquiry Facility
RTD	research and technological development
SAHSU	Small Area Health Statistics Unit at Imperial College London
SedNet	European Sediment Network
SFD	Soil Framework Directive
SMR	standardized mortality ratios
SNOWMAN	sustainable management of soil and groundwater under the pressure of soil pollution and soil contamination
SoE	state of the environment
SOM	self-organizing map
UNECE	United Nations Economic Commission for Europe
VOCs	volatile organic compounds
WFD	Water Framework Directive
WISE	Water Information System for Europe
WHO	World Health Organization

Introduction to the report

In November 2011 and June 2012, the WHO European Centre for Environment and Health organized two technical meetings on the topic "contaminated sites and health". The meetings were attended by representatives of environmental and public health agencies (at the national and international levels) and research experts.

The aims of the two meetings were to explore priorities, interests and needs and to review the state of the art, the current methodological options, and the gaps in knowledge about contaminated sites and health.

The first meeting was designed as an exploratory workshop, to evaluate the feasibility of developing a network on contaminated sites and health. This was pursued by analysing experiences and studies carried out in several European countries.

The second meeting was held to address some of the questions identified after the first meeting, to further define topics and goals for collaborative work within the WHO network. At the second meeting, available definitions of "contaminated sites" were reviewed; European and/or national datasets with aggregated environmental data related to contaminated sites were explored; and methods and tools that could be applied to the health impact assessment of contaminated sites were compared and contrasted.

The present document includes the reports of the two meetings.

Contaminated sites and health: priorities, interests, needs, methodological options

Syracuse, Italy, 18 November 2011

1 Introduction

In Europe and beyond, industrially contaminated sites are often referred to as one of the priority issues in environment and health. Both scientific and policy circles express concern about the established or suspected health impact of these sites. This issue is particularly challenging for several reasons: the hazards are very heterogeneous; reliable exposure data are sparse; most associations between industrially contaminated sites and health refer to conditions with multifactorial etiology; and the underlying social, economic and occupational framework is complex. Furthermore, industrially contaminated sites are often located close to urban areas, making exposure patterns more complex.

These difficulties explain the relative scarcity of available evidence of causal associations. In fact, published studies are few and difficult to compare, so the extent of the overall problem is unclear. In addition, many industrially contaminated sites have traditionally been located in run-down areas with high unemployment rates, so that conflicts between economic interests and the impact on environmental quality and people's health is a common problem (afterwards) that generates great concern and controversy among residents. Against this background, handling specific control measurements and formulating sound policy advice to inform the debate, at various levels, is often a thorny task for health agencies and public administrations. Thus, it seems desirable to bring together existing expert groups, to discuss strategies, experiences, needs and perspectives, through a multidisciplinary exercise.

2 Possible objectives of a network coordinated by the WHO Regional Office for Europe

Against this background, collaboration or the exchange of information and experiences between institutions and centres concerned with the issue of contaminated sites seems desirable. An initial step is the creation of a European network.

Possible objectives of the collaboration are outlined as follows:

- establish a network of experts/institutions with common interests and duties to study the health effects of contaminated sites and to provide information and advice on risk management or remediation, through the following steps:
  - identify a set of existing representative studies, completed or underway;
  - establish criteria for the recognition of firm knowledge or at least a reliable suspicion of the existence of a problem, either in terms of contamination or health effects;
  - share information on the main public sources of data; and
  - identify institutions and areas within a country with special needs and gaps across Europe (WHO European Region – 53 countries) to face the problem;
- exchange experiences and practices and identify common or preferred methodologies, especially for the following specific areas of interest:
  - analytical epidemiological studies, small-area statistics and tools, and the interpretation of routine health statistics;
  - exposure assessment – for example, emission and/or concentration modelling, distribution of contaminants in environmental matrices or daily activity patterns;
  - biomonitoring;
  - socioeconomic determinants (confounding and interactions); and inequalities and inequities of hot spots;
  - recognition and understanding of the differences between the impact of occupational and environmental exposures;
  - risk of industrial accidents and health security;
  - remediation (economic analysis); and
  - risk governance, perception and communication;
- assess the interest and feasibility of: compiling international data on the effects on health of local contamination of industrial origin; and conducting parallel or joint studies at the international level, by considering the:
  - comparability of published studies;
  - availability and comparability of data on site emissions and/or environmental impacts;
  - availability of data on human exposure;
  - possible classification of sites by nature of industrial activity, type of hazard and potential impact; and
  - availability and comparability of health data on such issues as mortality versus morbidity and spatial resolution.

3 Aims of the exploratory workshop

A project launched in Sicily, which includes studies of three industrial sites, provided the opportunity to convene a small meeting, designed as a workshop. This meeting aimed at discussing and exploring options, interests, and the feasibility and constraints of the above objectives.

More specifically, the aims of the workshop were:

- to share priorities, interests and needs in selected countries, regions and local areas concerning contaminated sites; and
- to discuss methodological options, available data, gaps and opportunities in different countries.

Several case studies from Greece, France, Italy, Slovenia, Spain and the United Kingdom were presented. Starting with the analysis of case studies, possible topics and goals for collaborative work were explored. Finally, short- and medium-term next steps – before a meeting, to be held in 2012 – were identified.

4 Case studies

Ten environment and health studies of contaminated sites were presented, together with an overview of the topic "Health impact of contaminated sites in children". The summaries of those presentations are reported in Annex 1.

The cases reported concerned either local studies that assessed the health impact of contamination sources in a given area or national approaches that evaluated the health risk in the neighbourhood of sites contaminated by comparable sources. There were two experiences at the national level: (a) exposure assessment in waste-related studies in the United Kingdom; and (b) methods and results of the SENTIERI Project (a mortality study of residents in polluted Italian sites). In the latter, for each site, one or more of the following sources of contamination were considered: the chemical industry, petrochemical plants and refineries, steel plants, power plants, mines and/or quarries, harbour areas, asbestos or other mineral fibres, landfills, and incinerators. Approaches, methods and main critical aspects were described in each presentation.

In addition to the national approaches, the following experiences were reported:

- health effects of multiple point sources of air pollution (a municipal solid waste landfill, municipal solid waste and hospital waste incinerator, and a petrochemical refinery) in the same area (Latium, Italy);
- health studies of two industrialized sites (Andalusia, Spain);
- a biomonitoring study of a site contaminated with lead (Mežiška dolina, Slovenia);
- the health effects of air pollution from a large power plant (Eordaia, Greece);
- epidemiological studies in two sites contaminated by petrochemical and refinery plants, and naturally occurring asbestos (Sicily, Italy);
- diffusion modelling and a geographic information system (GIS) as tools for assessing individual exposure to dioxins: the case study of a municipal solid waste incinerator (Besançon, France);
- exposure assessment of people living near regional incinerators (Emilia-Romagna, Italy); and
- epidemiological studies around a steel plant (Piedmont, Italy).

Priorities, interests, needs and methodological options in studying contaminated sites were discussed after each presentation.

5 Priorities, interests and needs

Environment and health studies and strategies developed to study single contaminated sites can have local and/or general interest. The main objectives of local strategies were identified as:

- contribute to the retrospective health impact assessment of local contamination;
- define preventive and/or precautionary public health interventions;
- define priorities in remediation and clean-up activities;
- elucidate exposure pathways;
- identify relative contributions of different risk factors to health status;
- identify any interaction between environmental factors and other determinants – for example, socioeconomic factors; and
- contribute to effective communication with the local population and stakeholders.

In the study of contaminated sites, the following main issues were identified: communication, contamination of environmental media, biomonitoring, children, tools for rapid analysis, exposure and risk over time, environmental justice, and industrial accidents – as described in the following.

5.1 Communication

Three aspects of communication were considered to be of major interest. The first is training activities that promote collaboration between experts in the fields of environment and public health.

In environmental and health studies of contaminated sites, exposure assessments need to be integrated with health risk estimates. Of great importance is the establishment of a common language between experts of different disciplines. Exposure assessment is a complex and challenging exercise, due to several uncertainties about emission and diffusion processes, transportation and fallout, pathways between different environmental media (soil, water, air and biota), and human intake. Also, common major problems in communication are found in acknowledging and explaining the limits of the studies and the uncertainties of their results.

Mutual understanding between environmental and health disciplines is a key prerequisite for their better integration and, ultimately, for the improvement of studies. In this sense, training activities, specially designed to promote real intersectoral collaboration between environmental and public health experts, are identified as a first key aspect to be addressed in the future.

The second aspect is to reduce or eliminate communication obstacles between researchers and policy-makers, so that research findings effectively support the decision-making process.

The third aspect is the need to develop a framework for consistent translation of study results into non-specialized language, to improve the communication of results to the media and other stakeholders. The main obstacles identified in doing so are: (a) scepticism about data quality; and (b) results that contrast with perceived risks. These may follow the loss of credibility and confidence in the Institutions involved in studies and the inadequacy of communication strategies adopted. The need for a more transparent tool for promoting the participation of citizens and advocacy groups throughout the whole process of research studies has been pointed out as a crucial element in understanding and accepting research findings.

5.2 Contamination of environmental media

Even though most of the cases discussed at the meeting referred to industrial contamination and atmospheric emissions, there are several possible sources and pathways for contamination and several different pollutants. Also, the presence of pollutants in different environmental media, their diffusion between media and by different exposure pathways can vary. Defining exposure assessment strategies should be enforced, and the involvement of environmental experts from different fields from the early stages of study design is desirable.

The role of the food-chain is of particular interest. In many contaminated sites, it is an important (yet an understudied) exposure pathway and, potentially, a crucial area for preventive action.

5.3 Biomonitoring

Biomonitoring is a key tool in studying the relationship between environment and health in contaminated sites. Biomonitoring refers to: (a) monitoring contaminants or their metabolites in human biological matrices (for example, in blood, urine or hair); (b) monitoring contaminants or their metabolites in animals or the use of animals as bioindicators; (c) monitoring pollutants in environmental matrices (for example, in moss or lichens). In contaminated sites, biomonitoring can be used with different aims: (a) to identify the presence of a given pollutant in biological matrices, for a qualitative and quantitative evaluation of exposure; (b) to verify the validity and/or consistency of dispersion and/or diffusion exposure modelling; (c) to contribute to exposure assessment approaches based on multiple sources of information.

Biomonitoring can be especially useful when specific pollutants are present – for example, lead contamination. Also, biomonitoring can be particularly relevant in studying small populations, as risk estimates are inevitably uncertain. In these cases, biomonitoring exposure evaluations can be instrumental in planning public health interventions.

5.4 Children

To describe the health profile of populations living in the surroundings of contaminated sites, it is necessary to consider proper subgroups by age. In particular, children should be taken into account, given their high sensitivity to environmental agents. Such sensitivity is due mainly to: (a) higher exposures in infants than in adults under identical environmental conditions (for example, due to hand-to-mouth behaviour); and (b) the physiological and metabolic aspects of childhood (for example, higher intakes per body mass), leading to higher vulnerability to the toxic effects of environmental pollutants.

The protection of children's health from environmental risks was the main theme of the Fifth Ministerial Conference on Environment and Health of the WHO Regional Office for Europe. This topic is particularly relevant to contaminated sites where the exposure to environmental pollutants can be very high and where children can be 20% of the total resident population.

In studying the environmental health risk of children in contaminated sites, birth cohort studies can be very valuable. These studies are designed to evaluate the effects of environmental exposures and their possible interactions with genetic factors and socioeconomic characteristics. They are based on the growing awareness about the health consequences of pre-conception, intrauterine and early life exposures. These exposures might have different and more marked consequences than exposures during adulthood. In cohort studies of newborns, early life environmental exposures are also assessed, using biological samples; these data can be used for an integrated exposure assessment at later stages of life.

5.5 Tools for rapid analysis

In the development of strategies to study contaminated sites, tools for disease mapping and small-area risk analysis are useful, especially when freely available as software or as web-based platforms. Given the availability of routinely collected data about health outcomes, and geocoded data about contamination sources or diffusion and/or dispersion models of contaminants, these tools can be effectively deployed for obtaining rapid answers to address emerging concerns. The Rapid Inquiry Facility (RIF) software, developed over the last 10–15 years at Imperial College London, is a notable example of such tools.

5.6 Exposure and risk over time

The time dimension in exposure assessment and in risk evaluation is a common weak point in environment and health studies. The difficulties are amplified in contaminated sites where the time variability of contamination and exposure pathways are especially complex and such confounding variables as migration flows have usually been ignored. Major efforts should be made to fill this gap, by trying to develop models for space–time patterns of different contaminations.

5.7 Environmental justice

Populations living in contaminated sites are exposed to several risk factors. Besides being exposed to environmental contaminants, they are often socioeconomically deprived. Therefore, they are subject to various unfavourable health factors. This gives rise to uneven distributions of the health impacts of environmental determinants; however, the situation can be worse, and consideration of environmental justice can emerge. The socioeconomic factors can have a synergistic or supra-additive interaction with the environmental ones. Methods for considering these factors in risk assessment and management, and more generally in public health, are currently lacking.

5.8 Industrial accidents

In several contaminated sites, heavy industrial plants (for example, chemical, petrochemical plants, and steel plants) are the main source of contamination. These plants can pose health risks to the population living in the neighbourhood, both through long-term processes of environmental contamination and through industrial accidents. A review of the literature on accidents and their health effects in European countries is not available and is desirable, to reach a broader consensus on preventive actions in the future.

6 Methodological options and available data

Several topics of interest and high priority emerged during the discussion on methodology, which mainly focused on the study strategy choices and exposure assessment.

6.1 Strategies for environment and health studies in contaminated sites

In studying environment and health associations in contaminated sites, it is necessary to integrate epidemiological geographical or micro-geographical studies (small area) with analytical studies – for example, cohort, case-control, and biomonitoring studies. Different approaches should be applied to different contaminated sites. They should take into account type of contamination source, contaminants, populations and objectives – for example, identification of prevention or precautionary strategies.

A *funnel approach* was proposed to progressively verify associations between exposures and health effects. This approach progressively allows insights into the association between exposure and health effects through different phases, gradually shifting the evaluation from the population to the individual level. It starts with small-area analysis at the population level and ends with individual human biomonitoring.

The method used in the SENTIERI Project was also proposed as a first level approach at the population level. It consists of defining the health profile of populations living in the neighbourhood of contaminated sites, on the basis of health risk estimates at the area (municipality) level. The health profile is described by selecting morbidity/mortality causes to be analysed, on the basis of the assessment of epidemiological evidence for each source of contamination (chemical industry, petrochemical plants and refineries, steel plants, power plants, mines and/or quarries, harbour areas, asbestos or other mineral fibres, landfills, and incinerators). Risk indicators are subsequently produced by using routinely collected data (for example, mortality and hospital discharge files – and/or data from pathology registries, such as those on cancer and congenital malformations. The novel characteristic of this approach is the selection of a set of health end-points specific to the kind of industrial activity under investigation; the analysis is restricted to those end-points that can be identified *a priori* as possibly associated with the present contamination. By limiting *data dredging*, therefore, more specificity is likely to be achieved.

The use of software tools, such as the RIF, was proposed as an exploratory approach for the first phase of these inquiries.

Depending on the study's objectives, the need to study outcomes other than mortality, together with a detailed exposure assessment, may arise.

The analytical studies to be performed in each contaminated site should be carefully selected on the basis of objectives, previously acquired evidence and the characteristics of the local context. Priority studies could also result from preliminary evidence on exposure or from small-area descriptive studies.

Multilevel studies (studies providing information at the individual and area levels) can be useful for disentangling the contribution of different factors in defining the health risk at the population level. For example, socioeconomic status can be attributed to and evaluated at the individual level and area level, where it may carry different types of information.

Uncertainty due to migration flows in small-area studies should be assessed and taken into account, as it could lead to biased risk estimates.

6.2 Exposure assessment

Exposure assessment in studies of environment and health in contaminated sites is commonly recognized as one of the most complex tasks. When considering contaminated sites, exposure is generally considered by following a point source model, often referring to airborne emissions. However, in many contaminated sites, the contamination process is extremely complex and variable through space and time, with localized (but multiple) sources. Frequently, exposure assessment is indirect and based on short-term environmental monitoring and/or modelling of contaminant diffusion. Finally, the latent period of many conditions requires exposure to be assessed retrospectively, which is often difficult, because of the paucity of historical environmental data.

Greater use of human biomonitoring studies is of interest, as they potentially offer several advantages. In some cases, they contribute to obtaining an overall assessment of the contribution of different exposure pathways and routes. A workshop to investigate, in depth, the use of biomonitoring studies in contaminated sites was proposed.

In some cases and for some pollutants (such as heavy metals), vegetables act as bioaccumulators and contribute substantially to the environmental burden of medium- and long-term contamination. Therefore, biomonitoring vegetable species (such as lichens) is suggested.

To adopt strategies to reduce or remove risky exposures, the importance of defining exposure pathways (especially the more recent ones) was highlighted. The study of the food-chain should also be performed in greater depth.

At the meeting, the health effects of air pollution were discussed in great depth. To identify areas with different levels of contamination, the use of such proxies as the distance from pollution sources has important limitations, and real diffusion models should be considered preferentially. Software for modelling is available at no great cost; such software makes it possible to use environmental parameters and different tracers for different sources. Meteorological conditions and winds are the main environmental parameters for predicting the diffusion of contaminants from most of pollution sources. Context is also important in devising dispersion models; specifically, it is necessary to distinguish between rural and urban contexts.

The complexities, interdependencies and uncertainties of risk factors attributable to contaminated sites demand integrated strategies that not only consider the exposure to mixtures, but also consider stressors other than environmental factors. In this respect, lessons learned from some European Union (EU) projects (such as the Integrated Assessment of Health Risks of Environmental Stressors in Europe; INTARESE, 2012) could be applied to contaminated sites.

6.3 Data availability and harmonization

An ambitious, yet important goal is to define criteria and procedures for comparing the health profiles of populations living in the neighbourhood of different contaminated sites, within and between countries. First, the available environment and health data in each country or site should be collected; second, their quality should be verified; and third, data should be harmonized to allow comparisons in space and time.

7 Short- and medium-term next steps

Two activities that can be considered to be preliminary for the work of the full network were identified.

The first one is to develop an operational definition of *contaminated site* (and/or industrially contaminated site) for common reference. In fact, contaminated/polluted sites can be defined differently. For example, based on a review of the definitions used in several countries for contaminated soils, the European Environment Agency proposed a distinction between "potentially contaminated sites" (PCS) and "contaminated sites", giving a qualitative and quantitative definition for both (see Table 7.1).

Table 7.1. Definition of potentially contaminated site and contaminated site

Category	Qualitative definition	Quantitative definition
Potentially contaminated site	In the case that an unacceptable hazard to health and environment might exist	a location where as a result of human activity, waste and/or harmful substances with an anthropogenic origin and suspected to be dangerous to human health and/or the environment are present in, on or under the soil, and/or in nearby controlled groundwater and surface waters resources
Contaminated site	In the case that an unacceptable hazard does exist	is a potentially contaminated site in which the quantities and/or concentrations of waste or harmful substances are such that – on the basis of the results of risk assessment – they constitute danger to human health and/or the environment

Source: Prokop G, Schamann M, Edelgaard I (2000). *Management of contaminated sites in Western Europe*. Copenhagen, European Environment Agency (Topic report No 13/1999; http://www.eea.europa.eu/publications/Topic_report_No_131999; accessed 20 December 2012). Reproduced with permission.

It is necessary to verify the existence of other definitions, taking into account that contamination can be referred to all environmental media (air, water, soil) and also to the food-chain. It may also be useful to check EU legislation for existing definitions.

The second activity is to carry out a systematic review of studies on environment and health in contaminated sites. Since previous, informal attempts have produced limited results, the review should be made using an ad hoc bibliographic research strategy.

Contaminated sites and health: integrating data and resources

Catania, Italy, 21–22 June 2012

1 Introduction

In the European context, earlier industrialization and poor environmental management practices have left a legacy of thousands of contaminated sites. Past and current activities (such as mining, industrial and commercial activities, inadequate waste disposal, and overapplication of agrochemicals) can cause local and diffuse accumulation of environmental stressors (notably chemical substances) to such an extent that they might threaten human health and the environment, by altering air quality, hampering soil functions, and polluting groundwater and surface water.

A network for "contaminated sites and health", coordinated by the WHO Regional Office for Europe, has therefore been established to explore a series of open questions that need to be addressed, to characterize the health implications of contaminated sites, both in qualitative and quantitative terms. A previous meeting held in Syracuse (Italy) on 18 November 2011 – in the framework of a WHO Regional Office for Europe project underway in Sicily, involving three industrial areas – provided the opportunity to take the initial steps in developing the network. On that occasion, several case studies from Greece, France, Italy, Slovenia, Spain and the United Kingdom were presented, and possible topics and goals for collaborative work were explored.

After the first meeting, an initial, operational definition of "contaminated sites" was drafted as follows: "localized areas hosting or having hosted large and/or hazardous industrial facilities, producing or with a strong potential to produce environmental contamination resulting in health impacts". For example, chemical, petrochemical, manufacturing, waste disposal/treatment, cement, power generation, mining, metal production, and processing plants and facilities are of interest. However, a definition of contaminated site from the public health perspective must be refined, taking into account the inputs of other scientists and national and International organizations that relate to the topic.

2 Objectives

The present report summarizes the discussions held at the meeting in Catania (Italy) on 21–22 June 2012 on several points considered to be priorities requiring action to strengthen the collaboration among participants of the ongoing network on contaminated sites and health and to evaluate common interests and potential interactions with other existing networks on contaminated sites.

Topics and goals of the meeting were:

- review how contaminated sites have been defined and inventoried in the work coordinated by the European Commission (EC) Directorate-General for the Environment (DG Environment), the European Environment Agency (EEA) and/or the Joint Research Centre (JRC) under the soil theme, what contaminants have been considered, and to what extent risk to human health has been characterized;
- adopt an operational definition, based on existing definitions of contaminated site, to be used within the WHO-network;
- explore if existing European and/or national datasets with aggregated environmental data related to contaminated sites are usable for the health assessment of contaminated sites;
- review past and current initiatives of other networks working on the topic;
- identify tools and models that could be applied to the health risk assessment of populations residing in contaminated areas; and
- identify common or preferred methodological procedures that could be applied to characterizing the health implications of contaminated sites, depending on available data and resources and for the following aspects analysed and discussed:
    - risk-based and toxicological approaches
    - design of epidemiological studies
    - human biomonitoring and study of the food-chain.

3 Environmental characterization of contaminated sites in Europe

3.1 Legal framework of contaminated sites and definitions at the EU level

EU legislation includes several provisions that address prevention and control of polluting activities – for instance, in the fields of waste, chemicals, industrial emissions, climate change, water, and agriculture and rural development. However, it is difficult to identify a proper and explicit definition of what a contaminated site is in legal terms.

The Thematic Strategy for Soil Protection (EC, 2006a) and the Soil Framework Directive (SFD) (EC, 2006b) proposed by the EC in 2006, address soil protection, including contamination. Since 2006, however, this SFD legislative proposal has been subjected to the co-decision procedure for approval and is still being negotiated at the Council. A minority of Member States have blocked the proposed SFD on the grounds of subsidiarity, excessive cost and administrative burden (EC, 2012a).

According to the proposed SFD (Article 10), a contaminated site is:

> … a site where there is a confirmed presence, caused by man, of dangerous substances of such a level that Member States consider they pose a significant risk to human health or the environment. That risk shall be evaluated taking into account current and approved future use of the land.

It is important to note that under this approach only a site with contamination generated by anthropogenic activity would be considered to be a contaminated site, thus excluding contamination from natural sources. It is also relevant to point out that the proposed SFD, in accordance with the proportionality principle, allows each Member State to define the most appropriate specific measures at the most appropriate geographical and administrative level, thus establishing a particular threshold for the different major soil pollutants, according to their specificities in soil diversity, land use, local climatological conditions and socioeconomic aspects.

Under this proposed framework, Member States would be required to identify the contaminated sites in their national territory and establish a National Remediation Strategy on the basis of a common list of potentially polluting activities (Annex II of the proposed SFD).

The preparatory technical work of the Soil Thematic Strategy undertaken by JRC in collaboration with EEA (Van-Camp et al., 2004) provided the following operative definitions:

- site: a particular area of land related to a specific ownership or activity
- potentially contaminated site: a site where an activity is or has been operated that may have caused a soil contamination

The list of potentially soil-polluting activities initially recorded under Annex II of the proposed SFD includes:

- Seveso installations
- integrated pollution prevention and control (IPPC) installations
- former military sites
- dry cleaners
- mining installations
- petrol and filling stations
- landfills of waste
- pipelines for the transport of dangerous substances
- wastewater treatment installations
- airports
- ports

In 2010, the Presidency of the Council of the EU introduced some modifications to the text of the SFD proposed by the Commission. Annex II was substantially shortened. Some Member States even pushed for the whole Annex to be only indicative, but not a compulsory requirement for contaminated site investigations.

The identification of potentially contaminated sites in each Member State should be based on the list of potentially soil-polluting activities (Annex II). In practical terms, this could be done by basing such identification on: desk studies that gather information related to maps; historical risk activities (discrimination between active versus non-active sites); historical archives; local knowledge; industrial permits and license records; administrative information; surveys of surface and groundwater quality; and site inspections.

Following a modification by the Presidency of the Council in 2010, simplified risk assessment procedures could be applied at this stage to prioritize the selection of sites where a preliminary soil investigation is required first. Following the process of identifying potentially contaminated sites, it would be beneficial if competent authorities from Member States measured the concentration levels of dangerous substances (chemical analysis) in the sites identified as potentially contaminated; and where the levels of substances might pose a significant risk to human health or the environment, it would be beneficial to carry out an on-site risk assessment (EC, 2006b: Article 11.3). This process will result in a national inventory of contaminated sites that shall be made public and reviewed at least every five years.

EEA and JRC promoted the development of a consistent risk assessment model to rank risks in terms of their magnitude, rather than produce absolute estimates of health and/or ecological impacts. The Preliminary Risk Assessment Model for the identification and assessment of problem areas for Soil contamination in Europe (PRA.MS) (Fons, 2006) adopts the source-pathway-receptor paradigm, considering four exposure pathways for human health risk assessment: groundwater, surface water, air, and direct contact. Parameters adopted in the model, as well as factor weighting and scoring and overall risk calculation criteria, are derived from a review of preliminary risk assessment methodologies used quite extensively at the international level. However, the specificity of the geological, topographical and climatological characteristics and land use practices in each country – as well as differences in the legal backgrounds, public perception of the problem and acceptable level of risk (threshold) – made it unfeasible for the PRA.MS model to be adopted as compulsory by all Member States.

A consolidated version of the model was finalized in 2008; guidelines and conditions of use are available on the web site for the European Environment Information and Observation Network (Eionet) software tools (Eionet, 2008).

To reduce the cost of chemical analysis for public administrations, the proposed SFD establishes that where a site on which a potentially polluting activity listed in Annex II is taking place is to be sold, or for which the official records (such as national registers) show that it has taken place, Member States shall ensure that the owner of that site or the prospective buyer makes a soil status report available to the competent authority and to the other party in the transaction. The soil status report should include the following details: (a) a background history of the site; (b) results of soil chemical analyses; and (c) the concentration levels (adopted by Member States) at which there is sufficient reason to believe that the dangerous substances concerned pose a significant risk to human health or to the environment (EC, 2006b: Article 12).

At present, national inventories of contaminated sites are still not a reality across Europe. The designation of a site as "contaminated" is still visualized in some countries as a potential stigma that would discourage possible investors, thus hindering economic developments.

Depending on the type of source polluting activities, it is also possible to distinguish between two concepts: local contamination and diffuse soil contamination. In the report *The state of the soil in Europe*, conducted by JRC and EEA, both concepts are described as follows (Jones et al., 2012):

> Local soil contamination occurs where intensive industrial activities, inadequate waste disposal, mining, military activities or accidents introduce excessive amounts of contaminants.
>
> Diffuse soil contamination is the presence of a substance or agent in the soil as a result of human activity that caused it to be emitted from moving sources, from sources with a large area, or from many sources. Diffuse soil contamination occurs where emission, transformation and dilution

> of contaminants in other media has occurred prior to their transfer to soil. ... As a result, the relationship between the contaminant source and the level and spatial extent of soil contamination is indistinct.

3.2 Available information on contaminated sites at the EU level

The lack of current EU legislation that obliges Member States to identify contaminated sites (the above-mentioned proposed SFD is still under debate) makes it very difficult to assess the real extent of the problem across Europe. However, it is important to note the efforts made since 1998 by EEA, JRC and DG Environment in this direction.

3.2.1 Core set indicator CSI 015

In this respect, EEA developed the core set indicator for progress in management of contaminated sites (CSI 015). This indicator tries to answer the following key policy question: how is the problem of contaminated sites being addressed (clean-up of historical contamination and prevention of new contamination)?

This indicator also intends to gather information at the EU level about the main soil polluting activities, the most relevant contaminants affecting soil and groundwater, the costs to society of the clean-up actions, and the achievements in managing contaminated sites. On the other hand, following different steps suggested by the proposed SFD to establish a national contaminated sites inventory, the indicator shows progress in four management steps: preliminary study, preliminary investigation, main site investigation, and implementation of risk reduction measures.

Previous assessments were conducted in 2003 and 2006, and the most recent one was undertaken by the European Soil Data Centre (ESDAC), a thematic centre for soil related data and information on a pan-European scale; the Centre was established in JRC. In 2011, the Centre in collaboration with Eionet members performed the project on collection, analysis and assessment of data on contaminated sites in Eionet countries, which is a continuation of work done by EEA on CSI 015. In the guideline provided to the countries for gathering this information, the following definitions were used (Van Liedekerke, 2011).

> Contaminated site: refers to a well-delimited area where the presence of soil contamination has been confirmed. The severity of the impacts to ecosystems and human health can be such that remediation is needed, specifically in relation to the current or planned use of the site. The remediation or clean-up of contaminated sites can result in a full elimination or in a reduction of these impacts.
>
> Potentially contaminated site (PCS): includes any site where soil contamination is suspected but not verified and detailed investigations need to be carried out to verify whether relevant impacts exist.

These definitions are based on the international standard ISO/DIS 10381-5 (ISO, 2005).

In the 2011 data collection exercise, 27 of 39 countries returned the questionnaire (70% response rate). According to the first preliminary results (report not yet published), the number of sites in EEA countries and in western Balkan countries where potentially polluting activities are occurring, or have taken place in the past, is estimated to be about 2.4 million PCSs, of which 38% have already been identified (930 000). This number is lower than that in the previous data collection, in 2006, which referred to 3 million PCSs (EEA, 2007). Some locations, depending on their use and the nature of the contaminant, may only require limited measures to stabilize the dispersion of the pollution; however about 190 000 sites have been designated as contaminated sites and may need urgent remediation. This number is also considerably lower than that in the previous data collection (EC, 2006d, 2006e), in 2006, which referred to 250 000 contaminated sites. The impact assessment document of the Soil Thematic Strategy (EC, 2006d, 2006e) estimates that the annual cost of soil degradation due to the contamination process in the EU-25 (the Member States belonging to the EU from 1 May 2004 to 31 December 2006) might range between €2.4 billion and €17.3 billion.

Although the order of the main polluting activities vary across Europe, industrial and commercial activities, together with the disposal and treatment of waste, are reported to be the most important sources of local contamination. In general, this distribution is very similar to data recorded in the 2006 survey (EC, 2006d, 2006e). National reports for the 2006 and 2011 assessments indicate that heavy metals and mineral oil are the most frequent soil contaminants at the sites investigated, while mineral oil and chlorinated hydrocarbons are the most frequent pollutants found in groundwater. Phenols and cyanides make a negligible contribution to the total contaminant load, in terms of their overall description.

Data on diffuse contamination across Europe is even more limited than that for local contamination, as there are no harmonized requirements to collect information. The over-application of agrochemicals used for intensive agriculture practices or farm waste management can significantly affect soil functions, groundwater quality and crop uptake (Jones et al., 2012).[9]

3.2.2 FOREGS Geochemical database and LUCAS

The Forum of European Geological Surveys (FOREGS) database (Rodriguez Lado, Hengl & Reuter, 2008), built up from 1588 georeferenced topsoil samples, provides mapping concentrations of eight heavy metals (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc). The concentrations were interpolated using block regression kriging over the 26 EU countries that contributed to the database. This information is being updated under the land use/cover area frame statistical survey (LUCAS), with data gathered through direct field observations, in more than 20 000 soil samples across Europe. The first results for heavy metals from the LUCAS project will be available at the end of 2013.

All the above-mentioned information on soil is available at the European Soil Portal (JRC, 2012) considered to be the virtual site where all ESDAC resources are located. The current data and information service makes available four types of product: data, documents, data-based applications and scanned maps.

3.2.3 European Pollutant Release and Transfer Register

An indirect source of information on contaminated sites is provided by the European Pollutant Release and Transfer Register (E-PRTR), adopted by the European Community through Regulation (EC) No. 166/2006 (EC, 2006f). The Register provides accessible online key environmental data from industrial facilities in EU Member States and in Iceland, Liechtenstein, Norway, Serbia and Switzerland. It replaces and improves upon the previous European Pollutant Emission Register (EPER). The Register contributes to transparency and public participation in environmental decision-making. For the European Community, it implements the United Nations Economic Commission for Europe (UNECE) Protocol on Pollutant Release and Transfer Registers to the UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention).

Data are reported annually by individual facilities to the relevant competent authorities. The respective authorities in the countries compile and check the quality of the data reported and send them to the EC for editing and dissemination on the E-PRTR web site, with the support of EEA (E-PRTR, 2012). Detailed information on the reporting procedures and content is available in the E-PRTR Guidance Document (EC, 2006c).

The E-PRTR contains data reported annually by some 28 000 industrial facilities that cover 65 economic activities (listed in EC, 2006f: Annex I) within the following nine industrial sectors:

- energy
- production and processing of metals
- mineral industry
- chemical industry
- waste and wastewater management
- paper and wood production and processing
- intensive livestock production and aquaculture
- animal and vegetable products from the food and beverage sector
- other activities

It also contains data on off-site transfers of wastewater and waste from these facilities. These data represent the total annual emission releases during normal operations and accidents.

An industrial facility has to report data under the E-PRTR, if it fulfils one of the following criteria:

- its capacity exceeds at least one of the E-PRTR capacity thresholds;
- the facility transfers waste, which exceeds specific thresholds set out in Article 5 of Regulation (EC) 166/2006, off-site; and
- the facility releases pollutants that exceed specific thresholds specified for each media – air, water and soil listed in Annex II of Regulation (EC) 166/2006.

For each facility, information is provided on the amounts of pollutants released to air, water and soil, as well as off-site transfers of waste and of pollutants in wastewater from a list of 91 key pollutants (EC, 2006f: Annex II), including heavy metals, pesticides, greenhouse gases and dioxins for the years 2007, 2008 and 2009. Some information on releases from diffuse sources is also available and will be gradually enhanced.

All facilities have to report their geographical coordinates, which are shown on the maps. However, in a small number of cases, the coordinates reported for a particular facility might not be correct. As a result, this facility may appear on maps outside the EU.

According to all this information, it is possible to map the emissions of specific pollutants. The accuracy of this information varies very much, depending of the hazardous substance.

For contaminated sites (assuming a previous designation that links a *site* to a particular area of land), the identification is related to the injection of pollutants in the soil, but not to the release or spread of pollutants. Data is this field is relatively limited.

The database can be searched at different levels, providing information referring to:

- a list of facilities and their location on the map, as well as their reported releases and transfers (where above E-PRTR thresholds);
- a report that shows the aggregated releases and transfers (pollutants and waste) of a specific industrial activity or a sector and the list of facilities;
- a report of the aggregated releases of a specific pollutant, displaying the information in several sheets that show a summary of releases of the selected pollutant per activity group, the total release of each pollutant per country (table and graph) and a list of facilities releasing the pollutant of concern;
- a report of the aggregated transfers of a specific pollutant (in a way similar to that described above); and
- a report of the annual waste transfers with disaggregated information by type of waste, by activity group; total transfer of each category per country (table and graph); a list of facilities that transfer each type of waste; a graph that displays hazardous waste transfers, and a table of countries that lists the quantity of hazardous waste received.

Finally, it is important to clarify that E-PRTR only provides information on the volume of certain pollutants released, but it does not conduct an assessment of the possible impacts of those emissions on human health or the environment.

3.2.4 Directive on industrial emissions

In addition to the information provided by E-PRTR, the implementation of Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control) also sets up some provisions to ensure that the operation of an installation does not diminish the quality of soil and groundwater (EC, 2010:17; EC, 2012b:25). In this respect, Article 22 of the Directive on site closure (EC, 2010) establishes that:

> Where the activity involves the use, production or release of relevant hazardous substances … the operator shall prepare and submit to the competent authority a baseline report on the state of soil and groundwater contamination before starting operation or before a permit for an installation is updated for the first time after 7 January 2013.

The baseline report should, therefore, contain information making use of existing data on soil and groundwater measurements and historical data related to past uses of the site.

3.2.5 The INSPIRE Directive

Among the efforts that support the exchange of data at the EU level, it is important to mention the Infrastructure for Spatial Information in the European Community (INSPIRE) Directive (EC, 2007), which aims to make available relevant, harmonized and high-quality geographic information to support the formulation, implementation, monitoring and evaluation of European Community policies, particularly those relating to the environment. The Directive is based on the infrastructures for spatial information already created and maintained by EU Member States (it does not require the collection of new data) and addresses the following components: metadata, interoperability of spatial data themes (as described in Annexes I, II and III of the Directive) and spatial data services, network services and technologies, data and service sharing, and monitoring and reporting procedures. *Interoperability* is understood to be providing access to spatial data sets through network services, typically via the Internet.

The INSPIRE Directive came into force on 15 May 2007 and will be implemented in various stages, with full implementation required by 2019.

The INSPIRE Directive human health and safety theme describes the:

> Geographical distribution of dominance of pathologies (allergies, cancers, respiratory diseases, etc.), information indicating the effect on health (biomarkers, decline of fertility, epidemics) or well-being of humans (fatigue, stress, etc.) linked directly (air pollution, chemicals, depletion of the ozone layer, noise, etc.) or indirectly (food, genetically modified organisms, etc.) to the quality of the environment.

While the definition in the INSPIRE Directive refers to direct or indirect links between pathologies and the quality of the environment, the human health and safety data model currently defined is able to accommodate all health data, while the linkage of specific health issues and the environment is a matter of user preference. The data used under this theme are reused spatial objects identified by the Technical Working Group statistical units (primary statistical data and/or indices expressed at different spatial levels) and a general model for environmental data, relevant as a health determinant (envhealth) (INSPIRE Thematic Working Group Human Health and Safety, 2011).

The INSPIRE soil theme does not address explicitly the concept of contaminated sites as such (it would require the approval of the proposed SFD), although in the published draft guidelines for the implementation of this theme (INSPIRE Thematic Working Group Soil, 2011), a generic case study is provided as an example of how the model could be extended to deal with this topic. On the other hand, soil data are recorded indirectly under several other regulations.

The roadmap for implementing INSPIRE and detailed information on the availability of data referred to above can be found o the EC-Inspire web site (INSPIRE, 2012).

3.2.6 WISE gateway and Water Framework Directive

Another source of data that indirectly tackles the issue of contaminated sites is the Water Information System for Europe (WISE) web site (WISE, 2012), a partnership between the EC (DG Environment, JRC and Eurostat) and EEA that provides information on European water issues. The legal and regulatory framework behind WISE is the Water Framework Directive (WFD) (EC, 2000), an innovative approach to water management based on river basins. Such basins are the natural geographical and hydrological units that correspond to "the area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta" (EEA, 2012). About 60% of the EU's surface area lies in river basins that cross at least one national border, and all EU Member States, except Cyprus and Malta, contain sections of at least one international river basin district (IRBD). Under the WFD, each Member State is responsible for implementing the portion of an IRBD lying within its territory and should coordinate these actions with the other Member States in the district (DG Environment, 2008). The river basin management plans, available in all IRBDs across the EU since 2009, include a programme of measures (Article 11 of the WFD) to meet the directive's environmental objectives (Article 4 of the WFD). These plans aim to improve the environmental status of all European water bodies (surface and groundwater) by 2015.

The WFD also specifies that all EU Member States should review the environmental impact of human activity on the status of surface and groundwater (Article 5 and Annexes II and III of the WFD). In particular, they should identify significant pollution point sources related to urban, industrial, agricultural and other installations and activities that release the hazardous substances listed in Annex VIII of the WFD (organohalogenated compounds, organophosphorous compounds, heavy metals, arsenic). For hazardous chemical substances, the strategy of the WFD is based mainly on the selection of a list of European priority substances that should be reduced or eliminated (priority hazardous substances) from all emissions, discharges, releases and losses within specific deadlines. For these substances, Directive 2008/105/EC has set legislative limits (environmental quality standards) that should be achieved in surface water bodies, with the aim of protecting human health and the environment (EC, 2008).

The WFD has also established a coherent and comprehensive obligatory monitoring programme on the status of water bodies within each IRBD. The programme concerns surface waters (rivers, lakes, transitional and coastal waters), groundwaters and protected areas since December 2006 (Article 8 and Annex V of the WFD). There are 3 types of programmes: surveillance (every management plan), operational (to assess the status for water bodies at risk) and investigative (accidents and unknown causes of deterioration) (DG Environment, 2009).

In addition to the country reporting, JRC (in cooperation with a network of laboratories) monitors pollutants released to surface waters or within the aquatic environment. Further information about the FATE project and data can be found on its web site (JRC, 2013).

WISE State of the Environment (SoE) data flow covers complementary data reported under the WFD, based on international agreements between European countries and the EEA. The reporting process is not mandatory, but it entails some responsibilities for countries, including the 32 Eionet member countries (EU-27, i.e. the Member States belonging to the EU after 1 January 2007, plus Iceland, Liechtenstein, Norway, Switzerland and Turkey) together with 6 west Balkan countries as cooperating countries (Albania, Bosnia and Herzegovina, Croatia, Montenegro, Serbia and the former Yugoslav Republic of Macedonia). The link between SoE and WFD data for these countries is only optional, depending on the degree to which they follow any WFD scheme in their national monitoring. WISE, with both compliance and SoE-reporting, is the integrative, water-related part of the EC Shared Environmental Information System and is fully committed to the INSPIRE principles (EEA, 2009).

WISE reported datasets on European water issues, especially those that address the status of chemical pollution in Europe's waters, do not refer directly to contaminated sites. They are, however, potential sources of information that complement and improve attempts to better characterize human exposure at contaminated sites, using new geographical-statistical methods – a key element in epidemiological studies.

3.3 Data availability and needs at the country level

Some countries have specific national legal frameworks for identifying and managing contaminated sites, which refer normally to soil contamination, as described at the EU level. Also, some countries have attempted to create an inventory of contaminated sites (potential and/or established), following definitions similar to the one included in the proposed SFD. However, differences in policies and in the time since those policies were applied may result in large differences between countries, and among regions in some countries, in the data gathered. Data between countries or regions are difficult to compare due to: differences in the administrative data collection level (more or less decentralized); the disparity in the technical criteria used for investigating the sites and for their remediation; lack of homogeneous procedures for selecting the concentration standards and thresholds of hazardous substances; differences in the acceptability of risks and whether action is necessary; and variability in the risk analysis approaches and risk assessment models used in each case.

At the national level, the polluting activities generally related to contaminated sites include operations at industrial and commercial sites, power plants (energy sector), landfills, and waste disposal and treatment. In eastern Europe, relevant contamination from animal farming and pesticide storage and mixing facilities was also reported. Atmospheric deposition due to transport activities (road traffic, shipping and airports) is also a major local and diffuse soil pollution problem.

3.4 Review of initiatives on contaminated sites

Because of their past and present economic importance and the environmental impact of contaminated sites in Europe, some national governments and agencies began planning, from the early 1990s, strategies on how to deal with contaminated soil and groundwater.

In this respect, the Common Forum on Contaminated land in Europe is a transnational initiative (Common Forum, 2012). Created in 1994, it is a network that brings together policy-makers, regulators and technical specialists for the design and implementation of better long-term solutions. The Common Forum collaborates with the other networks or initiatives operating in the same field, such as the Network for Industrially Contaminated land in Europe (NICOLE, industry and service providers), the European Sediment Network (SedNet – sediment management), the Concerted Action on Brownfield and Economic Regeneration Network (CABERNET), European Coordination Action for Demonstration of Efficient Soil and Groundwater Remedation (Eurodemo+, promotion of innovative technologies), SNOWMAN (national research funding programmes related to contaminated soil and groundwater), the EU Network for the Implementation and Enforcement of Environmental Law (IMPEL – European environmental inspectorate) and the International Committee on Contaminated Land (ICCL – 45 countries involved).

The Common Forum's mission is to:

- be a platform for the exchange of knowledge and experiences and to initiate and follow up international projects among members;
- establish a discussion platform on policy, research, and technical and managerial concepts of contaminated land; and
- offer an exchange of expertise to the other stakeholders.

The exchange of information between the network experts is done via meetings, technical reports, position papers and thematic questionnaires – such as the Implementation of Environmental Liability Directive, the Implementation of Industrial Emission Directive, the regulatory framework in Member States, and the Mining Residues Inventory -- available online.

According to the experience gained in the countries that participate in the Common Forum, the geographical and geological contexts and the land use needs are too different in Europe to have a unique set of soil quality standards. However, some common ground may exist for such technical and political issues as: the development of a tool box for risk assessment, the development of common protocols and sets of exposure factors, the definition of common targets to be protected, or a list of substances to be covered or excluded.

The risk assessment and management procedures are applied in different countries with different objectives for: obtaining soil quality standards and/or threshold values, assessing potential or future risks at a specific site, deriving remediation objectives, or ranking sites. Consulting with those potentially affected by contamination and the communication of risks is considered to be one of the critical phases of the procedures. Exceeding reference values (thresholds) set up as guidelines for clean-ups does not necessarily mean a real risk to human health and should be interpreted on a case-by-case basis (generally leading to further investigations or site-specific risk assessment or management measures). In this respect, it is necessary to evaluate the exposure pathways for the population affected.

To deal with the complex issue of the health impact of contaminated sites, good interaction is needed between the environment and health communities. In some countries, the working relationships between public health and environment professionals on a site-by-site basis are well established and bring a common view to the issues – for example, the United Kingdom (potential exposure from contaminated lands and other sources), the United States (public health assessment of contaminated sites) and France (a national programme on *sensitive* sites located on or near contaminated sites).

4 Health impact assessment of contaminated sites

Characterizing the health impacts of contaminated sites is a complex exercise. Several things contribute to making this particularly challenging: the very heterogeneous nature of the hazards; a lack of reliable exposure data; the multifaceted etiology of most of the associations; and the complexity of underlying social, economic and occupational factors. Furthermore, contaminated sites are often located close to urban areas, making the exposure patterns more complex. Well-known approaches can be applied for some aims, and other methods were developed to be used in other contexts but, if properly adapted, they can also be useful in contaminated sites.

4.1 Health risk assessment

Health risk assessment can be defined as a procedure for characterizing the nature and magnitude of health risks to human beings of chemical contaminants and other stressors that may be present in the environment. It uses standardized tools, formats, and scientifically established assumptions for risk modelling.

The main two approaches used for health risk assessment are: (a) chemical - agent based (IPCS, 2010); and (b) population - health outcome based (Kay, Prüss & Corvalán, 2000).

The first approach, normally referred to as risk assessment, is a traditional toxicological approach based on a multistep procedure that leads to theoretical estimates of the potential health risk due to estimated exposure levels. It can end in a comparison of estimated potential exposure to the tolerable dose – that is, a comparison between estimated exposure levels and reference values.

The main characteristics of this approach are that it:

- is usually based on the evaluation of a single substance or stressor at a time;
- analyses all the key pathways, from the source of contamination to the adverse effects on health;

- is based mainly on a conceptual exposure scenario that identifies sources, pathways and receptors for the situation described (often reasonable or worst-case);
- uses models to estimate exposure and to quantify risk;
- leads to theoretical estimates of potential health risks for the exposure scenario defined;
- is usually applied to predict current and future risk, sometimes residual risks; and
- is commonly applied for chemical safety issues.

The second approach, involving the estimation of the environmental burden of disease or the use of such tools as *comparative risk assessment*, is based on producing or (more frequently) gathering and compiling epidemiological evidence and dose–response functions and estimating the excess health risk associated with different exposure scenarios – for example, attributable cases and disability-adjusted life years (DALYs).

The main characteristics of this approach are that it:

- is based on various forms of evidence about the multiple associations between (environmental) risk factors and diseases;
- is based on epidemiological evidence and rarely on toxicological evaluations;
- is founded on modelling the causal webs;
- uses health statistics on mortality and morbidity and leads to the attributable burden of disease; and
- is usually applied to assess the likely health impacts and gains associated with alternative scenarios.

Both approaches can be applied to predict and/or estimate the health risk of contaminated sites.

4.1.1 Tools for health risk assessment

Several tools can potentially be used for a health risk assessment of contaminated sites. They are sophisticated, scientific, well-founded tools, typically developed in the scientific environment and available (partly) for free. The following list of tools is not exhaustive, as it reports only those mentioned at the meeting and available in English. Examples of tools for water pollution are not reported, because they were not mentioned at the meeting.

General tools

- PREVENT is a multiple risk factor, multiple disease dynamic population model that allows the user to evaluate the benefits of risk factor interventions (www.epigear.com).
- DYNAMO-HIA (DYNAmic MOdel for Health Impact Assessment) is a tool that can be used to quantify the health impact of policies in the EU through their influence on health determinants (www.dynamo-hia.eu).
- The HEIMTSA (Health and Environment Integrated Methodology and Toolbox for Scenario Assessment) toolbox produced within the INTARESE (Integrated Assessment of Health Risks of Environmental Stressors in Europe) Project is a tool that helps design and carry out integrated environmental health impact assessments; it is defined as a means of assessing health-related problems derived from the environment, and health-related impacts of policies and other interventions that affect the environment, in ways that take into account the complexities, interdependencies and uncertainties of the real world. It is aimed primarily at policy-makers who may commission assessments or need to use their results and at scientists responsible for conducting assessments (www.integrated-assessment.eu).

- The impact calculation tool (ICT), developed in the context of the European founded projects INTARESE and HEIMTSA, is a modelling tool for quantifying health impacts from environmental exposures. It applies dynamic life-table modelling for calculating target population specific mortality and morbidity impacts (http://en.opasnet.org/w/Impact_calculation_tool).
- Health Forecasting is a tool developed at the University of California at Los Angeles Fielding School of Public Health, to produce credible forecasts to support policy decisions that improve population health and reduce health disparities, by using the best available research evidence and microsimulation (www.health-forecasting.org/).
- MicMac (Bridging the micro-macro gap in population forecasting) is a tool for monitoring and forecasting demographic changes in the provision of high-quality and sustainable health care services and pension systems. MicMac distinguishes multiple cohorts (overlapping generations) and monitors and forecasts intra-cohort and inter-cohort variations in life histories. MicMac is a generic model. It can be applied to any domain of life. Examples include employment histories, health histories, fertility histories and educational histories (www.nidi.knaw.nl/en/micmac).

Tools for soil contamination

- PRA.MS model is a tool developed by EEA within Eionet for preliminary risk assessment of contaminated sites (Fons, 2006). It is based on a source-pathway-receptor model that considers four exposure routes for human health risk assessment: groundwater, surface water, air, and direct contact (http://www.eionet.europa.eu/software/prams).
- The contaminated land exposure assessment (CLEA) model is a risk assessment procedure applied to health risks from soil pollution. It was developed by the Environment Agency for England and Wales and is based on a package of technical guidance to estimate the risk to health from long-term exposure to soil contamination (some details are reported in Section 2.1.3) (http://www.environment-agency.gov.uk/clea).
- RISC-HUMAN is a knowledge-based system for risk identification of individual contaminated sites. It was developed at the Van Hall Instituut in the Netherlands. The RISC framework uses expertise on the presence and behaviour of contaminants in soils, to predict potential risks to people and the environment (http://www.risc-site.nl/).
- RISC5 is a software package for modelling fate and transport and for performing human health risk assessments and ecological risk assessments for contaminated sites. It was developed by a private company. RISC5 can be used to estimate the potential for adverse impacts on human health (both carcinogenic and non-carcinogenic) for as many as nine exposure pathways (www.groundwatersoftware.com).

Tools for air pollution

- AirQ is a software tool that performs calculations that allow the quantification of the effects on health of exposure to air pollution, including estimates of reduced life expectancy. It was developed by the WHO Regional Office for Europe. AirQ 2.2 estimates: (a) the effects of short-term changes in air pollution (based on risk estimates from time-series studies); and (b) the effects of long-term exposures (using the life-tables approach and based on risk estimates from cohort studies) (www.euro.who.int).
- The Health Impact Assessment of Outdoor Air Pollution (HIAIR) is a tool that provides the number of health events that could potentially be prevented from exposure to urban air pollution in a specific population. It allows the gain in life expectancy and years of life lost to be estimated, using the life-tables approach from AirQ software developed by the WHO Regional Office for Europe (http://www.hiair.eu/).
- The Hotspots Analysis Reporting Program (HARP) is a tool developed by the California Environmental Protection Agency. It is a single integrated software package that can be

used by air pollution control and air quality management districts, facility operators, and other parties to promote statewide consistency, efficiency, and cost-effective development of facility and emission inventories and health risk assessments (www.arb.ca.gov).

Other tools

- C-BAS (LifeLine Community Based Assessment Software) is one component of the LifeLine™ suite of software that allows the user to evaluate potential exposures and risks across a community or population. The LifeLine software is designed to analysise probabilistic exposure, risk and benefit assessments (www.thelifelinegroup.org).

The use of the above-reported tools in the context of a health risk assessment of contaminated sites should be evaluated cautiously, since users need profound knowledge of the underlying epidemiological and exposure assessment concepts used. Furthermore, no tool is suited for every purpose; they differ in the area of their development and application, from exposure assessment of soil contamination to health impact assessment of lifestyle risk factors.

4.2.1 The CLEA Initiative

Several countries have developed risk-based tools to estimate the risks to health of soil pollution, from living, working and playing on potentially contaminated sites. These tools are often used to develop generic assessment criteria for screening out low risk sites and to provide a technical framework for more detailed investigations of higher risk sites. They provide one of the lines of evidence that may be used to support decisions on the assessment and remediation of contaminated sites. A notable example is the CLEA Initiative of the Environment Agency for England and Wales.

The CLEA model is a risk assessment procedure applied to health risks from soil pollution. It is based on a package of technical guidance for estimating the risk to health of long-term exposure to soil contamination.

Its main uses are:

- for framework reports on toxicology and exposure assessment
- for substance-specific reports that describe soil guideline values
- as a Microsoft Excel-based software tool
- as support for technical reports, such as reviews of plant uptake models, compilations of chemical data and the VOCs Handbook.[1]

The soil guideline values are one of a number of tools developed to help regulators and industries to screen out low-risk sites.

The approach is suitable for practical use and is based essentially on the definition of a conceptual exposure model developed with consideration given to the following aspects:

- selection of sensitive receptors (usually children)
- understanding the work and life patterns, according to site use
- choosing pathways, such as soil ingestion and consumption of produce
- defining activities, such as contact length, frequency and exposure rates
- the level of protection (a reasonable worst case).

1 This publication provides guidance on the investigation, assessment and management of risks associated with Volatile Organic Compounds (VOCs) at land affected by contamination in the United Kingdom, primarily relating to inhalation by people.

The common scenarios analysed include residential sites, allotments, playgrounds, and commercial and industrial sites.

4.1.3 The ATSDR public health assessment procedure

Contaminated sites commonly involve requests to provide not only risk estimates obtained from modelling, but also to define the health profile of populations affected by contamination, using observational epidemiological approaches.

The Agency for Toxic Substances and Disease Registry (ATSDR) has developed a procedure, named Public Health Assessment(PHA), that provides both a health risk assessment and an epidemiological descriptive assessment (ATSDR, 2011).

The ATSDR uses the PHA procedure when responding to petitions, national priorities, or requests from other agencies. The PHA aims to determine if community exposures to environmental contaminants are occurring and if such exposures are likely to result in adverse effects on health under site-specific conditions. At the end of the process, information is made available to respond to community health concerns and to make recommendations to mitigate exposure and health impacts.

The PHA procedure is implemented through several steps, considering the participation and contribution of stakeholders in the whole process. Risk assessment and health assessment are combined through the following steps:

- evaluate environmental data
- identify and evaluate exposures
- define potentially exposed populations
- identify contaminants and pathways requiring further evaluation
- determine if adverse effects on health are likely.

At the end of the assessment procedure, the risk of environmental exposure is categorized and the hazard is graded as follows:

- short-term exposure, acute hazard
- long-term exposure, chronic hazard
- lack of sufficient data
- exposure, but no harm expected
- no exposure, no harm expected

Finally, recommendations are provided on: (a) practical ways to stop, reduce, or prevent exposure; (b) activities to further characterize the site and possible exposure; and (c) health activities that are service- or research-oriented – for example, medical monitoring, health education, health studies and/or health surveillance and substance-specific research.

4.2 Describing the health profile of populations living in contaminated sites

Some tools can be used as methods for a first level approach to describing a population health profile. Two of these methods are the RIF tool and the SENTIERI approach. They are essentially based on routinely collected health data and have the potential to be applied in several countries.

These tools are defined as methods for a fist-level approach, because they do not require an *ad hoc* collection of data. Their main aim is to describe the health profile of populations, suggesting possible associations with local environmental risks. Also, they have the potential to give responses in short times at low costs.

The Plateforme intégrée pour l'Analyse des Inégalités d'Exposition environnementale (PLAINE, environmental inequalities analysis platform) approach is another example of a method that has the potential to be used as a first-level approach. It is based on the collection of information on environment and health using a GIS-based platform.

4.2.1 The RIF tool for risk analysis and disease mapping

The RIF tool for risk analysis and disease mapping was developed by the Small Area Health Statistics Unit (SAHSU) of the Imperial College London (SAHSU, 2012). It consists of a software package for small-area analysis and mapping embedded in a GIS. The RIF allows users to assess the relationships between environmental factors and health and has the following characteristics: (a) it uses routinely collected health and population data; (b) it can explain local geographical variation in disease with respect to other factors, such as demographic, socioeconomic risk factors; (c) it uses advanced spatial analysis and statistical methods; and (d) it allows links to be made between spatial and non-spatial data.

As noted, it can be used for risk analysis and disease mapping. The first allows assessment of whether a risk factor has a statistical association with a health outcome in a given population, at the aggregated level usually defined by area of residence. The second allows the user to visualize the geographical distribution of mortality or morbidity rates and spatial patterns of health outcomes.

The risk analysis is based on modelling the exposure. The exposure can be defined using distance bands around one or more user defined point or area sources; or it can be spatially modelled, using various types of information – for example, data from environmental monitoring.

Data requirements for the tools are as follows: (a) they need a geographical identity; (b) unit areas studied are based on the availability of data for the numerator (health) and the denominator (population); (c) each area studied needs to be defined spatially – for example, boundaries; and (d) an exposure level has to be attributed to each area studied – the difference in reliability of the exposure level attributed to each area depends on the information and/or model used in the exposure assessment.

4.2.2 The SENTIERI approach

The SENTIERI approach was developed in Italy, as part of a national project aimed at describing the health profile of populations living in national priority contaminated sites, as defined by Italian law. This approach uses routinely collected data on mortality and morbidity at the area level and can be outlined in different phases.

In the first phase, contaminated sites are identified and classified. The classification can be based on the sources of contamination documented in each contaminated site.

The populations affected by the contamination process must be defined as well.

A matrix of epidemiological *a priori* evidence about the strength of the causal association between each health outcome and source of environmental contamination is defined on the basis of the review of the literature. Table 4.1 shows an example of the SENTIERI approach, using a matrix of epidemiological *a priori* evidence for environmental exposures in a contaminated site for some selected causes.

Table 4.1. SENTIERI approach – example of matrix of epidemiological a-priori evidence

Cause of death	Chemical plant*	Chemical lant & refinery	Steel plant	Electric power plant	Mine and/or quarry	Harbour area	Asbestos or other mineral fibers	Landfill	Incinerator
All ages									
Malignant neoplasms of trachea, bronchus and lung	I	L	I	L	I	I	L	I	L
Malignant neoplasms of pleura		I	I	I	S+	L	S+		
Disease of the respiratory system	L	L	L	L	I	L		I	I
Asthma	L	L	L	L		L		I	I
Up to 14 years old									
Asthma	L	L	L	L				I	I

Legend
S = sufficient to infer the presence of a causal association
L = limited but not sufficient to infer the presence of a causal association
I = inadequate to infer the presence or the absence of a causal association

Source: adapted from Table 5 in Ancona C et al. (2010). Results of the evaluation. In: Pirastu R et al. SENTIERI: Studio Epidemiologico Nazionale dei Territori e degli Insediamenti Esposti a Rischio da Inquinamento: valutazione della evidenza epidemiologica [SENTIERI Project. Mortality study of residents in Italian polluted sites: evaluation of the epidemiological evidence]. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 34(5–6 Suppl 3):21–26. Reproduced with permission.

In the second phase, small-area statistics for all causes with a possible environmental etiology are computed for each contaminated site, using mortality and morbidity indicators. The indicators are computed for the whole potential contaminated area (the population of the area with major contamination).

Results are presented and discussed for each site, considering groups of causes – for example, all causes combined, all cancers and all respiratory diseases – and causes of *a priori* interest selected on the basis of the sources of contamination in each contaminated site. Results for groups of causes are used for a general description of the health status of the population, while results for causes of *a priori* interest provide a description of the health profile, considering the specificity of the contamination sources for each contaminated site.

In producing the report for each contaminated site, all the studies carried out locally and published in the literature on environmental monitoring, risk assessment and epidemiological investigations are examined. For each contaminated site, suggestions for further studies to fill the gaps in knowledge and for public health interventions, if applicable, are provided.

The SENTIERI approach allows the description of the health status of populations living close to contaminated sites. Furthermore, it is suitable for an overall analysis of data from different contaminated sites and for comparative analysis of data from contaminated sites with the same contamination sources.

4.2.3 The PLAINE approach for a GIS-based platform with environment and health data

The main aim of the PLAINE Project, developed in France, is to develop a map of environmental and health data. This platform is developed for systematic collection, integration, and analysis of data on emission sources, environmental contamination, exposure to environmental hazards, and population and health. A GIS is used to combine the district location information with the geographical concentration distributions. Once modelled as spatial data, a multimedia exposure model is applied for population exposure and risk assessments.

At the local scale, the platform could be used in the classical risk assessment study context or to design further environmental sampling in detected hot spot areas.

The platform could be used also for other purposes, such as:

- mapping environmental disparities;
- identifying vulnerable populations and determinants of exposure to manage and plan remedial actions;
- highlighting hot spot areas with significantly elevated exposure indicator values, to define environmental monitoring campaigns; and
- assessing spatial relationships between health and environmental and socioeconomic data, to identify factors that influence the variability of disease patterns.

4.3 Exposure assessment of contaminated sites, using human biomonitoring and studying the food-chain

In the first workshop on contaminated sites, exposure assessment was recognized – as it was many times before – as one of the most complex issues in dealing with contaminated sites and health. In this respect, two topics seem to deserve special attention: (a) biomonitoring, given its great power to measure human exposure directly; and (b) contamination of the food-chain, because of its large potential contribution to exposure, which is not always fully considered in evaluating the health risk of contaminated sites.

4.3.1 Human biomonitoring

Human biomonitoring studies can contribute to exposure assessment, helping local authorities and public health professionals to monitor the effects of policy actions targeted at curbing emissions and reducing population exposure.

Some aspects of using human biomonitoring in contaminated sites were discussed at a recent WHO Regional Office for Europe meeting on the topic of biomonitoring-based indicators of exposure to chemical pollutants (WHO Regional Office for Europe, 2012).

At that meeting, the application of human biomonitoring to exposure assessment of inorganic and organic chemicals, especially for petrochemical industry areas, was considered. The discussion notably referred to the Sicily Region (Italy), where three highly contaminated petrochemical areas are located.

A crucial aspect of a human biomonitoring assessment is identifying an appropriate reference population. The following options for identifying this population are possible.

- If available, general reference values at the country or regional level can be used as a first approximation reference.
- A local reference population would be preferable.
- Human biomonitoring data for a population living in a *clean area* in the same geographical context, comparable for all variables other than the source of contamination under study, can be considered as an additional reference.

In selecting the biomarkers, the following criteria must be considered.

Primary criteria:

- existence of validated biomarker(s)
- toxicological potential and health hazard
- availability of an appropriate sampling matrix
- existence of health-based guidance values
- manageable sample volume
- affordable cost of laboratory analysis;

Additional (secondary) selection criteria:

- magnitude of exposure
- availability of environmental and/or health information
- existing capacities to conduct laboratory analysis
- specificity of the biomarker
- link to industrial pollution sources.

In contaminated sites, newborn and young children are considered elective subgroups to be studied using human biomonitoring for the following reasons: (a) transplacental transport of contaminants from the mother to the fetus; and (b) vulnerability during the in-utero development phase.

- The options of human biomonitoring proposed for the Sicilian petrochemical areas, with their corresponding major limitations, are as follows.
- Maternity, mothers, newborns and fathers: the option may be possible only for areas with populations large enough to achieve sufficient numbers.
- Family-based approaches: there may be different baseline levels of biomarkers by age. Although the study power may be sufficient, different age groups may not be strictly comparable.
- Young children recruited through the school system: there may be problems in defining the reference population.

To place this in perspective, it is important that several aspects be considered in planning and designing human biomonitoring surveys in contaminated sites.

- Additional biomarkers – not yet available as reference values – may be required in the reference population, if it serves as a control for the population of the contaminated site.
- In areas with complex exposures, effect markers may be considered; however, their interpretation is difficult.
- In areas with complex exposures, additional clinical analyses can be informative – for example, haematograms, kidney function parameters and hormone levels (such as thyroid hormones).

- In contaminated sites with a small affected population, recruitment during maternity may not be straightforward. Additional recruitment procedures need to be developed, or other population groups should be selected – for example, young children.
- When running a human biomonitoring assessment, simultaneous collection and analysis of data on food contamination and air pollution are also recommended because of the opportunity and consistency they create and because they strengthen the findings.

4.3.2 An example of overall exposure assessment considering the food-chain

The food-chain is an important (yet under-studied) exposure pathway and, potentially, a crucial area for preventive action. The relevance of considering the food-chain in contaminated sites has been apparent in some cases, as (for example) in the chemical–petrochemical industrial zone of Tarragona (Catalonia, Spain). In that area, an approach was developed for assessing human health risk due to exposure to environmental pollutants. This approach consists of the following three steps.

In the first step, an evaluation of the chemicals of concern is carried out. The following properties are considered in selecting the target chemicals: persistence, bioaccumulation, toxicity and long-range transport.

In the second step, a conceptual model of population exposure is developed by collecting information from environmental monitoring in a GIS platform. The environmental indicators of exposure considered are: (a) soil (long-term indicator); (b) vegetation (medium-term indicator); and (c) air (indicator of ongoing contamination). Food samples are considered as indirect exposure indicators.

A dispersion model of contaminants is defined to select the areas for environmental sampling. To assess the effects of urban pollution, two areas are chosen as references: one without urban or industrial contamination (blank) and the other affected by the traffic, but without any industrial contamination.

In the third step, the techniques of multivariate analysis are applied to evaluate the contribution of different sources of contamination to the overall exposure of the population affected.

The estimated contribution of the food-chain to the overall exposure to chemicals in Tarragona was more than 90%, showing that diet was the major pathway of exposure to chemicals.

4.4 Options for designing epidemiological studies on contaminated sites

Epidemiological studies on contaminated sites can be conceived and carried out with different aims. While a clear-cut classification is difficult, three main groups of studies can be identified, with the following objectives:

- to describe the health profile of populations living in contaminated sites (*descriptive)*;
- to analyse the associations between environmental exposures and health effects, to verify specific hypothesis (*analytical or etiological*);
- to plan the epidemiological surveillance, to evaluate the evolving pattern of the population health profile (*surveillance*).

All three are useful, for example, to evaluate the effectiveness of a remedial intervention or reduction of the contamination and/or exposure phenomena, by analysing the evolution of specific risks over time.

The environmental and social contexts of many contaminated sites are complex, and the relevant questions, in terms of knowledge gaps or policy advice, are not always clearly formulated; this creates challenges for deciding on the most suitable epidemiological study designs. The variability of several aspects of both contamination and the exposed population must be considered, including:

- multiple sources of contamination
- contamination by multiple substances
- different pathways: soil, water, air, food-chain
- variable time of contamination
- population size (and sizes of the exposed groups)
- socioeconomic status and environmental justice
- occupational exposures
- definition of outcomes and data collection (scale)
- environmental worries and media attention.

The selection of study designs can also be informed by considering the time dimension – in particular, the latency time between exposure and adverse effects on health. To evaluate short-term effects, study designs capable of evaluating temporal differences should be adopted. To evaluate long-term effects, study designs capable of evaluating spatial differences are more suitable. The following are study designs for:

- short-term effects:
  - time series or case-crossover studies
  - panel studies;
- long-term effects:
  - ecological studies (municipalities, small-area statistics)
  - cross-sectional (biomonitoring) studies
  - cohort studies
  - case-control studies.

Most of the study designs are well known and commonly applied; a possible exception is the case-crossover design used infrequently in contaminated sites. This study design has the following qualities.

- The case-crossover study design is useful in evaluating the effects of a given exposure that manifests itself within a short period of time.
- It uses the of case-control design, where each subject who experienced the event being studied is matched with himself or herself for an adjacent time period where he or she did not experience the event.
- The subject's characteristics and exposures at the time of the case event are compared with those of a control period in which the event did not occur.
- Multiple control periods may be used.
- Matched pairs are analysed using conditional logistic regression.

- In this analysis, because each subject serves as his/her own control, using a day nearby as the control period, all covariates that change slowly over time (such as smoking history, age, body mass index, usual diet and diabetes) are controlled for by matching.
- Also, variables with seasonal variations or trends and confounders ´that vary slowly over time are controlled for by design, because the case and control periods in each risk set are separated by a relatively small interval of time.

As mentioned above, a critical aspect of epidemiological studies (in general) and of contaminated site studies (in particular) is exposure assessment. The first step in planning an epidemiological study in a contaminated site is to define a *conceptual exposure model* for the target population, considering possible exposure scenarios in the time and space dimensions.

In studying contaminated sites, when the contribution of a specific contamination source of a given contaminant is examined, an additional problem is the possible presence of environmental confounders, such as multiple sources of the same contaminants or contaminants with the same health effects in the same area – for example, multiple industrial point sources of air pollution.

A special case is the socioeconomic status at the individual level and/or at the area level (contextual deprivation), which often operates as a confounder or an effect modifier for some health outcomes and causes. This is due to differential distributions of environmental exposures in different social strata. Typically, environmental contaminated site risks are positively correlated with low socioeconomic status at both the individual and area levels.

In the case of a confounding effect, the socioeconomic status is causally and independently associated with the outcomes and causes of interest. In this case, to assess the specific contribution of environmental factors to health risks, the effect of the socioeconomic factors must be removed.

When socioeconomic factors act as effect modifiers, they interact with environmental stressors to modify the health risk – that is, the risk of the joint action of environmental factors and socioeconomic status is higher than it would be if they acted as independent risk factors. In this case, the estimated risk due to their joint action must be reported. In both cases, considering and accounting for socioeconomic determinants (at the individual and area levels) are key issues in the health impact assessment of contaminated sites.

Occupational exposures should also be taken into account. As industrial facilities are often the main source of contamination, workers can be exposed to the same contaminants or multiple contaminants with the same adverse effects on health, because of exposures in both the occupational and residential settings. Disentangling their separate contributions, however, is often problematic.

5 Discussion

Assessing the possible health impact of contaminated sites is a challenging exercise **–** for several reasons linked to their inherent heterogeneity and complexity. Each contaminated site has its own characteristics, and it is difficult to describe typical or exemplary cases or exposure scenarios, especially in the case of industrially contaminated sites with ongoing multiple industrial activities.

A variety of methods and tools for health risk assessment have been developed and applied, and a broad range of resources is available. Also, most of the technical guidance documents are publicly available for a fully transparent assessment. Due to the heterogeneity of contaminated sites, available resources must be carefully reviewed and applied, depending on the needs, objectives and local feasibility.

Approaches with mixed designs, including health risk assessments and direct epidemiological evaluations, are often used to assess the health impact of contaminated sites – as exemplified by the ATSDR public health assessment procedure. These approaches can be further strengthened by deploying tools and methods for a first descriptive epidemiological evaluation developed in other settings – for example, the RIF software and the SENTIERI approach.

In case of huge complex contamination and/or a large population affected, specific epidemiological studies can be appropriately selected to further characterize the possible health impact of a given contaminated site, considering the results of the health risk assessment and the first descriptive epidemiological evaluations.

In defining the health profile of populations affected by environmental contamination, two crucial aspects – not directly related to the contamination phenomena – should be carefully considered and studied: (a) the contribution to the risk due to occupational exposures; and (b) the interplay between socioeconomic factors (at the individual and group level) and environmental risks.

Strategies and tools for evaluating the contribution of a specific contamination of a given environmental pathway – for example, through the food-chain – are available, as are proposals on how human biomonitoring can contribute to exposure assessment in the case of areas affected by relevant industrial contamination.

In many exposure assessments and epidemiological studies, a crucial element is human exposure assessment. This means describing how individuals or population come in contact with contaminants released from single or multiple sources, including the quantification of the amount of contact across space and time. The direct approach measures pollutant concentrations directly on or within the person through the point of contact, or biological monitoring. However, an indirect approach is often adopted by measuring the pollutant concentrations within different environmental media (such as air, soil and water). This process is minimally invasive to the population and is associated with lower costs than the direct approach, although it involves several limitations.

Despite the limitations of analytical tools and the lack of accurate exposure assessment data, notable good quality, reliable studies and assessments exist that document the substantial health impacts of contaminated sites in Europe and worldwide. The variety of available assessments suggests that contaminated sites are an important public health issue at the national and international levels. The heterogeneity of contaminated sites and the lack of an unambiguous agreed upon definition of contaminated site make it difficult to quantify the extent of the problem. It is therefore desirable to gather and compile more and more systematic evidence, to characterize the problem more precisely.

To this end, more complete and systematic data are needed. Many initiatives on contaminated sites at the EU level have soil as the *entry point*. Because of this, many rich and informative data exist on contaminated sites and focus on the soil component of contaminated media. Due to the current voluntary principle for reporting on this issue by Member States, the available information is heterogeneous, with uneven spatial coverage. However, the steps undertaken by DG Environment, EEA, and JRC in refining data collection provide a good base for acquiring information. Such data are not universally known to the environmental health community at large and could be used more extensively for human health assessments, at various levels.

However, with regard to estimating health Impacts, several contaminated sites involve simultaneous contamination of multiple media besides soil, such as water, air and the food-chain. In many cases, contaminated sites also involve a complex mix with other types of health determinants – such as lifestyle risk factors, mediated by socioeconomic characteristics – that produce highly complex, impactful patterns of health stressors for populations residing and/or working in contaminated sites.

Other European data sets relevant to human exposure assessment include those of E-PRTR (releases from industrial facilities to air, water or soil) or WISE on European water issues. These data sets provide valuable information on the status of chemical pollution of water, air or soil, although with no reference to contaminated sites directly. Adding full georeferencing data for this type of information would be an important step.

The possibility of using these data sets in human health exposure assessments at the European level requires still further work and a stronger and deeper collaboration between environment and public health professionals. More initiatives in this aspect of assessment would be desirable, at the national or regional levels, especially in countries or regions with limited resources to conduct analytical studies.

6 The way forward

Priorities for further work will be defined, taking into account solicitations and requests from the governments of the 53 countries of the WHO European Region, considering, in particular, those from countries without strong capacities and with limited experience in the domain of contaminated sites.

The health impact of contaminated sites will be considered in the following two main perspectives.

- Local health impact. That is, what is the health impact in populations affected by a given contamination in a single specific area of local/regional interest - for example, to define public health interventions and to contribute in identifying priorities for remediation activities?
- Aggregate health impact. That is, what is the health impact of different types of contaminated sites, at the regional, national and international levels?
- As reported in Section 1.1, the EU has different definitions of contaminated sites, each one developed to define the boundaries of specific actions. In most of the cases, definitions are provided to identify target sites where remediative interventions should be applied (contaminated soils).

Considering a general public health perspective, the following operational definition of contaminated site is proposed as a reference for the network on contaminated sites and health coordinated by the WHO Regional Office for Europe.

> Areas hosting or having hosted human activities which have produced or might produce environmental contamination of soil, surface or groundwater, air, food-chain, resulting or being able to result in human health impacts.

This definition has the operational aim of identifying the targets and the limits of action for collaborative work at its beginning, without the intent of being definitive and applicable to other purposes.

7 Topics and goals for collaborative work

The following topics and goals have been identified for collaborative work within the European network on contaminated sites and health coordinated by the WHO Regional Office for Europe:

- producing guidelines on: (a) strategies for studying environment and health in contaminated sites, focusing on methodology (when and how to apply different methods and study designs); and (b) strategies for communication among: (i) researchers of different fields, to plan environment and health studies; (ii) researchers and policy-makers; and (iii) researchers and other stakeholders, the media, and populations affected;
- preparing and disseminating materials on the topics addressed by the guidelines (updated web pages and leaflets);
- strengthening the methodology on exposure assessment – in particular, on biomonitoring and the food-chain;
- implementing health assessments that include the separate analysis of population subgroups – in particular, children;
- developing training modules on: (a) the approaches and methodology to be applied in different sites and contexts; and (b) communication strategies; and
- planning a system to collect data and produce comparative analyses of the health impact of different sources of contamination within and among different countries of the WHO European Region, allowing socioeconomic factors to be included.

References

ATSDR (2011). Public health assessments & health consultations [web site]. Atlanta, GA, Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/HAC/PHA/index.asp, accessed 2 January 2013).

Common Forum (2012). Common Forum on Contaminated land in the European Union [web site]. Orléans, Common Forum (http://www.commonforum.eu/, accessed 2 January 2013).

DG Environment (2008). *Water Note 1*. Brussels, European Commission (http://ec.europa.eu/environment/water/participation/pdf/waternotes/water_note1_joining_forces.pdf, accessed 1 January 2013).

DG Environment (2009). *Water Note 6*. Brussels, European Commission (http://ec.europa.eu/environment/water/participation/pdf/waternotes/water_note6_monitoring_programmes.pdf, accessed 1 January 2013).

EC (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. *Official Journal of the European Union*, L327:1–72 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:en:PDF, accessed 1 January 2013).

EC (2006a). *Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions: thematic strategy for soil protection*. Brussels, European Commission (COM(2006) 231; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0231:FIN:EN:PDF, accessed 28 December 2012).

EC (2006b). *Proposal for a Directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC*. Brussels, European Commission (COM(2006) 232; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0232:FIN:EN:PDF, accessed 28 December 2012).

EC (2006c). *Guidance Document for the implementation of the European PRTR.* Brussels, European Commission (http://prtr.ec.europa.eu/docs/EN_E-PRTR_fin.pdf, accessed 30 December 2012).

EC (2006d). *Commission Staff Working Document – Accompanying document to the Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – Thematic Strategy for Soil Protection – Summary of the impact assessment {COM(2006)231 final} {SEC(2006)620} /* SEC/2006/1165 */.* Brussels, European Commission (SEC (2006) 1165; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52006SC1165:EN:HTML, accessed 30 December 2012).

EC (2006e). *Commission Staff Working Document accompanying the communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions Thematic Strategy for Soil Protection impact assessment of the Thematic Strategy on Soil Protection*. Brussels, European Commission (SEC (2006) 620; http://ec.europa.eu/environment/soil/pdf/SEC_2006_620.pdf, accessed 30 December 2012).

EC (2006f). Regulation (EC) No 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC, Official *Journal of the European Union*, L33:1–17 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:033:0001:0017:EN:PDF, accessed 30 December 2012).

EC (2007). Directive 2007/2/EC of the European Parliament and of the Council of 14 March, establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). *Official Journal of the European Union*, L108:1–14 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:108:0001:0014:EN:PDF, accessed 1 January 2013).

EC (2008). Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council. *Official Journal of the European Union*, L348:84–97 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:348:0084:0097:EN:PDF, accessed 1 January 2013).

EC (2010). Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (recast) (text with EEA relevance). *Official Journal of the European Union*, L334:17–119 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ%3AL%3A2010%3A334%3A0017%3A0119%3Aen%3APDF, accessed 1 January 2013).

EC (2012a). *Report from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions: the implementation of the Soil Thematic Strategy and ongoing activities*. Brussels, European Commission (COM (2012) 46; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0046:FIN:EN:PDF, accessed 28 December 2012).

EC (2012b). Corrigendum to Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control), *Official Journal of the European Union*, L158:25. (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:158:0025:0025:EN:PDF, accessed 1 January 2013).

EEA (2007). *Progress in the management of contaminated sites (CSI 015) – assessment published Aug 2007.* Copenhagen, European Environment Agency (http://www.eea.europa.eu/data-and-maps/indicators/progress-in-management-of-contaminated-sites/progress-in-management-of-contaminated-1, accessed 30 December 2012).

EEA (2009). *Guidance on the reporting required for assessing the state of, and trends in, the water environment at the European level.* Copenhagen, European Environment Agency.

EEA (2012). River basin. Environmental Terminology and Discovery Service [web site]. Copenhagen, European Environment Agency (http://glossary.eea.europa.eu/EEAGlossary/R/river_basin, accessed 1 January 2013).

Eionet (2008). Eionet's software tools. PRA.Ms [web site]. Copenhagen, European Environment Agency (http://www.eionet.europa.eu/software/prams, accessed 12 January 2013).

E-PRTR (2012). Welcome to E-PRTR [web site]. Copenhagen, European Environment Agency (http://prtr.ec.europa.eu/, accessed 30 December 2012).

Fons J (2006). *Towards an EEA Europe-wide assessment of areas under risk for soil contamination: PRA.MS Application (Trier 2)*. Copenhagen, European Environment Agency (http://www.eionet.europa.eu/software/prams/release1/PRA.MS_Manual.pdf, accessed 2 January 2013).

INSPIRE (2012). INSPIRE [web site]. Brussels, European Commission (http://inspire.jrc.ec.europa.eu/index.cfm, accessed 14 January 2013).

INSPIRE Thematic Working Group Human Health and Safety (2011). *INSPIRE: D2.8.III.5 data specification on human health and safety – draft guidelines.* Ispra, INSPIRE Thematic Working Group Human Health and Safety (http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_HH_v2.0.pdf, accessed 1 January 2013).

INSPIRE Thematic Working Group Soil (2011). *D2.8.III.3 Data specification on soil – draft guidelines,* Ispra, INSPIRE Thematic Working Group SOIL. (http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_SO_v2.0.pdf, accessed 1 January 2013).

INTARESE (2012). INTARESE [web site]. London, Imperial Consultants (http://www.intarese.org/, accessed 13 January 2013).

IPCS (2010). *WHO Human Health Risk Assessment Toolkit: chemical hazards.* Geneva, World Health Organization (http://www.who.int/ipcs/publications/methods/harmonization/toolkit.pdf, accessed 2 January 2013).

ISO (2005). *Soil quality – sampling, Part 5: guidance on the procedure for the investigation of urban and industrial sites with regard to soil contamination*. Geneva, International Organization for Standardization (ISO/DIS 10381-5).

Jones A et al. (2012). *The state of soil in Europe: a contribution of the JRC to the European Environmental Agency's Environment State Outlook report – 2010.* Luxembourg, Publication Office of the European Union. (http://ec.europa.eu/dgs/jrc/downloads/jrc_reference_report_2012_02_soil.pdf, accessed 28 December 2012).

JRC (2012). European Soil Portal (web site). Ispra, EC Joint Research Centre (http://eusoils.jrc.ec.europa.eu/, accessed 30 December 2012).

JRC (2013). FATE and impact of pollutants in terrestrial and aquatic ecosystems [web site]. Ispra, EC Joint Research Centre (http://fate.jrc.ec.europa.eu/monitoring/monitoring-overview, accessed 1 January 2013).

Kay D, Prüss A, Corvalán C (2000). *Methodology for assessment of environmental burden of disease*. Geneva, World Health Organization (http://www.who.int/quantifying_ehimpacts/methods/en/wsh0007.pdf, accessed 2 January 2013).

Rodriguez Lado L, Hengl T, Reuter HI (2008). Heavy metals in European soils: a geostatistical analysis of the FOREGS Geochemical database. *Geoderma*, 148(2):189-199.

SAHSU (2012). Small Area Health Statistics Unit [web site]. London, Imperial College London (http://www.sahsu.org/content/about-us, accessed 3 January 2013).

Van-Camp L et al. (2004). *Reports of the technical working groups established under the thematic strategy for soil protection. Vol. 5. Monitoring.* Luxembourg, Office for Official Publications of the European Communities (EUR 21319 EN/4;. http://ec.europa.eu/environment/soil/pdf/vol5.pdf, accessed 28 December 2012).

Van Liedekerke M (2011). *Guidelines for the collection of contaminated sites data through EIONET.* Ispra, EC Joint Research Centre (http://eusoils.jrc.ec.europa.eu/library/data/eionet/2011_Contaminated_Sites.htm, accessed 30 December 2012).

WHO Regional Office for Europe (2012). *Biomonitoring-based indicators of exposure to chemical pollutants: report of a meeting, Catania, Italy, 19–20 April 2012.* Copenhagen, WHO Regional Office for Europe (http://www.euro.who.int/__data/assets/pdf_file/0004/170734/e96640.pdf, accessed 3 January 2013).

WISE *(*2012). About WISE [web site]. Copenhagen, European Environment Agency (http://water.europa.eu/info, accessed 1 January 2013).

Annex 1.
Contributions and case studies – workshop "Contaminated sites and health: priorities, interests, needs, methodological options"

1.1. A retrospective cohort study of residents near multiple point sources of air pollution

Carla Ancona[1],Chiara Badaloni[1], Andrea Bolignano[2], Giulia Cesaroni[1], Francesca Mataloni[1], Simone Bucci[1], Roberto Sozzi[2]and Francesco Forastiere[1]

[1] Department of Epidemiology, Lazio Regional Health Service, Italy
[2] Regional Environmental Protection Agency, Lazio Region, Italy

Background and aims

In the area of Malagrotta, a suburb of Rome (Italy), a large waste landfill, an incinerator and an oil refinery plant have been operating since the early 1960s. To evaluate the health effects due to airborne contamination, a retrospective cohort study is in progress, using GIS and dispersion modelling to characterize the exposures.

Methods

The study area was defined as the 7 km zone around the landfill. The cohort was based on the Rome Longitudinal Study, based on the 2001 census with a mortality follow-up until 2008. For each cohort member, individual (education, occupation, place of birth, civil status, area-based socioeconomic status) and GIS variables (distance from motorways and from high traffic roads) were available. Exposures to NO_2 from traffic and from diesel trucks collecting waste were available from a land use regression model (R2=0.72) and an Atmospheric Dispersion Modelling System (ADMS), respectively. Exposure assessment of the incinerator (NO_X), the refinery plant (SO_X) and the landfill (H_2S, indicator of diffuse emissions) was done with the SPRAY Lagrangian dispersion model. Cox regression analysis was used to consider individual and GIS variables as confounders.

Results

The cohort included 85 559 individuals (8.5% distant less than 3 km from the plants). During the study period, 4848 deaths for all causes and 1741 for cancer were observed. There was some degree of correlation among the three exposure indicators of interest (NO_X, SO_X, and H_2S).

Conclusions

Evaluation of the health effects near multiple sources of air pollution is difficult. We used a large retrospective cohort with detailed exposure assessment.

1.2. Experiences of exposure assessment in waste related studies in the United Kingdom

Kees de Hoogh

Small Area Health Statistics Unit (SAHSU), MRC-HPA Centre for Environment and Health, Department of Epidemiology and Biostatistics, Imperial College London, United Kingdom

The SAHSU has long-lasting experience in investigating the relationship between waste-related activities and possible health effects. Exposure assessment plays a crucial role in these studies, and this presentation gives an overview of the different types of exposure modelling undertaken. This includes the number of studies that look at landfill sites where buffering was used to quantify exposures of the United Kingdom population (Elliott et al., 2001; Morris et al., 2003; Jarup et al., 2007; Elliott et al 2009). Current studies include the case-control study of birth outcomes around Municipal Waste Incinerators in England and Wales in which dispersion modelling will be used to assess the exposure of the selected cases and controls. Another study is investigating the health impact of bioaerosols from large scale bio-composting waste facilities.

Lastly, I will give an update of the redevelopment of the RIF we are currently undertaking, which could be a useful tool as part of the European health impact assessment.

References

Elliott P et al. (2001). Risk of adverse birth outcomes in populations living near landfill sites. *British Medical Journal*, 323:363–368.

Elliott P et al. (2009). Geographic density of landfill sites and risk of congenital anomalies in England. *Occupational and Environmental Medicine*, 66:81–89.

Jarup L et al. (2007). Down syndrome in births near landfill sites. *Prenatal Diagnosis*, 27:1191–1196.

Morris SE et al. (2003). No excess risk of adverse birth outcomes in populations living near special waste landfill sites in Scotland. *Scottish Medical Journal*, 48(4):105–107.

1.3. SENTIERI project: epidemiological study of residents in Italian contaminated sites

Roberta Pirastu

Sapienza University of Rome, Italy

SENTIERI Project (epidemiological study of residents in Italian contaminated sites) studies the mortality of residents in the sites of national interest for environmental remediation (national priority contaminated sites, NPCSs). NPCSs are located in the vicinity of industrial areas, either active or inactive, near incinerators or dumping sites of industrial or hazardous waste.

SENTIERI includes 44 out of 57 sites comprised in the "National environmental remediation programme". For each NPCS, contamination data were collected both from national and local environmental remediation programmes. Contamination data are mainly for private industrial areas; municipal and/or green and agricultural areas were poorly studied; therefore, it is difficult to assess the environmental exposure of populations living inside and/or near NPCSs.

Each one of the 44 SENTIERI NPCSs includes one or more municipalities. Mortality in the period 1995–2002 was studied for 63 single or grouped causes at the municipal level by computing: crude rate, standardized rate, standardized mortality ratios (SMR), and SMR adjusted for an *ad hoc* deprivation index. Regional populations were used as references for SMR calculations.

The deprivation index was constructed using 2001 national census variables for the following socioeconomic domains: education, unemployment, dwelling ownership and overcrowding.

A characteristic element of the SENTIERI Project is the *a priori* evaluation of the epidemiological evidence of the causal association between cause of death and exposure. Exposures for which the epidemiological evidence was assessed are divided into NPCS environmental exposures and other exposures. The former are identified on the basis of the decrees that define site boundaries; they are coded as chemicals, petrochemicals and/or refineries, steel plants, power plants, mines and/or quarries, harbour areas, asbestos or other mineral fibres, landfills and incinerators. The other exposures, considered for their ascertained adverse health effects are: air pollution, active and passive smoking, alcohol intake, occupational exposure and socioeconomic status.

The epidemiologists in SENTIERI Working Group developed a procedure to examine the epidemiological literature published from 1998 to 2009; the Working Group identified a hierarchy in the literature examined to classify each combination of cause of death and exposure in terms of strength of causal inference.

The epidemiological information selected included primary sources (handbooks and monographs and reports of international and national scientific institutions), meta-analyses, literature reviews, multicentric studies and single investigations. This hierarchy relies on an epidemiological community consensus, on assessments based on the application of standardized criteria, weighting the studies design and the occurrence of biased results. Therefore, to put forward the assessment, the criteria used first favoured primary sources and quantitative meta-analyses and, second, consistency among sources.

The epidemiological evidence of the causal association was classified into one of the following three categories: Sufficient (S), to infer the presence of a causal association; Limited (L), to infer the presence of a causal association; and Inadequate (I), to infer the presence or the absence of a causal association. The procedures and results of the evidence evaluation have been presented in a 2010 Supplement of *Epidemiologia & Prevenzione* devoted to the SENTIERI Project (Pirastu et al., 2010).

SENTIERI Project studied NPCS specific mortality and the overall mortality profile in all the NPCSs combined (Pirastu et al., 2011).

Some NPCS-specific results are noteworthy and are mentioned here. The presence of asbestos (or asbestiform fibres in Biancavilla) was the motivation for including six NPCSs (Balangero, Emarèse, Casale Monferrato, Broni, Bari-Fibronit, Biancavilla) in the "National environmental remediation programme". In these sites (with Emarèse the only exception), increases in malignant pleural neoplasm mortality were observed; in four of them – the excess was in both genders. In six other sites (Pitelli, Massa-Carrara, *Aree del Litorale Vesuviano* [Vesuvian littoral], Tito, *Area industriale della Val Basento* [industrial area of the Basento valley], Priolo), where additional sources of environmental pollution were reported, mortality from malignant pleural neoplasm increased in both genders in Pitelli, Massa-Carrara, Priolo and *Litorale Vesuviano*. In the twelve sites where asbestos was mentioned in the decree, a total of 416 extra cases of malignant pleural neoplasms were computed.

Asbestos and pleural neoplasm represent an unique case. Unlike mesothelioma, most causes of death analysed in the SENTIERI Project have multifactorial etiology; furthermore, in most NPCSs multiple sources of different pollutants are present, sometimes concurrently with air pollution from urban areas: in these cases, drawing conclusions about the association between environmental exposures and specific health outcomes might be complicated.

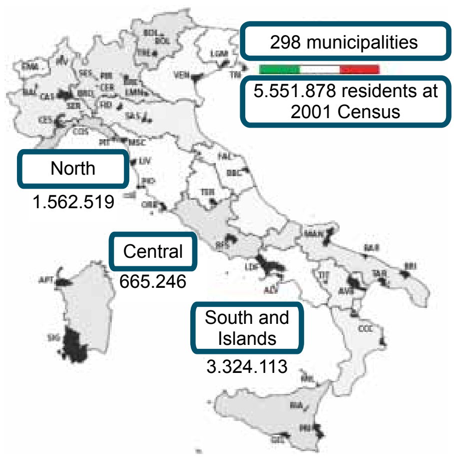
Notwithstanding these difficulties, in a number of cases an etiological role could be attributed to some environmental exposures. The attribution could be possible on the basis of increases observed in both genders and in different age classes, and the exclusion of a major role of occupational exposures was thus allowed. For example, a role for emissions from refineries and petrochemical plants was hypothesized for the observed increases in mortality from lung cancer and respiratory diseases in Gela and Porto Torres; a role for emissions from metal industries was suggested to explain increased mortality from respiratory diseases in Taranto and in Sulcis-Iglesiente-Guspinese. An etiological role for air pollution in the increase in congenital anomalies and perinatal disorders was suggested in Falconara Marittima, Massa-Carrara, Milazzo and Porto Torres. A causal role for heavy metals, polycyclic aromatic hydrocarbons (PAHs) and halogenated compounds was suspected for mortality from renal failure in Massa-Carrara, Piombino, Orbetello, *Basso Bacino del fiume Chienti* [lower basin of Chienti river] and Sulcis-Iglesiente-Guspinese. In *Trento Nord* [north Trento], Grado and Marano, and *Basso Bacino del fiume Chienti* increases in neurological diseases, for which an etiological role for lead, mercury and organohalogenated solvents is possible, were reported. The increase of non-Hodgkin's lymphoma in Brescia was associated with widespread Polychlorinated Biphenyls (PCBs) pollution.

The SENTIERI Project also assessed the overall mortality profile in all the NPCSs combined. The mortality for causes of death with *a priori* Sufficient or Limited evidence of causal association with environmental exposure showed 3508 excess deaths for all causes, corresponding to 439 per year; the number of excess deaths was 1321 for respiratory diseases, 898 for lung cancer and 588 for pleural neoplasms.

When considering excess mortality with no restriction to cause of death and with *a priori* Sufficient or Limited evidence of causal association with environmental exposures, the number of excess deaths for all causes was 9969 (SMR of 102.5, about 1200 excess deaths per year); the excess was 4309 for all neoplasms (SMR of 103.8, about 538 excess deaths per year), 1887 for circulatory system diseases, and 600 for respiratory system diseases. Most of these excesses were observed in NPCSs located in southern and central Italy. The distribution of the causes of deaths showed that the excesses are not evenly distributed: cancer mortality accounts for 30% of all deaths, but it is 43.2% of the excess deaths (4309 cases out of 9969). Conversely, the percentage of excesses in non-cancer causes is 19%, while their share of total mortality is 42%.

SENTIERI Project is affected by some limitations, such as the ecological study design and a time window of observation that is possibly inappropriate to account for the induction-latency time; the outcome analysed (mortality instead of incidence) might be unsuitable as well.

Fig 1.3.1. Italian polluted sites in SENTIERI Project. Municipalities residents by geographic macroarea



Source: adapted from Pirastu R, Comba P (2011). SENTIERI Project. In: Costa G, Paci E, Ricciardi W. United Italy, 150 years later: has equity in health and health care improved? *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 35(5–6 Suppl. 2):108–109. Reproduced with permission.

Despite its limitations, the SENTIERI Project documented increased mortality for single NPCSs and an overall burden of disease in residents in polluted Italian sites. These excesses could be attributed to multiple risk factors that also include environmental exposures.

The study results will be shared with the ministries of health and environment, regional governments, regional environmental protection agencies, local health authorities and municipalities.

Table 1.3.1. Environmental exposures in NPCS

Cause of death	Chemical plant*	Chemical plant & refinery	Steel plant	Electric power plant	Mine and/or quarry	Harbour area	Asbestos or other mineral fibers	Landfill	Incinerator
All ages									
Malignant neoplasms of trachea, bronchus and lung	**I**	**L**	**I**	**L**	**I**	**I**	**L**	**I**	**L**
Malignant neoplasms of pleura		**I**	**I**	**I**	**S**	**L**	**S**		
Disease of the respiratory system	**L**	**L**	**L**	**L**	**I**	**L**		**I**	**I**
Asthma	**L**	**L**	**L**	**L**		**L**		**I**	**I**
Up to 14 years old									
Asthma	**L**	**L**	**L**	**L**				**I**	**I**

Other exposures

Cause of death	Air polution	Active smoking	Passive smoking	Alcohol	Socio-economic status	Occupation
All ages						
Malignant neoplasms of trachea, bronchus and lung	**S**	**S**	**S**	**I**	**S**	**S**
Malignant neoplasms of pleura	**L**					**S**
Disease of the respiratory system	**L** onset/**S** wors	**S** onset/wors	**L** onset/wors	**S**	**L**	**S**
Asthma	**L** onset/**S** wors	**S** onset/wors	**L** onset/wors	**L**	**L**	**S**
Up to 14 years old consistency among sources						
Asthma			**S** onset/wors		**L**	

Legend
S = sufficient to infer the presence of a causal association
L = limited but not sufficient to infer the presence of a causal association
I = inadequate to infer the presence or the absence of a causal association

Source: adapted from Tables 5 and 6 in Ancona C et al. (2010). Results of the evaluation. In: Pirastu R et al. SENTIERI Project. Mortality study of residents in Italian polluted sites: evaluation of the epidemiological evidence. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 34(5–6 Suppl 3):21–26. Reproduced with permission.

A collaborative approach between institutions in charge of environmental protection and health promotion will foster, among other things, a scientifically sound and transparent communication process with concerned populations.

References

Pirastu R et al. (2010). SENTIERI: Studio Epidemiologico Nazionale dei Territorie degli Insediamenti Esposti a Rischio da Inquinamento: valutazione della evidenza epidemiologica [SENTIERI Project. Mortality study of residents in Italian polluted sites: evaluation of the epidemiological evidence]. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 34(5–6 Suppl. 3):1–96 (http://www.epiprev.it/materiali/2010/EP5-6_2010_suppl3.pdf, accessed 21 December 2012; in Italian and English).

Pirastu R et al. (2011). SENTIERI. Studio epidemiologico Nazionale dei Territori e degli Insediamenti Esposti a Rischio da Inquinamento: Risultati [SENTIERI Project. National epidemiological study of the territories and settlements exposed to the risk of pollution: results]. *Epidemiologia e Prevenzione [Epidemiology and Prevention*], 35(5–6 Suppl. 4):1–204 (http://www.epiprev.it/pubblicazione/epidemiol-prev-2011-35-5-6-suppl-4, accessed 21 December 2012; in Italian and English).

1.4. Health studies conducted in industrialized sites of southern Spain

Piedad Martin-Olmedo
Andalusian School of Public Health (EASP), Spain

Background: description of the industrialised sites

The western part of Andalusia (southern Spain), bordered by Huelva, Seville and Cadiz provinces, already showed a significant excess of mortality during the mid-1950s and early 1960s in relation to other areas of Andalusia or Spain (Blanes Llorens, 2007). Attempts were made to improve the very low socioeconomic status of the region at that time by the establishment in the late 1960s of two large petrochemical complexes, one in Algeciras Bay (Cadiz) and the other near *Ria of Huelva*, a highly polluted estuary – as a result of centuries of mining activities upstream of the Tinto and Odiel rivers. Other sources of pollutants common to both sites include a paper mill, chemical industries, and a power generation plant. In addition, the activity of a large fertilizer plant in Huelva has produced about 100 million tonnes of phosphogypsum wastes that have been piled up along the shores of the estuary, less than 1 km from the city of Huelva. Other industries located at this site are a copper smelter and a cement factory (Pérez-López, Alvarez-Valero & Nieto, 2007). Special attention also requires the very intense activity of merchant transportation occurring in Algeciras Bay, with a high volume of road traffic and shipping in the Bay. The Port of Algeciras Bay is also Spain's number one port for marine fuel supplies and, together with the ports of Gibraltar and Ceuta, represents the second largest bunker fuel market in Europe, after Amsterdam–Rotterdam–Antwerp (Pandolfi et al., 2011).

The discharge of large amounts of pollutants in both areas (mainly heavy metals, but also radioactive materials, benzene, toluene, ethylbenzene and xylene (BTEX), polycyclic aromatic hydrocarbons (PAHs), flame retardants, particulate matter, sulphur dioxide (SO_2), nitrogen oxides (NO_X), and ozone) and chronic oil spills (low or moderate, but continuous in time) from shipping and bunkering activity in the Bay has posed a huge environmental burden, affecting the aquatic biota, estuarine sediments, soils, and air quality.

For each site, the population affected is: 202 078 inhabitants in Algeciras Bay (4 municipalities and 3 districts); and about 160 000 inhabitants in the area adjacent to *Ria of Huelva* (8 municipalities).

Both sites have a Mediterranean climate, with an annual average temperature of 21–23 °C. Winters are mild and summers are hot and humid. Precipitation varies from 490 mm to 835 mm per year in Huelva and Algeciras, respectively. Winds are very changeable and might be very strong, especially in Algeciras Bay, with important events of Saharan dust intrusion every year.

Environmental diagnosis of the sites

Several accidents (that is, the discharge of a radioactive cloud from the stainless steel manufacturing plant in the Algeciras Bay in May 1998), a serious sulphur incident, and intermittent flaring episodes and oil spills provoked great outrage and public protests among citizens of both industrialized sites. As a result the Regional Government of Andalusia promoted an *environmental diagnosis* at the two contaminated areas. This independent research was coordinated by the National Research Council in collaboration with other scientific institutions (such as the University of Huelva and EASP). The first study was conducted at *Ria of Huelva*, from 2000 to 2003 (Ramos Martin, 2005), and the second at Algeciras Bay, from 2003 to 2006 (Ramos Martin, 2006).

Concentrations of heavy metals (As, Cd, Cu, Zn, Pb and Hg) and also persistent organic pollutants (POPs) were analysed in several food samples purchased in local markets. Fish and selfish showed the highest levels, and total daily intake for all the pollutants investigated were well below those proposed by WHO and European legislation (Ramos Martin, 2005, 2006; Bordajandi et al., 2004). Nonetheless, further investigation are required due to the large amounts of heavy metals reported in the soils and sediments of the estuary (Ramos Martin, 2005; Sainz, Grande & de la Torre, 2004) and the bay (Ramos Martin, 2006), which might pose a threat to human health if they enter the food-chain.

The assessment of ambient air quality showed a proven influence (~32%) of industrial activity on the chemical composition of particulate matter (PM_{10}, $PM_{2.5}$ and $PM_{1.0}$) at the two sites (Pandolfi et al., 2011; Ramos Martin, 2005, 2006; Querol et al., 2004). The annual mean concentration of As in PM-coarse (PM_{10}–$PM_{2.5}$) in Huelva was close to the target value of 6 ng/m^3 established under EU regulation (Directive 2004/107/CE) (Ramos Martin, 2005; Moreno et al., 2006). Relatively higher concentrations than in other cities in Spain were also reported for V, Ni, Zn, Cr and La measured in PM_{10} in Algeciras Bay (Ramos Martin, 2006), with a very relevant contribution from shipping emissions, especially in the case of vanadium (Pandolfi et al., 2011; Sánchez de la Campa et al., 2011). However, episodes of high peaks of PM_{10} (daily concentrations exceeding 50 µg/m^3) due to anthropogenic origin were usually below the EU limit of 35 days per year. A general steady decrease in annual mean concentrations of the main pollutants related to industrial activity (SO_2, NO_X and other organic compounds) was registered at both sites, due to new regulatory and control measurements (Ramos Martin, 2005, 2006). Even so, special attention to the sporadic high peaks of fine and ultrafine particles recorded at both sites is still required (Pandolfi et al., 2011; Querol et al., 2004; Moreno et al., 2006; Sánchez de la Campa et al., 2011).

Recent research showed significant higher personal exposure to BETX among the population of children living in the affected neighbourhood of Algeciras Bay, compared with a control population. This result is well correlated to sporadic peaks of benzene registered in the area, although never exceeding regulatory limits (EASP, 2008).

Main health studies conducted at the sites

Following (or in parallel with) the environmental diagnosis, several health studies were conducted, some funded directly by the Regional Government of Andalusia, others through national and international research calls. Scientific reports of the main governmental studies are available at the Regional Health Department of Andalusía's official web site.

The Interactive Mortality Atlas for Andalusia (AIMA) (EASP, 2012), developed at EASP, allows the analysis of the geographical distribution and time-related evolution of mortality in all Andalusian municipalities since 1981. This GIS system gives results for the main causes of death, by age group and gender. Using this approach, Ocaña-Riola and Mayoral-Cortes (2010) showed that mortality trends for the majority of Andalusian municipalities seem to converge with Spanish rates, and significant male and female mortality excesses for the period 1981–2006 in western Andalusia (including the two industrialized sites under study) were only recorded in the over-65 age groups. Due to the ecological design, it is difficult to account for explanatory factors for these differences. Social inequalities, access to the health care system, differences in lifestyles and unregistered migratory flows, together with differences in environmental exposure, might be interacting to provide such excess mortality. Given that death is the end-point of a past health record, mortality indicators should be complemented in future research by other sources of information and individual-based studies that provide an overall dynamic view of the population's health status.

According to updated data (year 2008) from AIMA, a significant excess of mortality for men over 65 years of age in the Huelva site was related mainly to ischaemic and cardiovascular diseases, and some cancers (lung and bladder); while in the case of women over 65 years of age, a significant excess of mortality was related to ischaemic and cardiovascular diseases, Alzheimer's disease and some cancers (breast and bladder). This pattern seems to be similar to the one observed in the general population from non-industrialized sites in Spain and Europe.

One of the key elements for better understanding the impact that industrial activities might have on human health is linked to a better characterization of human exposure assessment. In this sense, a biomonitoring study of urinary levels of arsenic and other heavy metals (Cd, Cr, Cu and Ni) in adults (n=857) and children (n=227) living in the industrialized area of the *Ria of Huelva* was conducted between 2003 and 2004 (Aguilera et al., 2008, 2010). These results were compared with a reference population living in other (less industrialized) areas of Andalusia, and the determinants of the variability in the concentration of metals were assessed. Arsenic levels were significantly higher in the adult population from Huelva than in populations in other Andalusian cities, whereas cadmium and nickel levels were significantly lower. Among the children from Huelva, no significant differences were found in the reference population for all metals, with the exception of cadmium levels, which were significantly higher in the reference group. Despite these differences, levels of the five metal ions in both groups were generally within the range of values reported by other European biomonitoring studies. Among the population of *Ria of Huelva*, the main determinants of the interindividual variation in urinary metals were age, sex, area of residence (children only), lifestyle (adults only), and frequency of intake of certain food items (mainly fish and shellfish).

Despite the efforts invested by public administrations to assess environmental and health impacts and despite existing research findings not identifying a stronger relationship between proximity of residence to industrialized sites and the status of health of the population, public perception of the threat for bad air quality was significantly higher in people living near Algeciras Bay and *Ria of Huelva* than in other urban areas in Andalusia (Martín-Olmedo et al., 2011).

Future actions recommended

The following future actions are recommended:

- update the environmental diagnosis and improve the characterization of the exposure route;
- set up new epidemiological studies on an individual basis that include better monitoring of environmental exposure and other factors linked to social position, occupational activity, diet and lifestyle;
- assess the quality of data on municipality of residence and cause of death (migratory flows);
- set up occupational studies; and
- improve cooperation between environmental and health professionals, risk communication, and capacity building.

References

Aguilera I et al. (2008). Biomonitoring of urinary metals in a population living in the vicinity of industrial sources: a comparison with the general population of Andalusia, Spain. *Science of the Total Environment*, 407(1):669–678.

Aguilera I et al. (2010). Urinary levels of arsenic and heavy metals in children and adolescents living in the industrialised area of Ria of Huelva (SW Spain). *Environment International*, 36(6):563–569.

Blanes Llorens AB (2007). *La mortalidad en la España del siglo XX: análisis demográfico y territorial [Mortality in twentieth-century Spain: demographic and territorial analysis]* [doctoral thesis]. Barcelona, Universitat Autònoma de Barcelona (http://sociales.cchs.csic.es/jperez/PDFs/Blanes2007.pdf, accessed 20 December 2012; in Spanish).

Bordajandi LR et al. (2004). Survey of persistent organochlorine contaminants (PCBs, PCDD/Fs, and PAHs), heavy metals (Cu, Cd, Zn, Pb, and Hg), and arsenic in food samples from Huelva (Spain): levels and health implications. *Journal of Agricutural and Food Chemistry*, 52:992–1001.

EASP (2008). *Evaluación de la exposición a BTEX en la población del Campo de Gibraltar [Evaluation of exposure to BTEX in the town of Campo de Gibraltar]*. Granada, Consejeria de Salud-Junta de Andalucía (http://www.osman.es/contenido/profesionales/BTEX.pdf, accessed 20 December 2012; in Spanish).

EASP (2012). Interactive Mortality Atlas for Andalusia (AIMA) [web site]. Granada, Junta de Andalucia (http://www.demap.es/en/products/aima, accessed 20 December 2012).

Martín-Olmedo P et al. (2011). Differences in air quality perception pattern between industrialized and urban areas in southern Spain, and its relationship to modeled ambient nitrogen dioxide. *23rd ISEE Congress, Barcelona, 13–16 September 2011* (Paper 0114).

Moreno T et al. (2006). Variations in atmospheric PM trace metal content in Spanish towns: illustrating the chemical complexity of the inorganic urban aerosol cocktail. *Atmospheric Environment*, 40(35):6791–6803.

Ocaña-Riola R, Mayoral-Cortes JM (2010). Spatio-temporal trends of mortality in small areas of Southern Spain. *BMC Public Health*, 10:26 (http://www.biomedcentral.com/1471-2458/10/26, accessed 20 December2012).

Pandolfi M et al. (2011). Source apportionment of PM10 and PM2.5 at multiple sites in the straight of Gibraltar by PMF: impact of shipping emissions. *Environmental Science and Pollution Research*, 18:260–269.

Pérez-López R, Alvarez-Valero AM, Nieto JM (2007). Changes in mobility of toxic elements during the production of phosphoric acid in the fertilizer industry of Huelva (SW-Spain) and environmental impact of phosphogypsum wastes. *Journal of Hazardous Materials*, 148:745–750.

Querol X et al. (2004). Speciation and origin of PM10 and PM2.5 in Spain. *Journal of Aerosol Science*, 35:1151–1172.

Ramos Martin JL (2005). *Diagnóstico de la calidad ambiental de la Ria de Huelva [Diagnosis of the environmental quality of the Huelva Estuary]*. Seville, Consejería de Medio Ambiente de la Junta de Andalucía y Consejo Superior de Investigaciones Científicas (in Spanish).

Ramos Martin JL (2006). *Diagnóstico de la situación ambiental del entorno del Campo de Gibraltar [Diagnosis of the environmental status of the environdmetal field of Campo de Gibraltar]*. Seville, Consejería de Medio Ambiente de la Junta de Andalucía y Consejo Superior de Investigaciones Científicas (http://www.eez.csic.es/files/InfoFinalAmpGibraltar.pdf, accessed 20 December 2012; in Spanish).

Sainz A, Grande JA, de la Torre ML (2004). Characterization of heavy metal discharge into the Ria of Huelva. *Environment International*, 30:557–566.

Sánchez de la Campa AM et al. (2011). Size distribution and chemical composition of metalliferous stack emissions in the San Roque petroleum refinery complex, southern Spain. *Journal of Hazardous Materials*, 190 (1–3): 713–722.

1.5. Contaminated sites in Slovenia – a case of a lead-contaminated area[2]

Peter Otorepec and Irena Jeraj

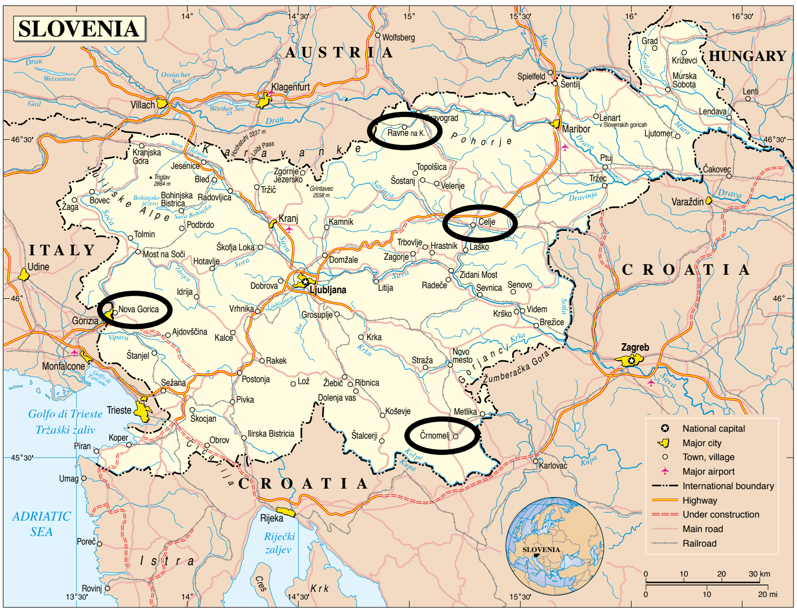
Institute of Public Health, Slovenia

Introduction

There are a number of contamined sites in Slovenia. Most of them are burdens of long-lasting production or mining, which was stopped years ago or for which production is now small.

Contaminated sites are indeed the burden of past times. The best known sites in the country are the Polychlorinated Biphenyls (PCBs)-contaminated site near the border with Croatia, an asbestos-fibre contaminated area near the border with Italy and a lead-contaminated site in the north of the country (see Fig.1.5.1).

Fig. 1.5.1. Map of the best known contaminated sites in Slovenia



Source: National Institute of Public Health of Slovenia, 2011. Based on United Nations map "Slovenia" no. 4134 Rev. 3 June 2004. Reproduced with permission..

2 This chapter is adopted with permission from Janet E et al. (2011). *Blood lead level in Children of Mezica Valley*. Ravne na Koroškem, Zavod za zdravstveno varstvo Ravne na Koroškem [Regional Institute of Public Health Ravne na Koroškem].

There is a lead-contaminated site – Zg Mežiška dolina (near the border with Austria). It has a long tradition of lead mining – more than 500 years of mining. The lead ore has also been processed in the same area, so the contamination is not only from the mine but is also from the smelter and battery-production plant.

The area is well defined geographically. It is in a secluded valley with evenly distributed pollution. The main burden of pollution is in the upper layer of soil and, consequently, air pollution, because of suspension lead particles. Food contamination and indoor air pollution (due to dust accumulated indoors) are the main sources of exposure to lead.

The intake of lead is through air and food and occurs mainly through the respiratory tract, alimentary tract and skin.

About 8000 people live in the area, and children are the most vulnerable population. For these children, the most dangerous impact of lead is on the development of the brain – cognitive impairment. Even low concentrations of lead in blood (above 100 µg/l and even below) can lead to mental impairment, especially in children below the age of six years. The latest study results show that there is already a noticeable impact on health at levels as low as 25 µg/l (O'Grady, 2001); therefore, the action level to reduce exposure is going down in most countries to levels as low as 50 µg/l (Jakubowski, 2006).

In children, the absorption of lead from the digestive system is much higher than it is in the adult population.

Lead accumulates in the upper level of soil. It is mostly in dust and in food, and the main intake is through air and food.

Results

To assess the level of exposure among the most vulnerable population, a biomonitoring programme on lead level in blood was started in children in the year 2003. The most reliable measurement of acute intake of lead is the blood lead level. It shows the intake of lead 1–2 months before measurement.

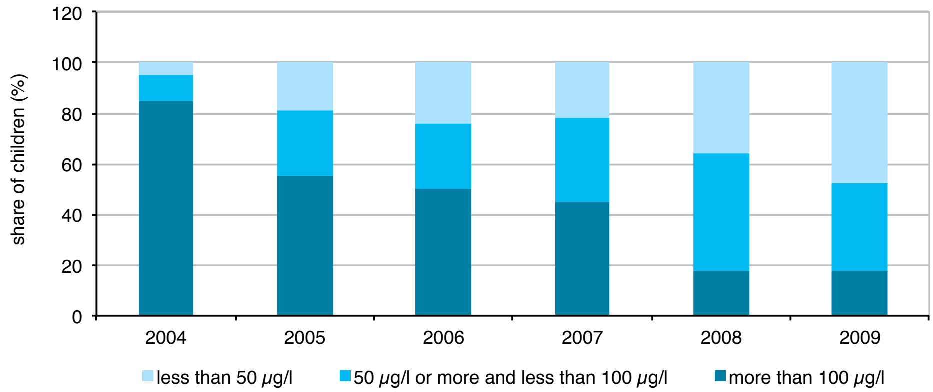
The first results revealed quite high levels of lead in the blood of children examined. The percentage of blood samples of children 3 years of age with different levels of lead in blood (period 2004–2009) are shown in Fig. 1.5.2.

In 2004, the level of lead in blood was above 100 µg/l in 85% of all samples, but in 2009 it was above 100 µg/l in 18% of all samples.

The percentage of blood samples of children 3 years of age with different levels of lead in blood are shown in Fig. 1.5.3, which compares two areas of the same valley for the year 2008.

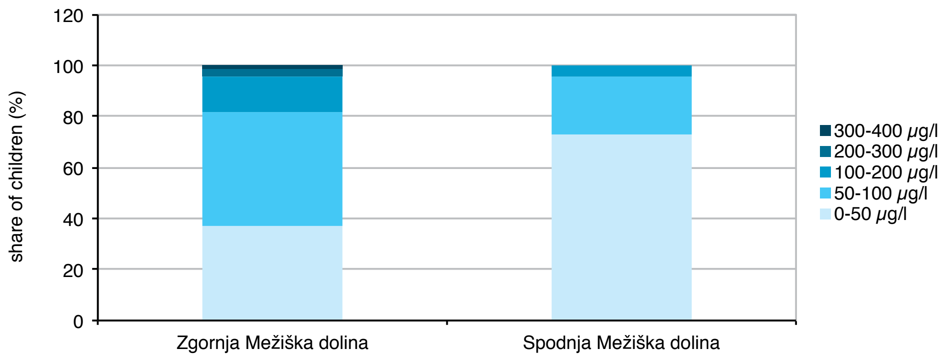
Fig. 1.5.4 shows the average level of lead in blood in children by age (year 2008).

Fig. 1.5.2. Percentage of children with different levels of lead in blood, 2004–2009



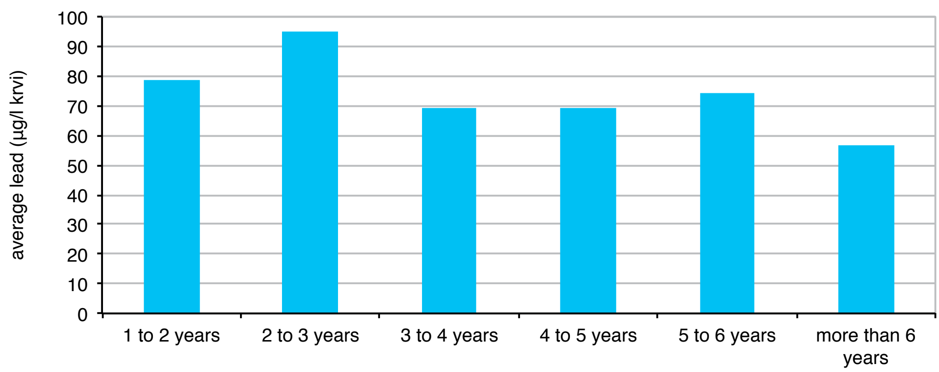
Source: Evgen Janet and Peter Otorepec. Reproduced with permission.

Fig. 1.5.3. Comparison of blood lead levels of 3-year-olds



Source: Evgen Janet and Peter Otorepec. Reproduced with permission.

Fig. 1.5.4. Comparison of level of lead in blood of children by age

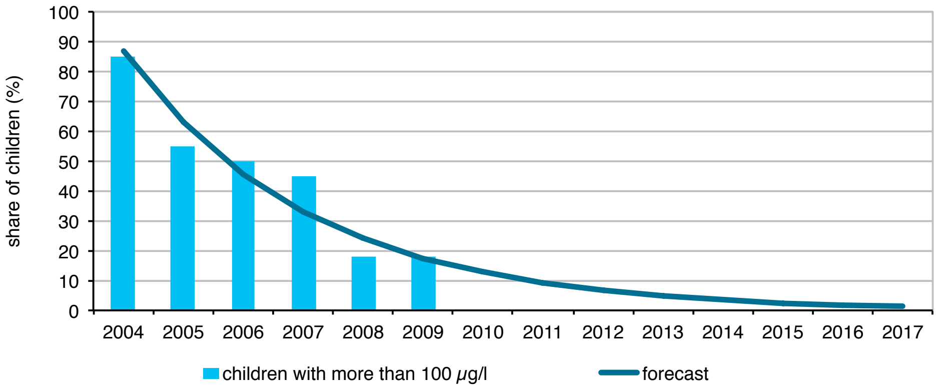


Source: Evgen Janet and Peter Otorepec. Reproduced with permission.

The highest average level of lead in blood was in a group of children 3 years of age (maximum level of lead in blood was 335 µg/l), followed by the children 2 years of age (maximum level of lead in blood was 256 µg/l).

Fig. 1.5.5 shows the predicted percentage of children with blood lead levels above 100 µg/l for the period 2012–2017 (Ivartnik & Eržen, 2010, Cornelis et al., 2006).

Fig. 1.5.5. Predicted percentage of children with blood lead levels above 100 µg/l, 2012–2017



Source: Evgen Janet and Peter Otorepec. Reproduced with permission.

Conclusion

The area of contamination described is pretty small in terms of number of people affected. It is a site with a long history of pollution. The environmental pollution data obtained were not too appalling (slightly above the maximum allowed levels) and did not prove to be very useful. Also, the health data did not reveal any appalling pathology (mortality or cancer cases). Therefore, biomonitoring seems to be good way to assess exposure and possible health impacts. The assessment of the burden of exposure with biomonitoring revealed a modest level of exposure in the most vulnerable group (children), in all age subgroups.

The highest level of lead in blood depends mostly on personal hygiene and on the intake of local food and the hygiene of living conditions. The main risk factor for lead intake proved to be house dust and contaminated soil in the vicinity of the residential area.

The National Programme on Remediation of the Area was adopted by the Government at the end of 2007. It has been focusing on raising awareness about the harmfulness of lead and giving the population good information about pollution. What seems to be of major importance is the hygiene of the inner and outer environment and proper nutrition (intake of vitamins C and, D, the minerals Fe and Ca, and proteins).

A number of activities have been undertaken to reduce the environmental burden of lead. Among them are replacing the upper layer of soil with clean soil, planting the soil with grass and low vegetation, covering gravel roads with asphalt or concrete, covering eroded areas with soil and vegetation, cleaning of ceilings, and cleaning and repainting the outer walls of buildings (Von Lindern et al., 2003).

The aim is to completely eliminate the possibility of a harmful burden from lead by the year 2022.

References

Cornelis C et al. (2006). Use of the IEUBK model for determination of exposure routes in view of site remediation. *Human and Ecological Risk Assessment*, 12:963–982.

Ivartnik M, Eržen I (2010). Uporaba modela IEUBK za napoved vsebnosti svinca v krvi otrok pri raziskavah in sanaciji okolja v Zgornji Mežiški dolini [Using the IEUBK model to predict levels of lead in the blood of children in research and environmental rehabilitation in the Upper Mežiška Valley. *Zdravstveno Varstvo [Slovenian Journalof Public Health]*, 49:76–85 (in Slovenian).

Jakubowski M (2006). *Development of a coherent approach to human biomonitoring in Europe. D 6.1–6.3: utility and sensitivity of biomarkers*. Brussels, Expert Team to Support BIOmonitoring in Europe (http://www.eu-humanbiomonitoring.org/doc/esbio_wp6.1_6.3.pdf, accessed 21 December 2012).

O'Grady K (2001). Lead Environmental Awareness and Detection [web site]. Pembroke, Ontario, Canada (www.webhart.net/lead, web site expired).

Von Lindern I et al. (2003). Assessing remedial effectiveness through the blood lead:soil/dust lead relationship at the Bunker Hill Superfund Site in the Silver Valley of Idaho. *Science of the Total Environment*, 303:139–170.

1.6. Air pollution effects from large power plants in northern Greece

Xanthi Pedeli, Antonis Analitis and Klea Katsouyanni

Department of Hygiene, Epidemiology and Medical Statistics, Medical School, University of Athens, Greece

Background and aim

Eordaia is a municipality in the Kozani Peripheral Unit, located in the north-western part of Greece, with a population of 46 540 (2001 census) over an area of 708 km^2. In the 1950s, the first power plant became operational, using as fuel the large local deposits of lignite. Today, five big power generation units are operational in Eordaia, comprising the largest power plant complex in Greece and providing about 70% of the country's electric power needs. Due to the use of lignite, this power plant complex is one of the largest polluters in Europe. Annually, 55 million tonnes of lignite are mined in the greater area and 108 kg of dust are emitted. We investigated the health effects of air pollutants (PM_{10} and NO_2), emitted mainly by the power plants, on the population of the area.

Data and methods

Daily counts of the total natural and cause-specific number of deaths, by age group for the years 1998–2001 (1461 days) for Eordaia, were obtained from the Hellenic Statistical Authority. Due to the small number of daily deaths (maximum 8 per day), only the total number of natural deaths for all age groups was considered in the analysis. Daily series of mean temperature and relative humidity for the same period were also available from the Hellenic National Meteorological Service, from the station located in the city of Kozani. Daily concentrations of PM_{10} and NO_2 from three fixed monitoring sites were also available for the study period. Based on completeness criteria (less than 25% missing annually and less than 15% missing over the study period), the series from one site was excluded. The remaining missing values were filled in using the formula developed in the APHEA project.

For the analysis, generalized additive models (GAMs) were used, assuming a Poisson distribution for the outcome variable (daily number of deaths). The average of same and previous day concentrations (lag 0 and lag 1) of PM_{10} and NO_2, alternatively, were the main exposure variables. Potential confounders were also taken into account: temperature (piecewise linear terms for lags 0–3), relative humidity (linear term), day of the week (set of dummy variables) and seasonal and long-term trends (smoothed term). Sensitivity analyses tested the robustness of the results, using various smoothing functions and/or number of degrees of freedom.

Results

PM_{10} concentrations ranged from 2.4 µg/m^3 to 982.6 µg/m^3 in one site (mean 72.9 µg/m^3) and from about 0.0 µg/m^3 to 209.00 µg/m^3 in the other site (mean 46.5 µg/m^3) while NO_2 mean concentrations were 48.4 µg/m^3 and 22.2 µg/m^3, respectively. The estimated percent increase (95% CI) in the total daily number of deaths for an increase of 10 µg/m^3 in PM_{10} concentration was 0.79% (-1.16%, 2.77%). This estimated increase ranged from 0.72% to 1.29% in the sensitivity analyses. An increase of 10 µg/m^3 in NO_2 concentration was associated with a 1.43% (-7.96%, 11.78%) increase in the total daily number of deaths and ranged from 0.80% to 1.72% in the sensitivity analyses.

Conclusions

Industrial activity causes high concentrations of air pollutants. Although not statistically significant, our findings indicate increased mortality in the area close to power plants. Measures to reduce pollution and protect public health should be adopted.

References

Analitis A et al. (2006). Short-term effects of ambient particles on cardiovascular and respiratory mortality, *Epidemiology*, 17(2):230–233.

Anderson RH et al. (1999). Recommendations for the monitoring of short-term health effects of air pollution: lessons from the APHEA Multicentre European Study. *Zentralblatt für Hygiene und Umweltmedizin*, 202(6):471–488.

Katsouyanni K et al. (2001). Confounding and effect modification in the short-term effects of ambient particles on total mortality: results from 29 European cities within the APHEA2 project. *Epidemiology*, 12(5):521–531.

Triantafyllou AG et al. (2002). Respirable particulate matter at an urban and nearby industrial location: concentrations and variability and synoptic weather conditions during high pollution episodes. *Journal of the Air & Waste Management Association*, 52(3):287–296.

1.7. Epidemiologic studies in the Sicilian polluted sites of Biancavilla and Priolo

Pietro Comba, Caterina Bruno, Marco De Santis, Lucia Fazzo and Amerigo Zona

Department of Environmental and Primary Prevention, National Institute of Health, Italy

Foreword

The purpose of this presentation is to describe two specific projects concerning the polluted Sicilian sites of Biancavilla and Priolo. The rationale and methods of epidemiological studies in polluted sites conducted by Istituto Superiore di Sanità have been presented in previous papers, about the SENTIERI Project (Pirastu et al., 2010, 2011).

Biancavilla

A significant increase in mortality from malignant pleural neoplasm, based on four observed cases, was originally detected in the municipality of Biancavilla − located in eastern Sicily at the slopes of Etna Volcano − within the frame of the permanent activity of surveillance of mesothelioma in Italy, conducted by Istituto Superiore di Sanità (ISS, Italian National Institute of Health) (Di Paola et al., 1996).

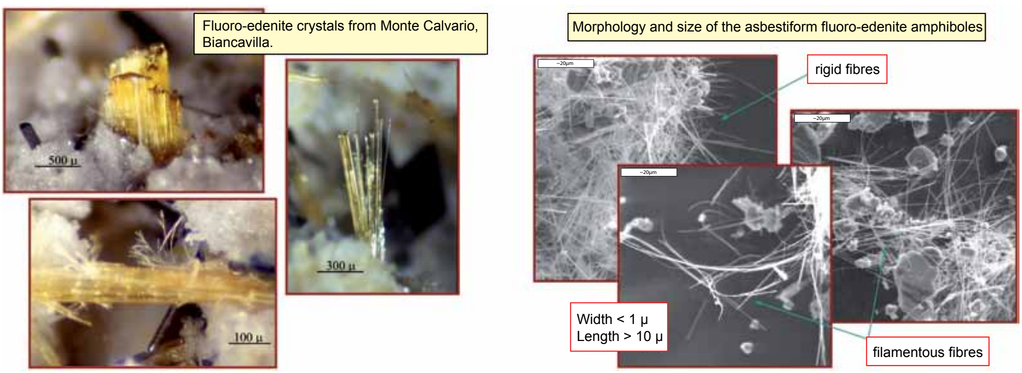
A temporal extension of the study showed the occurrence of a few more cases, thus corroborating the initial observation. The peculiarity of this municipality was the absence of asbestos-related industrial activities.

While further checks on case definition took place, taking into account hospital and pathology records in addition to death certificates, the occurrence of an asbestiform fibre was detected in a quarry used in the local building industry. The same fibre was detected in samples of sand and plaster produced from the quarry and in a sample of lung from a patient who died from mesothelioma and was never occupationally exposed to asbestos (Paoletti et al., 2000).

Based on this evidence, the quarry's activity was terminated and environmental remediation activities took place in Biancavilla; the latter was eventually recognized as a site of national interest for environmental clean-up.

Meanwhile, the fibre was identified as a new mineral species and was named fluoro-edenite by the International Mineralogical Association Commission on New Minerals and Mineral Names (Gianfagna & Oberti, 2001). Fluoro-edenite (see Fig. 1.7.1) was shown to induce mesothelioma in rats (Soffritti et al., 2004) and to interfere with cells in culture through mechanisms similar to those typical of asbestos fibres (Travaglione et al., 2006). Further studies performed by ISS in cooperation with the University of Florence (Biggeri et al., 2004), the Regional Epidemiological Observatory of Sicily (Cernigliaro et al., 2006) and Ragusa Cancer Registry (Bruno et al., 2007) confirmed the occurrence of high mesothelioma incidence and high mortality from acute and chronic lung disease.

Fig. 1.7.1. Fluoro-edenite



Source: Donelli G, Marsili D, Comba P (2012). *Le problematiche scientifico-sanitarie correlate all'amianto: l'attività dell'Istituto Superiore di Sanità negli anni 1980-2012 [Abestos-related scientific and health issues: activities of the Istituto Superiore di Sanità in the years 1980-2012].* Rome, Istituto Superiore di Sanità (http://www.iss.it/binary/publ/cont/quaderno_x_web_leggero.pdf, accessed 21 December 2012). Reproduced with permission.

A study of the spatial distribution of residence of mesothelioma cases in the Biancavilla area is currently in progress.

Research priorities include improvements in exposure assessment and ascertainment of occurrence of environmentally-induced lung fibrosis. Risk perception should also be investigated, with the aim of fostering community participation. Fluoro-edenite fibres were detected in the sputum of bronchitic subjects (Putzu et al., 2006) and in the lungs of locally bred sheep (De Nardo et al., 2004).

Priolo

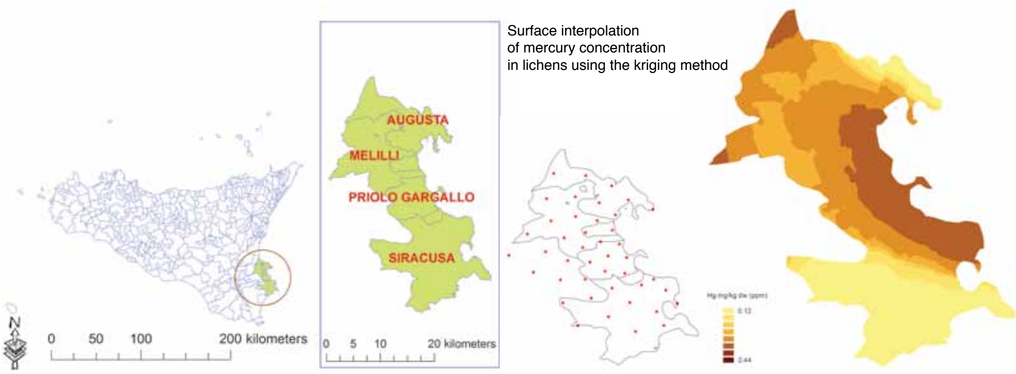
The polluted site in Priolo, located in south-eastern Sicily, includes four municipalities, among which is Syracuse. Priolo is the location of one of Italy's major petrochemical facilities; the industrial area also includes naval shipyards and a former asbestos-cement plant. Priolo is the centre of one of two Sicilian mesothelioma clusters (the other being Palermo; for details, see Fazzo et al., 2012).

The purpose of the study of this contaminated area is to investigate the spatial distribution of cancer incidence, the prevalence of malformations at birth and asbestos-related diseases, taking into account the spatial distribution of environmental monitoring and biomonitoring data.

The project is realized by ISS in cooperation with the Syracuse Health Authority (Dr Anselmo Madeddu), the Sicilian Region Mesothelioma Register (Dr Rosario Tumino) and the Palermo and Pisa national research councils (Dr Fabio Cibella and Dr Fabrizio Bianchi) and Syracuse Province Environmental Protection Agency (Dr Gaetano Valastro) The project is funded by the Ministry of Environment and by the Authority for Environmental Clean-up in Sicily.

The first stage of the project focused on collecting environmental monitoring and biomonitoring data, in order to implement a GIS database where epidemiological data will also be collected. In order to create a suitable statistical model, lichen data (see Fig. 1.7.2) will be integrated with atmospheric SO_2 concentration data (used as a marker of industrial emissions), taking into account the main industrial sources and meteorological data.

Fig. 1.7.2. Lichen data



Source: Authors. Reproduced with permission.

Meanwhile, information about 16 000 cases of neoplastic disorders – ascertained by Syracuse Cancer Registry, 1999–2006, in the whole Syracuse Province, half of which is resident in the four municipalities included in the polluted Priolo site – has been made available by the Cancer Registry and will soon be mapped as well. Besides carrying on spatial analyses, the feasibility of analytical epidemiological studies based on estimates of food-chain and water consumption at the individual level will be evaluated in this study.

Concluding remarks

The Biancavilla and Priolo areas are different in terms of environmental exposures and health impact; adopted methods and stage of development of the studies also differ, but they both point to the need to carry out field studies in polluted Sicilian sites. Conducting such field studies complies with the final recommendations of the SENTIERI Project and is required in order to inform the clean-up process with health-related priorities. The integration of this experience in a European perspective is of the utmost importance**.**

References

Biggeri A et al. (2004). Mortality from chronic obstructive pulmonary disease and pleural mesothelioma in an area contaminated by natural fiber (fluoro-edenite). *Scandinavian Journal of Work, Environment and Health*, 30:249–252.

Bruno C et al. (2007). An estimate of pleural mesothelioma incidence in Biancavilla, Sicily, Italy, 1998–2004. *European Journal of Oncology*, 12:183–188.

Cernigliaro A et al. (2006). Mortalità e ricoveri ospedalieri nella popolazione di Biancavilla (CT) con esposizione cronica a fibre naturali [Mortality and hospital discharges in the population of Biancavilla (Sicily) contaminated by natural fibres]. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 30(4–5):227–231 (in Italian and English).

De Nardo P et al. (2004). Pulmonary fibre burden in sheep living in the Biancavilla area (Sicily): preliminary results. *Science of the Total Environment*, 325:51–58.

Di Paola M et al. (1996). *La mortalità per tumore maligno della pleura in Italia negli anni 1988–1992 [The mortality rate for cancer of the pleura in Italy in the years 1988–1992].* Rome, Istituto Superiore di Sanità (Rapporti ISTISAN 96/40; http://www.iss.it/binary/publ/cont/Rapp.%20Ist.%2096-40%20Compr3.1213018385.pdf, accessed 21 December 2012; in Italian).

Fazzo L et al. (2012). Pleural mesothelioma mortality and asbestos exposure mapping in Italy. *American Journal of Industrial Medicine*, 55:11–24.

Gianfagna A, Oberti R (2001). Fluoro-edenite from Biancavilla (Catania, Sicily, Italy): crystal chemistry of a new amphibole end-member. *American Mineralogist*, 86:1489–1493.

Paoletti L et al. (2000). Unusually high incidence of malignant pleural mesothelioma in a town of Eastern Sicily: an epidemiological and environmental study. *Archives of Environmental Health*, 55(6): 392–398.

Pirastu R et al. (2010). Studio epidemiologico Nazionale dei Territori e degli Insediamenti Esposti a Rischio da Inquinamento. Valutazione dell'evidenza epidemiologica [SENTIERI Project. Epidemiological study in contaminated sites in Italy: evaluation of the epidemiological evidence]. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 34(5–6 Suppl. 3):1–96 (http://www.epiprev.it/materiali/2010/EP5-6_2010_suppl3.pdf, accessed 21 December 2012; in Italian and English).

Pirastu R et al. (2011). SENTIERI. Studio epidemiologico Nazionale dei Territori e degli Insediamenti Esposti a Rischio da Inquinamento: Risultati [SENTIERI Project. National epidemiological study of the territories and settlements exposed to the risk of pollution: results]. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 35(5–6 Suppl. 4):1–204 (http://www.epiprev.it/pubblicazione/epidemiol-prev-2011-35-5-6-suppl-4, accessed 21 December 2012; in Italian and English).

Putzu MG et al. (2006). Fluoro-edenitic fibres in the sputum of subjects from Biancavilla (Sicily): a pilot study. *Environmental Health*, 5:20 (http://www.ehjournal.net/content/5/1/20, accessed 21 December 2012).

Soffritti M et al. (2004). First experimental evidence of peritoneal and pleural mesotheliomas induced by fluoro-edenite fibres present in Etnean volcanic material from Biancavilla (Sicily, Italy). *European Journal of Oncology*, 9:169–175.

Travaglione S et al. (2006). Multinucleation and pro-inflammatory cytokine release promoted by fibrous fluoro-edenite in lung epithelial A549 cells. *Toxicology in Vitro*, 20:841–850.

1.8. Health impact of contaminated sites on children

Ivano Iavarone
Department of Environment and Primary Prevention, National Institute of Health, Italy

Protecting children from involuntary exposure to environmental pollutants is a major public health priority. In the final Declaration, ministers of health and environment of the 53 Member States of the European Region of WHO (WHO Regional Office for Europe, 2010) stated that they will intensify national efforts to implement the commitments set out in the Children's Environment and Health Action Plan for Europe (CEHAPE).

Compared with adults, children display a higher susceptibility to environmental agents. There are several reasons for this characteristic, and they can be grouped in two main categories: (a) factors that explain higher levels of exposure in infants than in adults under identical environmental conditions; and (b) physiological and development-related aspects in childhood associated with higher vulnerability to the toxic effects of environmental pollutants. In Environmental Health Criteria 237 (WHO, 2007, 2011), which examines principles for evaluating health risks in children associated with exposure to chemicals, both these groups of factors are described and analysed in depth.

In this document, we deem it helpful to point out some of the main aspects. Children have a much larger surface area relative to body weight than adults. This implies possible higher dermal absorption of contaminants and more rapid heat loss, which requires a higher rate of metabolism. Moreover, children also need extra metabolic energy to fuel growth and development. The higher basal metabolic rate and energy requirements in children mean that both oxygen and food intakes are greater than those in adults, per kilogram of body weight. The higher breathing and food consumption rates can result in higher exposures (inhalation and ingestion) to environmental contaminants in air and food. As an example, the volume of air that passes through the lungs of a child is twice that of an adult per unit of body weight, so the child can take a larger amount of gaseous and particulate air pollutants than an adult can. Moreover, the well known hand-to-mouth behaviour of children exposes them to contaminated soil.

As to the second group of aspects, it should be emphasized that the development of respiratory, reproductive, endocrine, gastrointestinal, and nervous systems reach maturity during the postnatal period, and windows of susceptibility in children are broad, extending from the preconception period to the end of adolescence; during puberty, exposure to environmental endocrine disruptors (pesticides, phthalates) can lead to serious reproductive and thyroid damage.

The lengthy period of brain development and the great number of neural processes available in this phase of development contribute to the susceptibility of the nervous system to toxicants. Prenatal and postnatal exposure to environmental chemicals, such as methylmercury, lead or certain pesticides, may produce, for instance, cellular or molecular changes that are expressed as neurobehavioural (functional) deficits or as increased susceptibility to neurodegenerative diseases later in life. Compared with the adult respiratory system, neonates have fewer alveoli and a faster breathing rate. The number of alveoli in the lungs of infants shows a rapid rise during the first year and a gradual increase up to age 12, when the number of alveoli are nine times higher than at birth. Due to these characteristics, children may be more susceptible to the effects of respiratory toxicants (exacerbation of asthma from exposure to particulates in the air or decreased lung function due to chronic ozone exposure) than adults.

In 2008, in the United States, approximately 2% of children lived within a mile of a Superfund site listed on the National Priorities List (NPL) that had not been cleaned up (EPA, 2011). In the European Region, the percentage of children living close to a contaminated site is expected to be large, since soil contamination requiring clean-up occurs in approximately 250 000 sites in the European Region, as estimated by the European Environment Agency through the Eionet priority data flows on contaminated sites (EEA, 2012).

In Italy, approximately 5.5 million people reside in 44 Italian polluted sites (IPSs) of national concern for environmental remediation (60% are in the most deprived groups), and a million children (< 20 years) live in these sites. The SENTIERI Project (Pirastu et al., 2010, 2011) investigated mortality of residents in the 44 IPSs. Crude and deprivation adjusted standardized mortality ratios (SMRs) were calculated (1995–2002, regional reference) for 63 causes.

The assessment of the health profile of children living in these areas is in progress. Selected causes of death were analysed for age classes 0–1 and 0–19 years. In eight IPSs (20%), increased risks for all causes and for perinatal conditions were observed among children 0–1 year. In four sites, where a steel plant and petrochemical/refinery/chemical industries are present, increased mortality for all causes was observed also among children 0–19 years of age. This is the first study focusing on children's health in IPSs. Despite the many limitations of a health indicator such as mortality, the increased mortality of children living in IPSs is a sentinel event, pointing out the need for thorough investigations. In line with this aim, we are extending the study to cancer incidence and congenital anomalies, to provide a more comprehensive picture of the health impact of contaminated sites on children and adolescents (Comba et al., 2011; Bianchi, 2011).

Social inequalities are rarely addressed in policy- and decision-making processes of relevance to children's environment and health. This low level of attention adds to inequalities in exposure and related health risks of children living in contaminated sites, since more deprived populations reside in these areas.

The establishment of a European network on environmental health in contaminated sites – focused also on children's health – would be a desirable goal to be achieved by a multinational collaborative group coordinated by WHO.

References

Bianchi F (2011). The study of congenital anomalies in contaminated sites of interest for environmental remediation. In: Pirastu R et al. (2011). SENTIERI Project. National epidemiological study of the territories and settlements exposed to the risk of pollution: results. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 35(5–6 Suppl. 4):199–204 (in Italian and English).

Comba P et al. (2011). Scientific collaboration between the Italian National Institute of Health and the Italian Association of Cancer Registries for the study of cancer incidence in polluted Italian sites. In: Pirastu R et al. (2011). SENTIERI Project. National epidemiological study of the territories and settlements exposed to the risk of pollution: results. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 35(5–6 Suppl. 4):192–198 (in Italian and English).

EEA (2012). European Environment Agency [web site]. Copenhagen, European Environment Agency (http://www.eea.europa.eu/, accessed 6 January 6, 2013).

EPA (2011). America's Children and the Environment [web site]. Washington, DC, United States Environmental Protection Agency (www.epa.gov/envirohealth/children, accessed 6 January 2013).

Pirastu R et al. (2010). SENTIERI Project. Epidemiological study in contaminated sites in Italy: evaluation of the epidemiological evidence. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 34(5–6 Suppl. 3):1–96 (in Italian and English).

Pirastu R et al. (2011). SENTIERI. SENTIERI Project. National epidemiological study of the territories and settlements exposed to the risk of pollution: results. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 35(5–6 Suppl. 4):1–204 (in Italian and English).

WHO (2007). *Principles for evaluating health risks in children associated with exposure to chemicals*. Geneva, World Health Organization (Environmental Health Criteria 237; http://www.who.int/ipcs/publications/ehc/ehc237.pdf, accessed 21 December 2012).

WHO (2011). *Summary of principles for evaluating health risks in children associated with exposure to chemicals*. Geneva, World Health Organization (http://www.who.int/ceh/health_risk_children.pdf, accessed 21 December 2012).

WHO Regional Office for Europe (2010). Protecting children's health in a changing environment [web page]. Copenhagen, WHO Regional Office for Europe (http://www.euro.who.int/en/what-we-do/event/fifth-ministerial-conference-on-environment-and-health, accessed 6 January 2013).

1.9. Exposure assessment of people living in small area near incinerators

Andrea Ranzi

Environmental Health Reference Centre, Regional Agency for Environmental Prevention of Emilia-Romagna, Italy

Introduction

In the Emilia-Romagna Region (northern Italy, about 4.5 million inhabitants), eight municipal solid waste incinerators (MSWI) operate in the territory. In 2007 The Regional Health Service and the Regional Agency for Environmental Prevention (ARPA) started a multisite project (MONITER Project) that focused its activity on the environmental and health impact of these eight MSWI (Arpa Emilia-Romagna, 2012).

The whole project consists of seven work packages. Within epidemiological activities, a chain-work between three different work packages was developed, in order to construct, characterize and analyse two separate populations of people living in the study area. The study areas were defined as the 4-km zones around plants. The populations investigated were:

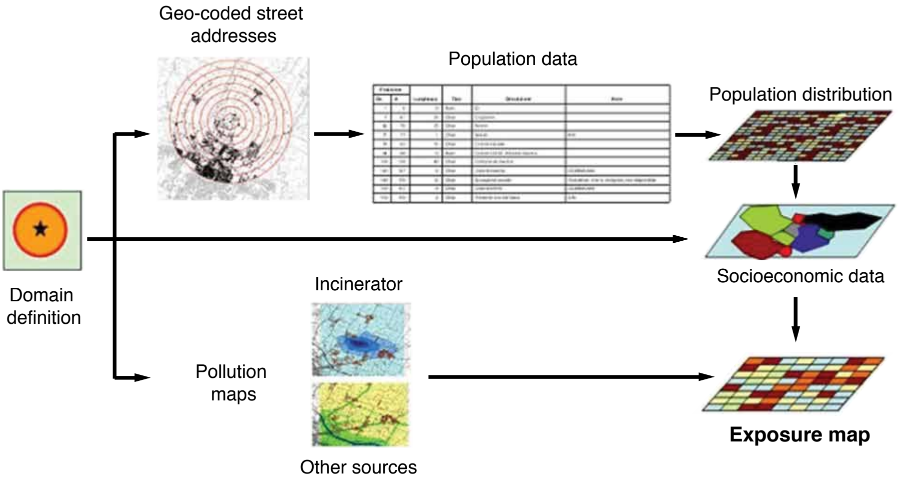
- newborn: all resident newborn babies within a study area throughout 2003–2006; and
- cohort of residents: all people living or having lived (for at least 6 months) in the study area of each incinerator, for the study period (1991–2006).

The flowchart (Fig. 1.9.1) illustrates the framework of the activity developed for each site, for the characterization of each population.

Newborn population

We collected (from registry offices) data on all newborn residents in the study areas for the period 2003–2006 (Ranzi et al., 2009). Pollution maps for the incinerators were provided by Atmospheric Dispersion Modelling System (ADMS) outputs for PM_{10}. Simulations of pollutant dispersion were also performed for all other sources in the areas (traffic, heating, industries, and agriculture). Exposure estimates at home locations were made using a geographic information system (GIS).

Fig. 1.9.1. Flowchart of framework of activity developed for each site



Source: Author. Reproduced with permission.

A total of 13 251 births were included in the eight areas. We considered yearly simulation data; and for each incinerator, we made five yearly simulations (2002–2006). These models considered monthly activity of the plants within the time period considered. By means of GIS analyses, we constructed an individual-based database with five yearly concentration values for each incinerator, and average concentration values for the other sources. We calculated a weighted exposure value for each first trimester and 9-month pregnancy period.To take into account the real monthly activity of each plant, we adopted a formula to calculate the mean exposure value (Exp), as follows:

$$Exp = \frac{\sum_{i=1}^{n1} Fi * C_1(x,y) + \sum_{j=n1+1}^{9} Fj * C_2(x,y)}{9}$$

where
(x, y) = geocoded residence of infant
$n1$ = number of months of pregnancy during the year before birth
$C_1(x, y)$ = map value at residence for the year before birth
$C_2(x, y)$ = map value at residence for the year of birth
Fi and Fj = monthly modulation factors.

The mean weighted exposure values of pollution due to the incinerators during pregnancy periods were 0.57 ng/m^3 (SD: 0.93) for PM_{10}, with a decrease of mean exposure with time, due mainly to renewal of some plants during the study period.

Cohort of residences

Study areas were defined as the 4-km zones around six MSW incinerators (that were already active before 1995). The follow-up period ranged from 1995 (first availability of health data) to 2006. Exposure assessments of incinerators were performed by means of pollution maps of particulate matter, provided by ADMS outputs, with an approach similar to that for the population of births (Ranzi et al., 2011). Collection of past emission data were used as inputs for models. Different models were constructed for each plant, according to the renewals during the study period. Exposure levels at enrolment (1995) were used, since cumulative exposure could not be estimated, as a complete residential history since the start of the plants was not available. Simulations of pollutant dispersion were also performed for all other sources in the areas (traffic, heating, industries, agriculture). The deprivation index was calculated at the census tract level.

A total of 219 615 residents were involved (2 157 390 person-years (pys)). During the study period 27 573 deaths from natural causes (mortality rate: 1278x100 000 pys), and 14 287 cases of cancer occurred (incidence rate: 758x100 000 pys). The mean exposure to particulate matter from incinerators at enrolment was 6.24 ng/m^3 (SD: 14.29). The mean exposure to NO_X from all other sources was 56.63 µg/m^3 (SD: 32.09). No clear relationship between deprivation index and exposure to incinerators was observed for the study area.

Conclusion

The experience presented gave us the opportunity to test different possible choices for a suitable indicator for exposure of a population living near a point source, with an impact that changes with time.

Regarding the calculation of exposure of mothers during pregnancy, to be utilized in studies on reproductive effects, some sensitivity analyses on birth outcomes – that is, preterm births – seem to demonstrate a better (and significant) association of our exposure indicator with respect to distance or map values without any calculation of pregnancy period. This aspect raises questions about health effects detectable for a very low level of pollutants and about if these effects are now evident due to a better exposure assessment or changes in composition of pollutants, or other environmental and social factors.

Dealing with exposure assessment of retrospective cohorts raises the issue of a complete reconstruction of residential history, fundamental information when we want to consider the cumulative exposure to time-dependent pressure factors, such as incinerators. In this specific study, the lack of specific information on whole residential history for many sites forced the choice of an exposure at enrolment into the cohort (1995), resulting in possible major misclassifications of exposure.

Last, but not least, the close collaboration between experts from different fields – specifically, environmentally modellers, air quality experts and epidemiologists – represents an added value for this experience. A continuous discussion between experts allowed us to compound the needs of an epidemiological investigation and the capability of environmental models and monitoring, thus raising awareness of the advantages and limitations of different approaches to exposure assessment.

References

Arpa Emilia-Romagna (2012). Moniter: Monitoraggio degli inceneritori nel territorio dell'Emilia-Romagna [Moniter Project: incinerator monitoring in Emilia-Romagna region] [web site]. Bologna, Arpa Emilia-Romagna (http://www.arpa.emr.it/moniter/, accessed 21 December 2012).

Ranzi A et al. (2009). Exposure Assessment of Newborn Babies Near Incinerators: A Geographical Approach. *Epidemiology*, 20(6):79 –80 (doi: 10.1097/01.ede.0000362947.92728.37; http://journals.lww.com/epidem/Fulltext/2009/11001/Exposure_Assessment_of_Newborn_Babies_Near.207.aspx#, accessed 21 December 2012).

Ranzi A et al. (2011). Exposure assessment of a retrospective cohort of residents near incinerators in Italy: a geographical approach. In: ISEE. *Abstracts of the 23rd Annual Conference of the International Society for Environmental Epidemiology (ISEE), September 13–16, 2011, Barcelona, Spain*. Boston, International Society for Environmental Epidemiology (http://ehp03.niehs.nih.gov/isee/PDF/isee11Abstract01259.pdf, accessed 21 December 2012).

Annex 2. Contributions and case studies – workshop "Contaminated sites and health: integrating data and resources"

2.1. European Soil Data Centre (ESDAC): available information on contaminated sites

Panos Panagos and Marc Van Liedekerke
Joint Research Centre of the European Commission, Institute for Environment and Sustainability, Italy

The development, implementation, monitoring and further improvement of environmental policies at the EU level depends on the availability of robust data on the pressures and state of the environment.

ESDAC is the thematic centre for pan-European soil-related data and information. It has been established in the JRC in order to support the European policies and data requirements coming from the EC. The main objective of ESDAC is to ensure that soil data are collected, checked for quality and organized in an efficient way and that all data are accessible to various parties.

ESDAC should provide EC services (such as DG Environment and Eurostat) with quality-assured scientific and technical support on issues related to the proposed SFD (EC, 2006). Such support includes the development of guidelines on the identification of risk areas related to the major soil threats and guidelines on data and metadata quality, utilization of historical data, methods, access and data-exchange formats related to the implementation of the Directive.

The information providers for ESDAC are in-house JRC projects (European Soil Database), soil sampling activities (LUCAS Soil, BioSoil), the network of soil data centres (European Soil Bureau Network), collaborative research projects (FAO, ISRIC, EuroGeoSurveys), other services (Eionet), new data coming from Member States and the 6th & 7th Framework Programmes for Research projects (ENVASSO, Ramsoil, DIGISOIL, Geoland 2).

The ESDAC user interface consists of three main elements: a catalogue of available resources, a map viewer and the European Soil Portal. The catalogue of soil resources is a light-weight metadata system that describes and points to various soil resource types: datasets, services/applications, documents, events, projects and external links. The ESDAC Map Viewer allows the user to navigate key soil data for Europe. It provides access to the attributes of the European Soil Database and some additional data related to the main soil threats, as identified in the Soil Thematic Strategy. The European Soil Portal (JRC, 2012) is considered to be the virtual place where all ESDAC resources are located. The current data and information service makes available four types of products: data, documents, data-based applications and scanned maps.

In 2011, ESDAC in collaboration with members of Eionet countries performed the project "Collection, analysis and assessment of data on Contaminated Sites in Eionet countries" which can be considered as a continuation of work done by the European Environmental Agency (EEA) since 1998 – namely, the data flow on contaminated sites. The data collected generate an input for the EEA's Core Set Indicator CSI 015 "Progress in management of contaminated sites".

This indicator provides answers to the key policy question: "How is the problem of contaminated sites being addressed (clean-up of historical contamination and prevention of new contamination)?" This indicator also provides answers to four more specific policy questions that refer to contributing sectors, management progress, main contaminants and brownfield issues.

The indicator EEA Core Set Indicator CSI 015 "Progress in management of contaminated sites" is based on the definitions shown in Table 2.1.1.

Table 2.1.1. Definitions of contaminated and potentially contaminated sites

Category	
Contaminated site	"The term 'contaminated site' refers to a well-delimited area where the presence of soil contamination has been confirmed. The severity of the impacts to ecosystems and human health can be such that remediation is needed, specifically in relation to the current or planned use of the site. The remediation or clean-up of contaminated sites can result in a full elimination or in a reduction of these impacts
Potentially contaminated site	The term "potentially contaminated site" includes any site where soil contamination is suspected but not verified and detailed investigations need to be carried out to verify whether relevant impacts exist.

Source: EEA (2005). Progress in management of contaminated sites: Indicator definition [web site]. Copenhagen, European Environment Agency (http://www.eea.europa.eu/data-and-maps/indicators/progress-in-management-of-contaminated-sites, accessed 20 December 2012). Reproduced with permission.

In the 2011 data collection exercise (39 countries received the questionnaire), 27 countries returned the questionnaire. Of the 12 missing countries, 6 countries (Bulgaria, Iceland, Liechtenstein, Romania, Slovenia, Turkey) replied that they were not able to complete the questionnaire for various reasons, such as lack of personnel or no available data in the requested format, 3 countries (the Czech Republic, Luxembourg, Portugal) did not reply at all and 3 countries (Greece, Latvia, Sweden) promised to complete the questionnaire in the future.

According to the first preliminary results, 2.4 million PCSs are estimated to exist in EEA countries and west Balkan states. This number is considerably lower than that in the last data collection in 2006, which referred to 3 million PCSs. The number of contaminated sites is estimated to be 190 000, which is also considerably lower than that in the last data collection in 2006, which referred to 250 000 contaminated sites.

About 930 000 PCSs are already identified, which corresponds to approximately 38% of the estimated total. With regard to contaminated sites, about 58 000 have been remediated and 46 000 identified, and another 75 000 sites still need to be assessed.

Regarding the sectors contributing to contamination, waste disposal and treatment, together with industrial and commercial activities, have caused almost two thirds of the local contamination that needs to be dealt with currently. In general, the distribution of local sources of contamination has not changed since 2006.

The distribution of the different contaminants is similar in the liquid and the solid matrix. The main contaminant categories are mineral oils and heavy metals. Phenols and cyanides make a negligible contribution to the total contaminant load in terms of their overall description. Compared with the last data collection in 2006, the shares of the various pollutants hardly changed.

Regarding heavy metal contamination, ESDAC provides pan-European data sets for eight heavy metals (Rodriguez Lado, Hengl & Reuter, 2008). The data sets are based on geostatistical analysis of the FOREGS Geochemical database. New updated information regarding heavy metals will be provided in the near future after the analysis of the LUCAS soil survey. LUCAS is an in-situ survey, which means that the data are gathered through direct field observations.

The aim of the LUCAS survey is to gather fully harmonized data on land use/cover and their changes over time in the EU 27. In the LUCAS (2009) survey, 265 000 georeferenced points were visited by more than 500 field surveyors. The survey points were selected from a standard 2-km x 2-km grid based on stratification information provided by Martino and Fritz (2008).

For the first time, the LUCAS (2009) survey included a soil module. Topsoil samples (0–30 cm) were collected from 10% of the survey points, thus providing approximately 20 000 soil samples. Each soil sample was taken from the topsoil zone to a depth of 30 cm and has an approximate weight of 0.5 kg. The objective of the soil module was to improve the availability of harmonized data on soil parameters in Europe. A chemical analysis of selected trace elements, such as AS (arsenic), Cd (cadmium), Cr (chromium), Cu (copper), Hg (mercury), Pb (lead) and Zn (zinc), is currently ongoing for the LUCAS samples. The first results for heavy metals will be available at the end of 2013.

References

EC (2006). *Proposal for a Directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC*. Brussels, European Commission (COM (2006)232 final; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0232:FIN:EN:PDF, accessed 22 December 2012).

JRC (2012). Welcome to the European Soil Portal [web site]. Ispra, EC Joint Research Centre (http://eusoils.jrc.ec.europa.eu/, accessed 7 January 2013).

Martino L, Fritz M (2008). New insight into land cover and land use in Europe. In: *Statistics in focus*. Vol. 3. Luxembourg, Eurostat.

Panagos P et al. (2012). European Soil Data Centre: response to European policy support and public data requirements. *Land Use Policy*, 29(2):329–338.

Rodriguez Lado L, Hengl T, Reuter HI (2008). Heavy metals in European soils: a geostatistical analysis of the FOREGS Geochemical database. *Geoderma* 148:189–199.

2.2. Needs and data on contaminated sites – Emilia-Romagna Region

Andrea Ranzi[1] and Claudia Ferrari[2]

[1] Environmental Health Reference Centre, Regional Agency for Environmental Prevention of Emilia-Romagna, Italy
[2] Environmental Service, Emilia-Romagna Region, Italy

In Italy, national legislation (Italian Parliament, 1997, 2006) identify the Remediation Plan as part of the Waste Plan; in particular, in relation to the list of contaminated sites, the following information is required:

- the identification of sites to be reclaimed and the general characteristics of pollutants in the area;
- the order of priority of interventions;
- the methods of environmental remediation;
- an estimation of remediation expenditure; and
- how to dispose of the materials to be removed.

At level of the Emilia-Romagna Region, since 2006 (Emilia-Romagna Region, 2006), the functions of management of contaminated sites (such as site census, registry creation and maintenance, and remediation plans) were transferred to the nine provinces.

At the end of 2011, the situation of contaminated sites in the Emilia-Romagna Region was:

- 193 potentially contaminated
- 243 defined as contaminated
- 89 required urgent safety plans
- 190 remediative actions concluded or being finished
- 2 sites included in the list of sites of national interest (SIN).

The different activities during the last few years in this field have emphasized some critical points, such as difficulties in monitoring and evaluating activated remediation actions, the lack of homogeneous procedures for the selection of the concentration limits to be accepted (cases of CTR < CTC, analytes not regulated), the right choice of limits in relation to land use in cases of mixed use, the choice of limits in soil water in cases where there are basic values of natural or diffuse origin, how to solve problems of contamination or poor quality of soil and water from old landfills that do not actually close their operations properly, and the inappropriate use of risk analysis to minimize or avoid remediation.

At the regional level, in general, the main criticalities are related to: the presence of important industrial sites (e.g. ceramic facilities or chemical industries); the need to reduce the volume of waste being sent to landfills; and widespread contamination of groundwater.

Recently, a clear need emerged for a process that re-centralizes the management of contaminated sites, from provinces to the regional government. This course of action is actually ongoing, with an update of the application for the census of sites – to activate earlier the database for a centralized management of contaminated sites.

In order to define the priorities for action based on environmental risk, the Emilia-Romagna Region intends to apply the methodology of prioritization of contaminated sites (called A.R.G.I.A.), which has been selected at the national level and fits the national criteria.

From the point of view of risk assessment and health impact procedures, the needs relate to: better integration between environmental experts and epidemiologists; a connection between risk analyses and epidemiological investigations; the need for common frameworks, to be modified according to the local situation; and improved exposure assessment methodologies for contaminated sites.

References

Italian Parliament (1997). Decreto Legislativo 5 febbraio 1997, n. 22: Attuazione delle direttive 91/156/CEE sui rifiuti, 91/689/CEE sui rifiuti pericolosi e 94/62/CE sugli imballaggi e sui rifiuti di imballaggio [Legislative decree of 5 February 1997, no. 22: Implementation of guidelines 91/156/EEC on waste, 91/689/EEC on hazardous waste and e 94/62/EC on packaging and packaging waste]. *Gazzetta Ufficiale [Official Gazette]*, 38(Suppl. 33) of 15–2–1997 (http://www.gazzettaufficiale.it/atto/stampa/serie_generale/originario, accessed 21 December 2012).

Italian Parliament (2006). Decreto Legislativo 3 aprile 2006 , n. 152: Norme in materia ambientale [Legislative decree of 3April 2006, no. 152: Environmental policy]. *Gazzetta Ufficiale [Official Gazette]*, 88(Suppl.96) of 14–4–2006 (http://www.gazzettaufficiale.it/atto/stampa/serie_generale/originario, accessed 21 December 2012).

Emilia-Romagna Region (2006). Legge Regionale 1 giugno 2006, n. 5: Modifiche ed Integrazioni alla Legge Regionale 9 Dicembre 1993, n.42 (Ordinamento della Professione di Maestro di Sci) e Disposizioni in Materia Ambientale: Capo II - Titolarità di funzioni in materia ambientale [Regional Law of 1 June 2006, no.5: Amendments and additions to Regional Law 9 December 1993, no. 4 (Regulation of the ski instructor profession) and norms on the environmental policy]. *Bollettino Ufficiale della Regione Emilia-Romagna [Official Bulletin of Emilia-Romagna Region]*, 75 (http://burer.regione.emilia-romagna.it/BUR/servlet/LeggiPdfServlet.pdf?ANNO=2006&NUM_BOLL=75, accessed 21 December 2012).

2.3. Surface water bodies in contaminated sites: needs and data

Mario Carere
Department of Environment and Primary Prevention, National Institute of Health, Italy

Contaminated sites often include water bodies that are affected by past or present chemical contamination with possible toxicological risks to human health and the environment. The possible exposure pathways for the population can differ in relation to the uses of the surface water bodies and also in relation to the environmental compartments affected. The main exposure pathways for the population can be: ingestion of fishery products (fish, shellfish), consumption of drinking-water (when surface waters are used for drinking-water purposes), ingestion of vegetables/fruits (irrigation with surface waters), food Industry (surface waters used for industrial purposes), bathing and recreational activities

Usually, in the contaminated sites, the chemical contamination of water bodies is caused by the presence of PBT (persistent, bioaccumulative and toxic) substances, such as heavy metals (e.g. mercury, lead, cadmium), dioxins, PCBs, PAHs and organochloride pesticides that are banned from use but, due to their persistence, remain for decades in the sediments of the water bodies. In river basins, it is possible also to detect "emerging substances", which can be defined as substances that have been found in the environment, but which are currently not included in routine monitoring programmes at the EU level and whose fate, behaviour and (eco) toxicological effects are not well understood (e.g. PFOS, DEHP, PBDE, pharmaceuticals, musks, personal care products).

In Italy, nowadays, 57 national remediation sites (NRS) have been identified on the basis of their possible risk to human health and the environment; these sites include mainly large industrial plants (e.g. petrochemicals, steel plants) and also harbours, mines and landfill sites. These areas, in which there is usually a high level of soil and groundwater pollution, can include surface water bodies (lakes, rivers, lagoons, wetland, marine-coastal waters) characterized by strong and diffuse contamination of the sediment (Carere et al., 2008) layers, caused by past industrial and human activities; the contamination can also be derived from interactions with soil and groundwater. In these national remediation sites and in the neighbouring areas aquaculture or shellfish culture activities can be present – together with sporting or professional fishing – some of these sites also have a high biodiversity value. In these areas, sometimes, the levels of contaminants in the edible fishery products are above the limits specified for the protection of human health, in relation to food consumption. The contamination of the sediments, added to recent contamination due to the anthropogenic pressures in these sites, can also be transferred to the water column, with possible risk from its use as drinking-water, in irrigation or for use in bathing and recreational activities. For these areas (NRS), the measures planned and in place are coordinated by the Italian Ministry of the Environment, with the support of the national scientific institutes (ISS and ISPRA) and the local authorities.

A typical case study is that of contamination by DDT and its metabolites in an area of Lake Maggiore and the Toce River in the north of Italy, caused by past industrial activity on land. The industrial activity (Pieve Vergonte NRS) contaminated the sediments with total DDT (in particular, p,p′-DDE) and suspended particulate matter in the Toce River and Maggiore Lake (Pallanza Bay) with levels higher than the PEL (probable effect level) derived for the ecological protection of benthic organisms. In the context of the work done by *Commissione Internazionale per la Protezione delle Acque Italo-Svizzere* (CIPAIS, International Commission for the protection of Italian Swiss waters), total DDT has been detected in: *Dreissena polymorpha* (Bivalvia; Dreissenidae), in the edible fish *Alosa agone* and in eggs of aquatic birds (great crested grebe) indicators of food-chain transfer. In the Bardello and Boesio rivers, concentrations of PBDEs (polybrominated dyphenyl ethers) have also been detected (Guilizzoni, 2011).

Another example is that of the area of Gela in Sicily where relevant sources of pollution are present: a relevant industrial settlement with large industrial enterprises, mainly petrochemical plants and refineries, a stockpiling centre and pipelines, and landfills with industrial waste. Inside the perimeter of the NRS, massive groundwater and soil contamination have been detected (Musmeci et al., 2009), with a possible risk of interaction with surface water bodies, such as the Gela and Acate rivers and the marine-coastal area. In this area, in the context of a project coordinated by the Ministry of the Environment, environmental data of soil, inland and marine waters, sediment, groundwater, drinking-water, and air and food have been screened and evaluated on the basis of their relevance to the health of the local population.

A selection of local priority substances has been performed in the area. For these substances, toxicological profiles have been elaborated and focus on the effects on human health; also, a comparison has been made between the concentration levels of the local priority substances and the threshold values or quality standards present in the legislation or in scientific studies, including MRL (minimal risk levels) or TDI (tolerable daily intake). The final result has been the drafting of preliminary risk assessments for the local priority substances of concern.

At the European level, the Water Framework Directive (WFD) (EU, 2000) aims to protect all water resources in Europe (surface waters, groundwaters, marine-coastal and territorial waters) and is considered one of the most innovative European laws in the environmental field. WFD is based on the concept of river basin management as a natural geographical and hydrological unit that encompasses surface, groundwater and land: river basin management plans should, since December 2009, be available in all river basin districts across the EU, and a programme of measures should be ready to achieve the environmental objectives by 2015. The WFD (EU, 2000) aims to achieve good environmental status by 2015 in all European water bodies (surface and groundwaters). For chemical substances, the strategy is mainly based on the selection of a list of European priority substances that shall be reduced or eliminated from all emission, discharges, releases and losses by 2021. For these substances, Directive 2008/105/EC has set legislative limits (environmental quality standard) that should be achieved in surface water bodies, with the aim of protecting human health and the environment. Most of the priority substances (e.g. mercury, cadmium, lead, PAHs,) can be detected in the water bodies of the contaminated sites – in particular, in the sediment compartment. The WFD has also established a coherent and comprehensive obligatory monitoring programme (Quevauviller, Carere & Polesello, 2012) on the status of the water bodies within each river basin district. The programme concerns surface waters (rivers, lakes, transitional and coastal waters), groundwaters and protected areas since December 2006. There are three types of programme: surveillance (every management plan), operational (to assess the status for water bodies at risk – for example, contaminated sites) and investigative (accidents, unknown deterioration causes). The data of the WFD are reported in WISE (WISE, 2012), which is a partnership between the EC (DG Environment, the Joint Research Centre and Eurostat) and the EEA, which provides web-portal entry to water related information, ranging from inland waters to marine waters. The WFD strategy and monitoring programmes – together with projects performed at the local level, such as those mentioned in the Italian case studies – should represent a good support for taking measures and giving recommendations, with the aim of reducing the exposure of the population to the chemical contamination of water bodies in contaminated sites.

References

Carere M et al. (2008). Assessment and management of contaminated sediments in Italian marine coastal waters. *Annali dell'Istituto Superiore di Sanità*, 44(3):239–243.

EU (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. *Official Journal of the European Communities*, L327:1–72 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF, accessed 22 December 2012).

Guilizzoni P (2011). *Indagini su DDT e sostanze pericolose nell'ecosistema del Lago Maggiore : Programma 2008–2012: Rapporto Annuale 2010 [Investigations on DDT and other dangerous substances in Lake Maggiore ecosystem: 2008–2012 Programme: 2010 Annual Report]*. Verbania Pallanza, Commissione internazionale per la protezione delle acque italo-svizzere (http://www.cipais.org/pdf/DDTeSSPP_Maggiore_Rapporto_2010.pdf, accessed 8 August 2012; in Italian).

Musmeci L et al., eds. (2009). Ambiente e salute a Gela: stato delle conoscenze e prospettive di studio [Environment and health in Gela (Sicily): present knowledge and prospects for future studies]. *Epidemiologia e Prevenzione [Epidemiology and Prevention]*, 33(3 Suppl. 1):1–160 (in Italian and English).

Quevauviller P, Carere M, Polesello S, eds (2012). Chemical Monitoring Activity for the Implementation of the Water Framework Directive. *Trends in Analytical Chemistry*, 36:1–184.

WISE (2012). About WISE [web site]. Copenhagen, European Environment Agency (http://water.europa.eu/info, accessed 8 January 2013).

2.4. Review of initiatives from other EU networks related to contaminated sites

Dominique Darmendrail

Common Forum on Contaminated Land in Europe General Secretary, c/o BRGM, France

The Common Forum on Contaminated Land in Europe (CF) and the International Committee on Contaminated Land (ICCL) are the networks of contaminated land policy experts, regulators and technical advisors. Created in 1993–1994, their missions are:

- being a platform for exchange of knowledge and experiences, for initiating and following up international projects among members;
- establishing a discussion platform on policy, research, and technical and managerial concepts of contaminated land; and
- offering an exchange of expertise to other stakeholders.

CF and ICCL collaborate with the other networks or initiatives operating in the same field, such as NICOLE (industry and service providers), Sednet (sediment management), Cabernet (brownfield regeneration), Eurodemo+ (innovative technologies), Snowman (national research funders club) and IMPEL (European environmental inspectorate). They bring together problem holders, technical specialists, policy-makers and regulators to design and implement better long-term solutions.

Within CF/ICCL several types of actions are conducted.

- New concepts for Contaminated land management: risk-based land management was developed in 2000 for designing solutions for "legacy sites" (where the preventive regulations were not in force or have been insufficient) at regional and site scales. It is now in place in some EU countries (Austria, France and the Netherlands). Considered to be the third generation of legal frameworks – (a) drastic source control/inventories, (b) risk assessment) – it is based on four dimensions (fitness for use, protection of the environment, long-term care and management constraints).

- Critical analysis of EU directive proposals: the regulatory environment at the European level is quite complex now (see slide 7). Its implementation at the local level (site management) requires additional legal and technical work in order to be cost efficient.
- CF has continuously discussed the technical and political aspects of the contaminated soil issues in the original proposal and in the alternative versions under each Presidency. Having failed to reach agreement in Council, in light of the desire of many Member States to have a framework directive for soil, and convinced that common grounds could be found; a "special task force" of Common Forum members from some Member States was established in July 2010 during the Belgian Presidency. An agreement was found and an alternative proposal for a Soil Protection Directive was published and proposed to EU institutions.
- Proposals have been made for technical guidance documents for EU directive implementation (e.g. guidance values for contaminated soil management, application of the polluter pays principle, how to tackle uncertainties, and INSPIRE consultation for soil data collection).
- The exchange of information between the network experts is done via thematic questionnaires (Environmental Liability Directive Implementation, Industrial Emission Directive Implementation, regulatory framework in Member States, Mining residues inventory).
- Technical support is provided in relation to special "incidents" (e.g. Hungarian red mud dam break in 2010).
- Research and technological development (RTD) needs have been identified, and discussions have taken place with researchers on specific topics, such as the need for harmonization to derive soil screening values in Europe (cf. JRC HERACLES projects). The geographical and geological contexts and the land use needs are too different in Europe to have a unique set of soil quality standards. But some common ground could be found on technical issues (with the development of a tool box for risk assessment and common protocols and sets of exposure factors) and even political issues (such as the targets to be protected or the substances to be covered/excluded).

Within the broader framework of industrial emissions (for operating industrial activities – for which there is a parallel legal framework with a lot of evolutions during the last 20 years) and soil protection policies, *contaminated site management* has a special position:[3] It has to address contamination due to past polluting activities, still present in soil and water, leading to risks for the surrounding populations and the environment.

Legal, financial, organizational and technical tools have been developed (and evolved) over 30 years for dealing with the four main types of situation that the authorities have to face, as posed by the following questions.

- Are the operating site impacts/risks acceptable?
- When an operating site is closing, what should I do to regenerate the land and propose it for future reuse?
- When land is suspected to be contaminated, is it risky? Should I remediate it?
- Is the future land redevelopment project feasible on a particular suspected site?

These questions are different from those related to health studies (What are the health concerns? Is there an exposure? Is there a health impact on the general population?).

3 Definition of contaminated site used: site where there is a confirmed presence, caused by man, of dangerous substances of such level that they pose or may pose in the future a significant risk to human health or the environment (including groundwater).

The *main lessons learnt* from the experiences developed in the participating countries (45 at the International level) and the networks are:

Managing contaminated sites covers several dimensions: (a) preventing new pollution; (b) reducing emissions and accidents at operating industrial sites (with the application of the polluter pays principle, remediation of pollution as soon as unacceptable emissions are detected); and (c) dealing with legacy pollution (with a tiered risk-based approach, combining and balancing the three pillars of sustainable remediation).

Humans are surrounded by and in close contact with contaminants (from transport, industrial sites, contaminated sites – holding materials and matrices and so on). At the overall population level, contaminated sites have a limited impact. But at the local level, exposure to contaminated sites can dominate. Due to these confounding exposures (cf. United Kingdom DEFRA, 2011), there is a need to estimate the amount of contaminants to which people are exposed and to assess the variability in exposure between people.

The risk assessment and management approach is used at specific sites in all countries, for achieving different objectives (derivation of soil quality standards/threshold values, assessing potential or future risks at a specific site, deriving remediation objectives, ranking sites). This risk assessment and management approach is a suitable instrument for determining when health risks are negligible, but not for quantifying the magnitude of the effects on human health due to contaminated sites. Regarding risks to the surroundings population, the critical phase is linked to the communication on risks: As shown, several cases of risk assessment and human health studies (such as epidemiological and cohort studies) can give different results. Exceeding reference values does not necessarily mean a real risk and should be interpreted on a case by case basis.

Dealing with such complex situations needs a good interaction between environmental and health communities. Some countries interact rather well and bring a joined-up view to the issue (e.g. the United Kingdom: potential exposure to contaminated lands and other sources; the United States: public health assessment at contaminated sites; France: national programme on "sensitive" sites located on or nearby contaminated sites).

Different areas of improvement or RTD have been identified to secure the approach. Some examples are given in table 2.4.1.

To fulfil some of these demands, ICCL is currently elaborating a follow-up action plan organized around four pillars: (a) establishment of an "operational cell" of expertise for contributions to site projects/specific demands; (b) development of an information/knowledge platform for promoting best practices and existing tools; (c) elaboration of a common framework/roadmap for contaminated land management that could be provided to low-income countries; and (d) identification of gaps to be addressed in the future (at policy, technical or RTD levels).

More information on CF and ICLL are available on their web sites (CF, 2012; ICCL, 2012).

Table 2.4.1. Examples of different areas of improvement or RTD

Risk prevention	Long-term efficiency of the prevention measures
Risk characterization	Development of fast and cost-effective screening and detection methods
Risk assessment	Influence of phase portioning in transfer Biodegradation processes in unsaturated zone Bioavailability quantification Vapour intrusion in buildings Background contribution (geochemical, food, air quality, …)
Remediation	New innovative technologies: in situ, biological, nanotechnologies, Acceptance of the innovative technologies
Risk management	Revision of toxicological reference values Balancing sustainable remediation Targets/groups to be protected Minimum (acceptable) level of risks
Link with Human Health studies	Combined exposures from various pathways Effects of cocktail of substances Appropriate exposure pathways – effects/responses Measuring effects on small populations that can be clearly associated with specific chemical exposures

Source: Author. Reproduced with permission.

References

CF (2012). Common Forum on Contaminated Land in the European Union [web site]. Orléans, Common Forum (www.commonforum.eu, accessed 8 January 2013).

ICLL (2012). International Committee on Contaminated Land [web site]. Bern, BAFU Bundesamt für Umwelt (www.iccl.ch, accessed 8 January 2013).

2.5. Assessing health risks from contaminated soils

Ian Martin

Environment Agency for England and Wales, United Kingdom

In common with other countries, the United Kingdom has a long industrial heritage that has unfortunately resulted in a legacy of land contamination. The Environment Agency for England and Wales has managed the development of technical tools for the assessment of risks to human health from soil contamination since the late 1990s. In 2009, we published an update to our Contaminated Land Exposure Assessment (CLEA) technical guidance to help risk assessors to consider the long-term risks posed to the health of adults and children living, working, and playing on PCSs. Our guidance package consists of two main technical reports, which provide a framework for assessing risk to health, a software tool for estimating exposure both for generic and site-specific scenarios, and a series of daughter publications that describe the human toxicology and the fate and transport of specific chemical substances in soils. An important factor in the success of the CLEA guidance has been close cooperation between the Environment Agency and other public health bodies, including the Health Protection Agency and the Food Standards Agency.

The principal objective of our research programme has been to develop effective tools to assist regulators in identifying contaminated sites that require further (often more detailed and site-specific) consideration. The main outputs are as follows.

- *Human health toxicological assessment of contaminants in soil* (Science Report SR2) (Environment Agency, 2009a). It describes the principles of chemical risk assessment and also how the toxicity of chemicals in soil are assessed to derive toxicological benchmarks (called health criteria values or HCV) that represent a minimal or tolerable risk to health.
- *Updated technical background to the CLEA model* (Science Report SR3) (Environment Agency, 2009b). It describes the principles of exposure assessment and the underlying algorithms/parameters used to estimate the fate and transport of contaminants by up to ten different exposure pathways. The report also describes land-use based exposure scenarios that show qualitatively and quantitatively how children and adults may be chronically exposed to soil contamination as they live, work, and/or play.
- *CLEA Software Version 1.06.* It is a Microsoft Excel-based spreadsheet version of the CLEA model that can be used to replicate and develop generic screening criteria and can be adapted to take into account site-specific information collected during a site investigation.
- *Soil Guideline Values (SGV).* They are a series of reports that set out scientifically based generic assessment criteria that can be used to simplify the initial assessment of health risks arising from long-term and on-site exposure to chemical contamination in soil. SGV do not consider risks to construction workers or risks from occupational exposure arising from activities in the workplace. They are not relevant for assessing acute exposures, including injury arising from direct bodily contact or other risks, such as explosion or suffocation associated with the build-up of gases. Estimating human exposure to contaminants in soil is a complex and challenging scientific area, and it is neither feasible nor practical to carry out a detailed site investigation and risk assessment on every suspected site affected by land contamination. SGV, therefore, represent a simple and effective tool for screening sites.

Other related research includes a compilation of chemical data for a large number of common organic contaminants for use in assessing the fate and transport of chemicals in the soil environment, a review of plant uptake models for organic contaminants, and a series of reports looking at the use of oral bioaccessibility in refining estimates of exposure to soil contamination.

An important feature of our work has been to clearly explain the structure and derivation of the framework and to make all decisions and assumptions open to scrutiny. It is essential that users of the guidance have a good understanding of the science, judgements and uncertainties inherent in the guidance, so that they are better equipped to apply it appropriately. One of the most satisfying outcomes of the introduction of the CLEA framework in 2002 is the increased awareness and expertise in human health risk assessment among professionals involved in the assessment and management of land contamination in the United Kingdom. Industry engagement has been high, with the development of their own screening criteria (to complement SGV produced by the Environment Agency) and work to provide more detailed guidance on specific aspects, such as vapour intrusion into buildings and the assessment of asbestos.

All the CLEA reports and the software mentioned in the presentation can be downloaded free of charge from the Environment Agency web site (Environment Agency, 2012).

References

Environment Agency (2006). *Evaluation of models for predicting plant uptake of chemicals from soil*. Bristol, Environment Agency (Science Report SC050021/SR; http://www.environment-agency.gov.uk/static/documents/Research/sc050021_2029764.pdf, accessed 22 December 2012).

Environment Agency (2008). *Compilation of data for priority organic pollutants for derivation of Soil Guideline Values*. Bristol, Environment Agency (Science Report SC050021/SR7; http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/scho1008bovo-e-e.pdf, accessed 22 December 2012).

Environment Agency (2009a). *Human health toxicological assessment of contaminants in soil*. Bristol, Environment Agency (Science Report SC050021/SR2; http://www.environment-agency.gov.uk/static/documents/Research/TOX_guidance_report_-_final.pdf, accessed 22 December 2012).

Environment Agency (2009b). *Updated technical background to the CLEA model*. Bristol, Environment Agency (Science Report SC050021/SR3; http://www.environment-agency.gov.uk/static/documents/Research/CLEA_Report_-_final.pdf, accessed 22 December 2012).

Environment Agency (2012). Soil Guideline Values [web site]. Rotherham, Environment Agency (http://www.environment-agency.gov.uk/clea, accessed 8 January 2013).

2.6. Development of a GIS-based platform and multimedia exposure model to map and analyse environmental inequalities

Julien Caudeville, Roseline Bonnard and Céline Boudet
INERIS, France

The term "exposome" emerged in an attempt to address the under-appreciation of exposure sciences in the elucidation of the role of environmental stressors in many common chronic diseases. To respond to this concept, there is a need for a new way to analyse the environment–human health relationships. The use of a GIS (geographic information system) as a platform for data storage, statistical analysis, and spatial interpolation remains a dramatic cornerstone in linking data from different sources and supports databases to describe the global source–effect chain. GIS is a promising tool to analyse health data and putative covariates, such as environmental, exposure, or socioeconomic factors. The objective of the PLAINE project is to develop a GIS-based platform, combining environment and health information to map environmental disparities and detect vulnerable populations. This platform should permit the ongoing systematic collection, integration, and analysis of data on emission sources, environmental contamination, exposure to environmental hazards, population and health. To achieve this objective, combining exposure assessment and spatial data is a fundamental prerequisite, which implies first overcoming different scientific limitations, such as the linkage of the several databases to describe the global source–effect chain, the feasibility of integrating these data in the platform at a fine scale and constructing variables and indicators of interest by the development of spatial analysis and geostatistic tools combined with an exposure model (Caudeville et al., 2012a).

Modelling the contamination of potential soil impacts is an important issue in Digital Soil Assessment. Indeed, the quality of the health risk assessment strongly depends on the quality of digital soil contamination mapping. Thus, communicating the risks should not be done independently for the overall uncertainties. One purpose of the PLAINE project is to spatially assess human exposure to soil contaminants as a second step in digital soil contamination mapping. To this aim, the GIS-based raster platform at 1-km^2 resolution is developed in order to integrate soil contaminants and the environmental pathways of these contaminants with human exposure. The modelling is performed in the Nord-Pas-de-Calais region. This French region is recognized as a former highly industrialized zone. Its population is extremely dense, with about four million inhabitants living in an area of 12 414 km^2.

Surface soil concentration is estimated by developing a kriging method able to integrate data from surface and point spatial supports (Caudeville et al., 2012b). Original soil contaminant concentrations are modelled across the study region using data from the newly INRA/ADEME collected trace metals in the soil surface in France (BD ETM, INRA & ADEME programme: Duigou & Baize, 2010), corresponding to a total of some 25 000 sample analyses for each trace metal in the Nord-Pas-de-Calais region. Losses and inputs of chemical substances by several mechanisms – including leaching, runoff and deposition – were also taken into account. Background soil concentrations were defined by data provided by the French National Institute of Agronomic Research (INRA) (Marchant et al., 2010).

The exposure pathways considered in this assessment include inhalation and ingestion of vegetation, meat, eggs, water and milk, both commercial and home-grown products. Contaminant soil concentrations are used to estimate the soil ingestion pathway and transfer in vegetation and animal home products. Spatial monitored and measured data from regional or national databases are used to estimate the concentration in air, surface water and drinking-water. The multimedia model combines air, water, soil, and bioaccumulation models to estimate concentrations in home-grown produce (vegetation and animal products).

The concentration in commercial foodstuffs is estimated using a French national survey. Data measured about 2004 are used and assumed constant for the whole exposure duration. Atmospheric concentration and wet and dry deposition on soil are described using the output of the atmospheric dispersion CHIMERE transport model. Drinking-water concentrations are derived from a French regulatory monitoring database (Sise-Eaux), which describes water pollutant concentrations in water supply systems at a communal scale. GIS is used to combine the district location information with the geographical concentration distributions.

Once the spatial data is modelled, the multimedia exposure model (Bonnard & McKone, 2010) is applied to get the population exposure risk assessment. A probabilistic approach integrates variations in the data used for exposure assessment and helps in interpreting results. The non-cancer risk is characterized using a hazard quotient (HQ). To achieve a better assessment of the transfer of contaminants, a large database on heavy metal uptake by plants is constructed to build probability distributions. Monte-Carlo simulations are then used to propagate uncertainty through the model.

In the modelling, the receptor population is exposed over a 70-year period. Because for each pollutant the group of 2- to 7-year-olds is the highly exposed group, this group is used for the analysis. The outputs of the model include the mean, median interquartile and complete probability density distribution. For cadmium, most exposure is mainly due to ingesting vegetation (average 67%). Except for water ingestion, other contributions are very low.

The results show two highly exposed areas, due to pathways of high ingestion of local vegetation. These areas are associated with intermediate soil concentration uncertainties, corresponding to an ancient industrial site (Metaleurop) and to the neighbourhood of Agglomeration de Lille. The population located in these areas presents then a high risk of developing chronic disease.

The purpose of this work was to present the scientific development of the platform, focusing on the soil compartment and based on the example of cadmium. A contaminated soil localization database could also be integrated in the platform, to build a distance from source indicator that works with other kinds of variables.

At the local scale, the platform could be used in the classical risk assessment study context or to design further environmental sampling in detected hot spots. For this kind of study, geostatistical tools permit the analysis of local and regional spatial variability, which helps to simulate a semivariogram, the range of influence, grid length(s) and the sampling campaign design.

Other purposes and illustrations of the several possibilities for the platform in the exposome characterization context could be:

- mapping environmental disparities;
- identifying vulnerable populations and determinants of exposure, to manage and plan remedial actions;
- highlighting hot-spot areas with significantly elevated exposure indicator values, to define environmental monitoring campaigns; and
- assessing spatial relationships between health, environmental and socioeconomic data, to identify factors that influence variability in disease patterns.

References

Bonnard R, McKone TE (2010). Integration of the predictions of two models with dose measurements in a case study of children exposed to the emissions of a lead smelter. *Human and Ecological Risk Assessment*, 15(6):1203–1226.

Caudeville J et al. (2012a). Development of a spatial stochastic multimedia model to assess population exposure at a regional scale. *Science of the Total Environment*, 432:297–308.

Caudeville J et al. (2012b). Spatial modeling of human exposure to soil contamination – an example of digital soil assessment. In: Minasny B, Malone BP, McBratney AB, eds. *Digital Soil Assessments and Beyond. Proceedings of the 5th Global Workshop on Digital Soil Mapping 2012, Sydney, Australia*.

Duigou N, Baize D (2010). *Nouvelle collecte nationale d'analyses d'éléments en traces dans les sols (horizons de surface) – (Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn)*. Angers, ADEME (Convention 0875 C0036).

Marchant BP et al. (2010). Robust analysis of soil properties at the national scale: cadmium content of French soils. *European Journal of Soil Science*, 61:144–152.

2.7. The redevelopment of RIF

Federico Fabbri,[1] Kees de Hoogh,[1] Peter Hambly,[1] Kevin Garwood,[1] Linda Beale,[2] Lea Fortunato[1] and Anna Hansell[1]

[1] MRC-HPA Centre for Environment and Health, Imperial College London, United Kingdom
[2] Environmental Sciences Research Institute (ESRI), CA, United States

Redevelopment of RIF

RIF has been developed by SAHSU at Imperial College London. The application integrates advanced methods in statistics, spatial analysis and spatial epidemiology to allow researchers to assess the health risks related to environmental exposure. It is able to produce disease maps with and without statistical smoothing.

The RIF supports two types of study:

1. risk analysis, which allows scientists to assess whether a risk factor has a statistical association with a health outcome in a local population (Fig. 2.7.1); and
2. disease mapping, which allows users to visualize mortality or morbidity rates and spatial patterns of health outcomes (Fig. 2.7.2).

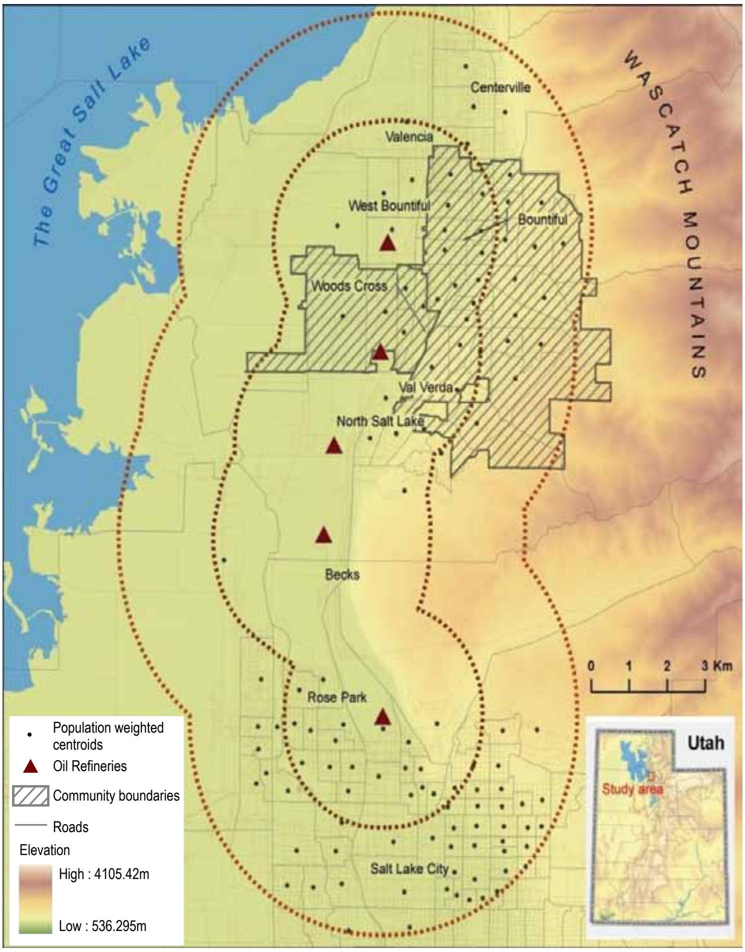
Why redevelop

For most of the past decade, the RIF has operated as an application embedded within a geographic information system (GIS) called ESRI® ArcGIS™ v9. Two year ago, ArcGIS stopped being compatible with the RIF code when ESRI adopted the scripting language Python instead of Visual Basic.

Open source

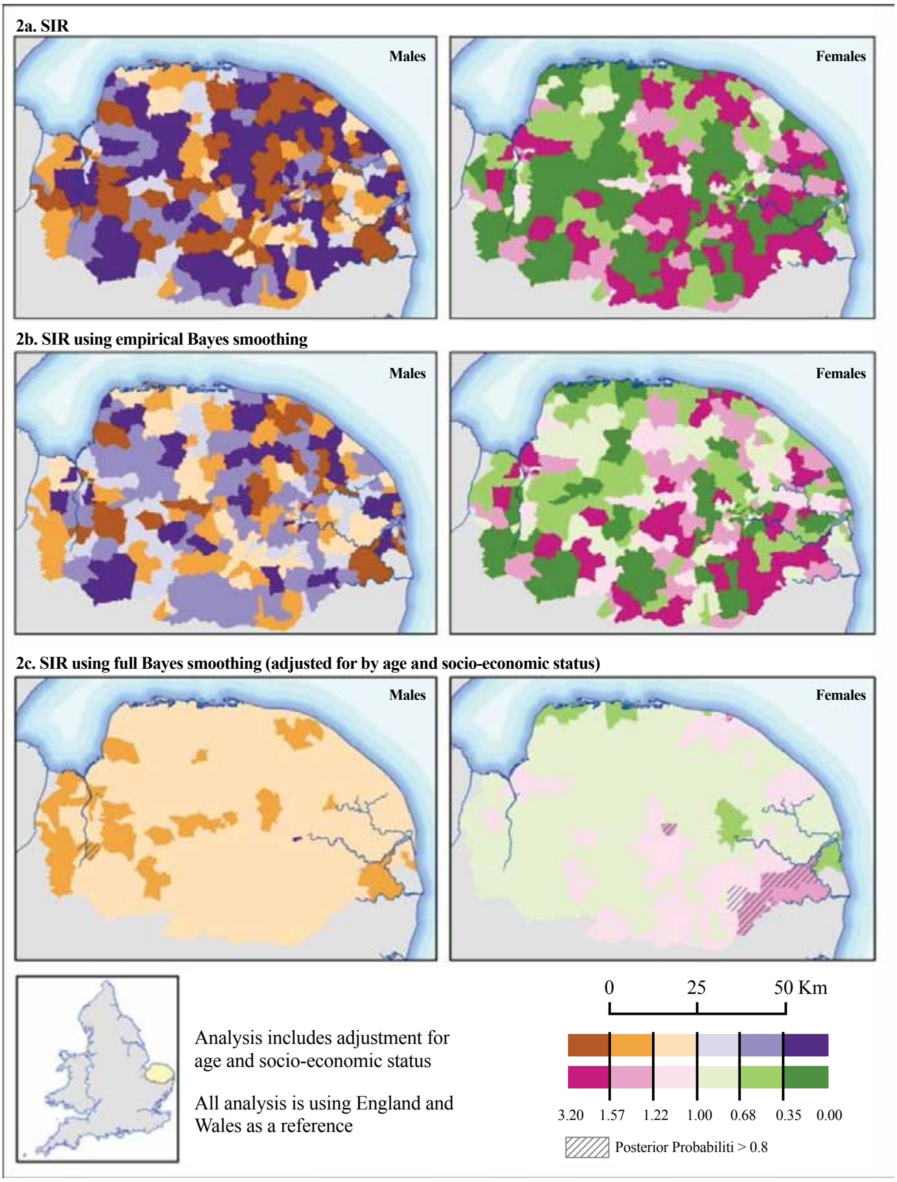
A recent survey of the RIF community has helped provide a clear picture of how the tool should develop in the near- to medium-term future. The RIF will be rewritten using Java and will store population, health and geographic data in PostgreSQL/POSTGIS databases. Many of the tool's GIS features will be supported through GEOTOOLS. Fig. 2.7.3 illustrates the relationships between the new RIF 4.0 components.

Fig. 2.7.1. Investigating the relative risks of leukaemia, multiple myeloma, Hodgkin's and non-Hodgkin lymphoma and proximity to oil refineries, Salt Lake City, UT



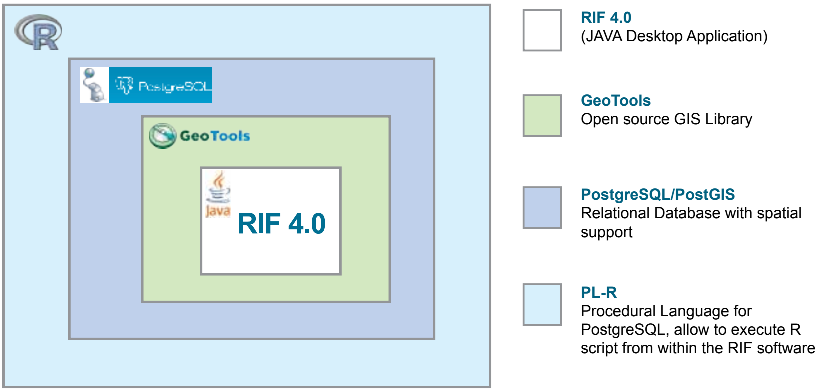
Source: Beale et al. (2010). Reproduced with permission from *Environmental Health Perspectives*. This is an Open Access article: verbatim copying and redistribution of this article are permitted in all media for any purpose, provided this notice is preserved along with the article's original DOI.

Fig. 2.7.2. Standard incidence ratio of oesophageal cancer, 1984–2003, Norwich, United Kingdom



Source: Beale et al. (2010). Reproduced with permission from *Environmental Health Perspectives*. This is an Open Access article: verbatim copying and redistribution of this article are permitted in all media for any purpose, provided this notice is preserved along with the article's original DOI.

Fig. 2.7.3. RIF 4.0 components

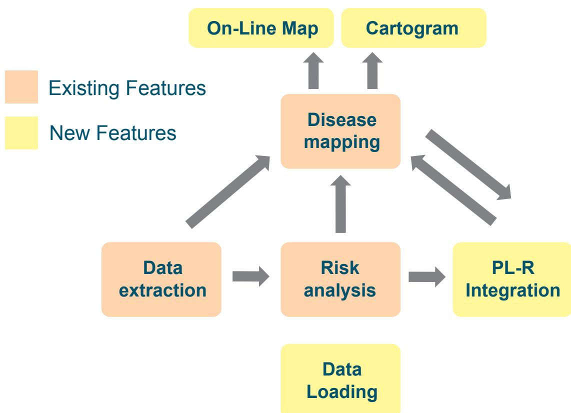


Source: Authors. Reproduced with permission.

Redevelopment plan

A focus on more statistical tests and an easier way to set up the database are the two key components of RIF4.0. Fig. 2.7.4 illustrates the relationships between new and existing features. The R Procedural Language (PL-R) will allow R script to be executed from the RIF interface. A user-friendly wizard will facilitate the process of configuring user's data. A function that generates Cartograms will provide alternative ways to represent the 'shape' of a disease, while the publishing feature will encourage users to share their maps and results on our online dedicated platform.

Fig. 2.7.4. Key features



Source: Authors. Reproduced with permission.

References

Beale L et al. (2010). Evaluation of spatial relationships between health and the environment: The Rapid Inquiry Facility. *Environmental Health Perspectives*, 118(9):1306–1312 (doi: 10.1289/ehp.0901849; http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2944094/, accessed 20 December 2012).

2.8. Exposure assessment of contaminants in the food-chain

Marta Schuhmacher, Marti Nadal and J. Luis Domingo.
Centre for Environmental, Food and Toxicological Technology, Spain

The presentation shows the results of the annually monitored chemical/petrochemical industrial zone of Tarragona County (Catalonia, Spain) developed by our group between 1998 and 2012.

The industrial surface is 130 km^2, with a production of 18 million tonnes per year, including such products as chlorine, propane, propylene, gasoline and refined petroleum. There are 300 000 inhabitants living around this area.

The objective of the study was to assess the human health risk of exposure to environmental pollutants.

First an evaluation of the chemicals of concern was carried out. Chemicals with the following properties were chosen: Persistence, Bioaccumulation, Toxicity, and Long range transport. Taking into account these considerations, the following pollutants were chosen for our study: Polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), PCBs, Polychlorinated naphthalenes (PCNs), PAHs and Heavy metals (As, Cd, Cr, Hg, Mn, Pb and V).

To evaluate the exposure of the population living in the surroundings of the industrial area, a conceptual model was developed. To that, a large quantity of information was gathered and plotted in a GIS.

As environmental indicators of direct exposure**,** soil (as a long-term indicator), vegetation (as a medium-term indicator), and air (active as a punctual indicator) were used. Also, food samples were determined as indirect exposure indicators.

To select the most appropriate areas to collect environmental samples, a dispersion model was run. They were chosen after considering the direction of the plume and also that the areas were inhabited. On the other hand, in order to assess the effects of traffic (that can be a confusing emission), samples from non-contaminated areas (blank), and non-contaminated areas impacted by traffic (blank + traffic) were chosen.

A total of 24 samples of soil and vegetation were collected in 4 areas of Tarragona County (chemical, petrochemical, urban/residential, and unpolluted). Moreover, the airborne concentrations of the same micropollutants were determined in each area. In soil samples, significantly higher levels of PCNs and higher concentrations of PCDD/Fs and PAHs were found in the urban zone. PCDD/F levels in vegetation samples decreased significantly from 2002. The concentrations of Cr in soil samples, as well as V levels in vegetation samples collected in the vicinity of an oil refinery were significantly higher than those found in the unpolluted zones. A significant and progressive increase in V concentrations was also noted. The current results clearly indicate that the petrochemical industry is still an important focus of inorganic pollution for the surrounding environment. In air, the higher amount of the 7 carcinogenic PAHs suggests a relatively greater impact on the petrochemical and urban areas.

The temporal trend of the global pollution was also studied and a GIS-Integral Risk Index was applied to assess human health risks in areas where multi-pollutants were present.

Contaminants were previously ranked by applying a self-organizing map (SOM) to their characteristics of persistence, bioaccumulation, and toxicity, in order to obtain the Hazard Index (HI).The Risk Index was integrated in a GIS, in order to create risk maps.

In general terms, PCBs were the pollutants showing the highest hazard. In comparison to the remaining chemicals, PCBs were the most persistent in the environment.

The results indicated that the risk of the chemicals under study did not show a homogeneous tendency.

This methodology can be highly valuable when allowing the settle-down of new chemical and petrochemical companies, as well as other potentially polluting activities in areas with a strong industrial activity.

In order to differentiate other sources of pollutants from those resulting from industrial activity, different multivariate techniques were carried out for environmental data analysis. Among them, principal component analysis (PCA) and Kohonen's self-organizing maps (SOM) were chosen.

PCDD/Fs are released by very different sources, such as traffic, home heating, crematories, or accidental fires. Each PCDD/F source is characterized by its own congener profile, which is the proportion of each congener in the mixture, also known as PCDD/F fingerprint.

Kohonen's self-organizing maps (SOM) are among the most popular neural network models. SOM is a multivariate technique that enables pattern recognition and classification without preliminary knowledge of the process. On the other hand, principal component analysis (PCA) is one of the most accepted techniques. However, SOM has some potential advantages over PCA, such as its straightforward interpretation, clustering power and ability to deal with nonlinear problems. The results showed that the SOM algorithm is able to detect differences in PCDD/F patterns of matrices that apparently are very similar. Consequently, complementary information can be extracted.

In the current study, different profiles have been observed for soils and herbage. The results confirm these matrices as long- and short- term monitors, being air samples (as expected) quite similar to herbage.

A second goal of the study was to assess the human health risks (carcinogenic and non-carcinogenic) of PCDD/F exposure for the adult population living in two different areas (industrial and residential) of Tarragona (Catalonia, Spain), as well as to compare these risks according to the socioeconomic status of the population. Two pathways were considered for PCDD/F exposure: direct (air inhalation, dermal contact and ingestion from soil and dust) and dietary. Although environmental exposure was higher for the population living in the neighbourhood of the industrial area (mainly lower socioeconomic group subjects), it only accounted for 1.05%. On the other hand, PCDD/F exposure through dietary intake was more important for those individuals at an upper socioeconomic level. This was due to the fact that their diet is richer in those foodstuffs containing higher PCDD/F concentrations. Consequently, taking together direct and dietary exposure to PCDD/Fs, the result is that upper socioeconomic group populations are more exposed to these toxic pollutants. In any case, the current levels of PCDD/F exposure would not mean significant carcinogenic and non-carcinogenic risks for the population living in the industrial and residential areas of Tarragona.

In general terms, the results show that diet is the major route of exposure to chemicals (> 90%).

The results for the levels in plasma observed showed a significant reduction over time (from 1998 to the present). This important decrease agrees well with the notable reduction in the dietary intake of PCDD/Fs noted for the population of the same area.

References

Mari M et al. (2010). Application of self-organizing maps for PCDD/F pattern recognition of environmental and biological samples to evaluate the impact of a hazardous waste incinerator. *Environmental Science and Technology*, 44:3162–3168.

Martí-Cid R et al. (2010). Dietary exposure to organochlorine compounds in Tarragona Province (Catalonia, Spain): health risks. *Human and Ecological Risk Assessment*, 16(3):588–602.

Nadal M, Schuhmacher M, Domingo JL (2004). Probabilistic human health risk of PCDD/F exposure: a socioeconomic assessment. *Journal of Environmental Monitoring*, (6):926–931.

Nadal M et al. (2008a). Applicability of a neuroprobabilistic integral risk index for the environmental management of polluted areas: a case study. *Risk Analysis*, 28(2):271– 286.

Nadal M et al. (2008b). Concentrations of PCDD/PCDFs in plasma of subjects living in the vicinity of a hazardous waste incinerator: follow-up and modeling validation. *Chemosphere*, 73(6):901–906.

Vilavert L et al. (2010). Monitoring temporal trends in environmental levels of polychlorinated dibenzo-*p*-dioxins and dibenzofurans: results from a 10-year surveillance program of a hazardous waste incinerator. *Archives of Environmental Contamination and Toxicology*, 59(4):521–531.

Annex 3.
Programme of the workshop "Contaminated sites and health: priorities, interests, needs, methodological options"

Syracuse, 18 November 2011

CHAIR: Benedetto Terracini, University of Turin (retired), Italy
RAPPORTEUR: Roberto Pasetto, National Institute of Health, Italy

Friday, 18 November 2011

09:00 – 09:30	Coffee and registration
09:30	Welcome and introduction. Objectives (Sicily Region, WHO) A. Cuspilici and M. Martuzzi
10:00 – 13:00	Contaminated sites and health: experiences, needs – Studies on waste landfills in Lazio, Italy (F. Forastiere) – Experiences of exposure assessment in waste related studies in the United Kingdom (K. de Hoogh) – The SENTIERI Project: methods and results (R. Pirastu)
11:20 – 11:40	Coffee break – Health studies conducted in industrialized sites of Southern Spain – (P. Martin-Olmedo) – Lead in Contaminated Sites – Case description (P. Otorepec) – Air pollution effects from the large power plant in Northern Greece (A. Analitis)
13:00 – 14:00	Lunch break

14:00 – 16:00	Contaminated sites and health: methods, priorities – Epidemiologic studies in Sicilian polluted sites: the Biancavilla and Priolo studies – (P. Comba) – Diffusion modelling and GIS as tools for assessing individual exposure to dioxins – (J.F. Viel) – Health impact of contaminated sites in children (I. Iavarone) – Exposure assessment of people living in small area near incinerators: experiences and proposals (A. Ranzi) – Epidemiological studies around contaminated sites in Piedmont and methodological issues in microgeographical studies (E. Cadum)
16:00 – 16:30	Coffee break
16:30 – 17:30	Way forward, discussion (Discussants: P. Comba, J.F. Viel, P. Martin)

Annex 4. Programme of the workshop "Contaminated sites and health: integrating data and resources"

Catania, 21–22 June 2012

CHAIR: Ivano Iavarone, National Institute of Health, Italy
RAPPORTEURS: Roberto Pasetto, National Institute of Health, Italy
Piedad Martín-Olmedo, Andalusian School of Public Health, Spain

Thursday, 21 June 2012

09:00 – 09:30	Coffee and registration
09:30 – 10:00	Welcome and introduction. Objectives of the meeting Marco Martuzzi and Piedad Martin-Olmedo
10:00 – 12:15	Availability of data on contaminated sites at the European level
10:00 – 10:30	Legal Framework for "contaminated sites" in Europe (Proposal for a Soil Framework Directive and others) (A.A. de la Fuente)
10:30 – 11:00	Data Collection regarding contaminated sites by EEA (D. Jarosinka)
11:00 – 11:30	Coffee break
11:30 – 12:00	European Soil Data Centre (ESDAC): available information on contaminated sites (P. Panagos)
12:00 – 12:15	Discussion
12:15 – 13:30	Needs and data on contaminated sites at the national or regional level (10 min each presentation) A. Ranzi M. Carere I. Zurlytė P. Otoropec G. McWeeney Discussion

13:30 – 14:30	Lunch break
14:30 – 15:00	Review of initiatives from other EU networks related to "contaminated sites" Common Forum activities and approaches on contaminated sites (D. Darmendrail)
15:00 – 17:30	Human health toxicological assessment in contaminated sites
15:00 – 15:30	CLEA Initiative and strategy for characterizing human health risk of contaminated soils (I. Martin)
15:30 – 16:00	Coffee break
16:00 – 16:30	Public Health Assessment procedure (L. Wilder)
16:30 – 17:00	Tools for Quantitative risk assessment applied to contaminated sites in Europe (O. Mekel)
17:00 – 17:30	Discussion: opportunities and hurdles to apply a risk based approach in contaminated sites
20:30	*Social dinner*

Friday, 22 June 2012

09:30 – 09:45	Opening by A. Cuspilici Needs and goals of the Sicilian Contaminated Sites Projects
09:45 – 10:00	Summary of day 1
10:00 – 15:00	Designing epidemiological studies in contaminated sites
10:00 – 10:30	Development of a GIS-based platform and multimedia exposure model to map and analyse environmental inequalities (J. Caudeville)
10:30 – 11:00	Tools for spatial epidemiology applied to contaminated sites: the case of RIF (K. de Hoogh)
11:00 – 11:30	Biomonitoring approach applied to contaminated sites (G. Schoeters)
11:30 – 12:00	Coffee break
12:00 – 12:30	Exposure assessment of contaminants in the food chain (M. Schuhmacher)
12:30 – 13:00	Mortality/morbidity profile of population close to contaminated sites: methodology of SENTIERI project (R. Pirastu)
13:00 – 13:30	Options for designing epidemiological studies in contaminated sites (F. Forastiere)
13:30 – 14:30	Lunch break
14:30 – 15:00	Discussion on designing epidemiological studies in CS
15:00– 16:30	Discussion: • Definition of boundaries within which the WHO network will focus • Future collaborative actions within the network
16:30 – 17:00	*Closure and coffee*

Annex 5. List of participants in the workshop "Contaminated sites and health: priorities, interests, needs, methodological options"

Syracuse, 18 November 2011

Participants

Antonis Analitis
Department of Hygiene and Epidemiology, University of Athens, Greece

Ennio Cadum
ARPA Piemonte, Italy

Pietro Comba
Department of Environment and Primary Prevention, National Institute of Health, Italy

Antonino Cuspilici
Regione Siciliana
Sportello Unico per il risanamento delle Aree ad Elevato Rischio di Crisi Ambientale, Italy

Kees de Hoogh
Small Area Health Statistics Unit, HPA Centre for Environment and Health, Department of Epidemiology & Public Health, Imperial College London, United Kingdom

Francesco Forastiere
Department of Epidemiology, Regional Health Service, Lazio, Italy

Ivano Iavarone
Department of Environment and Primary Prevention, National Institute of Health, Italy

Piedad Martin-Olmedo
Escuela Andaluza de Salud Pública, Spain

Peter Otorepec
Institute of Public Health, Slovenia

Roberto Pasetto
Department of Environment and Primary Prevention, National Institute of Health, Italy

Roberta Pirastu
Sapienza University of Rome, c/o National Institute of Health, Italy

Andrea Ranzi
ARPA Emilia-Romagna – Reference Centre for Environment and Health, Italy

Benedetto Terracini
University of Turin, Italy

Jean-François Viel
Faculté de Médecine, Département de Santé Publique, France

Observers

Carla Ancona
Department of Epidemiology, Regional Health Service, Lazio, Italy

Caterina Bruno
Department of Environment and Primary Prevention, National Institute of Health, Italy

Achille Cernigliaro
Sicilian Epidemiological Observatory, Sicily Region, Italy

Marco De Santis
Department of Environment and Primary Prevention, National Institute of Health, Italy

Paolo Lauriola
ARPA Emilia-Romagna – Reference Centre for Environment and Health, Italy

Concetto Puglisi
Institute of Chemistry and Technology of Polymers , National Research Council (CNR), Italy

Gaetano Settimo
Department of Environment and Primary Prevention, National Institute of Health, Italy

Amerigo Zona
Department of Environment and Primary Prevention, National Institute of Health, Italy

World Health Organization – Regional Office for Europe

Marco Martuzzi
Programme Manager
European Centre for Environment and Health, Rome, Italy

Pierpaolo Mudu
Technical Officer
European Centre for Environment and Health, Rome, Italy

Julia Nowacki
Technical Officer
European Centre for Environment and Health, Bonn, Germany

Manuela Zingales
Programme Assistant
European Centre for Environment and Health, Rome, Italy

Annex 6. List of participants in the workshop "Contaminated sites and health: integrating data and resources"

Catania, 21–22 June 2012

Participants

Mario Carere
Department of Environment and Primary Prevention, National Institute of Health, Italy

Julien Caudeville
Institut national de l'environment industriel et des risques (INERIS), France

Antonino Cuspilici
Sicily Region
Sportello Unico per il risanamento delle Aree ad Elevato Rischio di Crisi Ambientale [Office for remediation plans of areas at high risk of environmental crisis], Italy

Kees De Hoogh
Small Area Health Statistics Unit, HPA Centre for Environment and Health, Department of Epidemiology & Public Health, Imperial College London, United Kingdom

Dominique Darmendrail
Common Forum on Contaminated Land in Europe, C/O BRGM, France

Alia Atitar de la Fuente
European Commission, DG Environment

Francesco Forastiere
Department of Epidemiology, Regional Health Service, Lazio, Italy

Ivano Iavarone
Department of Environment and Primary Prevention, National Institute of Health, Italy

Dorota Jarosinka
Integrated Environmental Assessment, European Environmental Agency, Denmark

Ian Martin
Environmental Agency, United Kingdom

Piedad Martin-Olmedo
Andalusian School of Public Health, Spain

Odile Mekel
Centre for Health NRW (LZG.NRW), Germany

Peter Otorepec
Institute of Public Health, Slovenia

Panos Panagos
Euopean Commission, Joint Research Centre, Italy

Roberto Pasetto
Department of Environment and Primary Prevention, National Institute of Health, Italy

Roberta Pirastu
Sapienza Rome University, c/o National Institute of Health, Italy

Concetto Puglisi
Institute of Chemistry and Technology of Polymers , National Research Council (CNR), Italy

Andrea Ranzi
ARPA Emilia-Romagna, Reference Centre for Environment and Health, Italy

Juri Ruut
Health Board, Estonia

Greet Schoeters
The Flemish Institute for Technological Research, Belgium

Marta Schuhmacher
Environmental Analysis and Management Group, Centre for Environmental Food and Toxicological Technology, Spain

Lynn Wilder
Division of Community Health Investigations, ATSDR, USA

Ingrida Zurlytė
Centre for Health Education and Disease Prevention, Lithuania

Observers

Carla Ancona
Department of Epidemiology, Regional Health Service, Lazio, Italy

Paola Pesce
University of Catania, Italy

Francesco Platania
Catania, Italy

Alfio Russo
University of Catania, Italy

Gaetano Settimo
Department of Environment and Primary Prevention, National Institute of Health, Italy

Rosario Tumino
Ragusa Cancer Registry and Sicilian Mesothelioma Registry, Italy

World Health Organization – Regional Office for Europe

Kristine Dance
Programme Assistant

Marco Martuzzi
Programme Manager
European Centre for Environment and Health, Bonn, Germany

Geraldine McWeeney
Technical Officer
Regional Office for Europe, Serbia, Belgrade

Pierpaolo Mudu
Technical Officer
European Centre for Environment and Health, Bonn, Germany

Interpreters

Carmelo Donato
Alessandra Perricone
Giovanna Laura Scalia

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.

Member States:

Albania
Andorra
Armenia
Austria
Azerbaijan
Belarus
Belgium
Bosnia and Herzegovina
Bulgaria
Croatia
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Georgia
Germany
Greece
Hungary
Iceland
Ireland
Israel
Italy
Kazakhstan
Kyrgyzstan
Latvia
Lithuania
Luxembourg
Malta
Monaco
Montenegro
Netherlands
Norway
Poland
Portugal
Republic of Moldova
Romania
Russian Federation
San Marino
Serbia
Slovakia
Slovenia
Spain
Sweden
Switzerland
Tajikistan
The former Yugoslav Republic of Macedonia
Turkey
Turkmenistan
Ukraine
United Kingdom
Uzbekistan

Original: English

In Europe, earlier industrialization and poor environmental management practices have left a legacy of thousands of contaminated sites. Past and current activities can cause local and diffuse accumulation of environmental stressors to an extent that might threaten human health and the environment, by altering air quality, hampering soil functions, and polluting groundwater and surface water.

The WHO European Centre for Environment and Health organized two technical meetings – which included representatives of environmental and public health agencies (at the national and international levels) and research experts – to explore priorities, interests and needs and to review the state of the art, the current methodological options, and knowledge gaps in the domain of contaminated sites and health.

The assessment of the possible health impact of contaminated sites is a challenging exercise, especially in the case of industrially contaminated sites with ongoing multiple industrial activities and involving multiple human exposures. Notwithstanding these complexities, a variety of methods and tools for health impact assessment have been developed and applied to study contaminated sites, and a broad range of resources is available; these must be carefully selected and applied, depending on the needs, objectives and local feasibility.

Available assessments suggest that contaminated sites are an important public health issue at the national and international levels. Priority topics and goals for collaborative work on contaminated sites and health were identified at the two meetings.

WHO Regional Office for Europe
UN City, Marmorvej 51, DK-2100 Copenhagen Ø, Denmark
Tel.: +45 45 33 70 0 Fax: +45 45 33 70 01
Email: contact@euro.who.int
Website: www.euro.who.int

This report is also available at: http://www.euro.who.int/contaminatedsites-and-health