



EUROPE

# Health effects of transport-related air pollution: summary for policy-makers

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# Introduction

The effects on health of transport-related air pollution are one of the leading concerns about transport. Research in recent decades consistently indicates that outdoor air pollution harms human health, and the evidence points to air pollution stemming from transport as an important contributor to the adverse effects.

This summary lists the results of a systematic literature review and comprehensive evaluation of the health risks of such pollution, and suggests steps to reduce them. The review focuses on air pollution related to road transport (mostly from urban and suburban passenger and freight transport) and the risks to human health.<sup>1</sup> It considers the entire chain of relevant issues:

- the present understanding of the effects of transport-related air pollution on health;
- the patterns of human exposure to this pollution;
- how this exposure is determined by the emission of pollution from transport sources; and
- how patterns and trends of human activities influence the intensity of emissions in Europe.

Reducing the harm done by pollution requires action at each link in this causal chain; the summary concludes by presenting some effective actions.

## Observed health effects

### Facts

Evidence from epidemiological and toxicological studies on the health effects of transport-related air pollution has increased substantially, although it is only a fraction of the total evidence on the health effects of urban air pollution. A review of this evidence indicates that transport-related air pollution contributes to an increased risk of death, particularly from cardiopulmonary causes, and increases the risk of non-allergic respiratory symptoms and disease.

Experimental research indicates that the effects are linked to changes in the formation of reactive oxygen species, changes in antioxidant defence and increased inflammation, thus pointing out some parameters of susceptibility. Laboratory studies indicate

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<sup>1</sup> Readers wishing to consult the wide range of literature reviewed are referred to the larger book (Krzyzanowski M, Kuna-Dibbert B, Schneider J, eds. *Health effects of transport-related air pollution*. Copenhagen, WHO Regional Office for Europe, 2005). The Annex lists the many authors and contributors to the review and evaluation.

that transport-related air pollution may increase the risk of allergy development and can exacerbate symptoms, particularly in susceptible subgroups. The evidence from population studies, however, does not consistently support this notion.

Few studies have been conducted on the effects of transport-related air pollution on cardiovascular morbidity, but they report a significant increase of risk of myocardial infarction following exposure. Other studies and the experimental evidence indicate changes in autonomic nervous regulation and increased inflammatory responses as result of exposure. A few available studies suggest an increased incidence of lung cancer in people with long exposure to transport-related air pollution. While some studies suggest that it also causes adverse pregnancy outcomes, such as premature birth and low birth weight, the available evidence is not consistent.

Few intervention studies have been conducted, and most of them were not specific for traffic-related air pollution. Nevertheless, some evidence indicates that reducing such pollution may directly reduce acute asthma attacks and the need for related medical care in children. Long-term decreases in air pollution levels are associated with a gain in life expectancy and declines in bronchial hyperreactivity and the average annual trend in deaths from all causes and from respiratory and cardiovascular diseases.

Often, the effects observed in epidemiological studies cannot be attributed to the specific pollution indicator used in the study, but to a mixture of pollutants. Fine particulate matter (with a diameter of less than 2.5  $\mu\text{m}$  – PM<sub>2.5</sub> – and including black smoke) and ozone are associated with increased risks of mortality and respiratory morbidity, while exposure to nitrogen dioxide, ozone and PM has been linked to allergic responses. Other indicators of exposure to transport-related air pollution – such as living at or near major roads and, partly, high self-reported traffic intensity at one's home address – were associated with several adverse health outcomes.

## Human exposure

Exposure – that is, people's contact with a pollutant – is a necessary condition for the occurrence of a health effect. The number of exposed people, the duration of contact and the concentration of the pollutant in the place where the contact occurs determine the magnitude of the exposure and the extent of health effects in a population.

## Facts

Assessing the population's exposure to transport-related air pollution requires the consideration of a range of factors. Levels of pollutants vary between cities and even over short distances. Another important factor is where populations and individuals live and work.

The pollutants of concern to health are: nitrogen dioxide, carbon monoxide, PM<sub>10</sub> (PM with a diameter of less than 10  $\mu\text{m}$ ) and PM<sub>2.5</sub>, back smoke, benzene, polycyclic

aromatic hydrocarbons (PAHs) and metals, including lead. Many factors determine the levels of exposure for both individuals and populations.

The volume and spatial distribution of emissions, as well as dispersion conditions, affect pollution levels. Time–activity patterns – particularly living and/or working near busy roads – and time spent in traffic are critical for population exposure. Travellers are often exposed to pollution levels three times those of the background. In-vehicle exposures to primary exhaust gases and PM are especially high. Highly exposed and vulnerable groups include:

1. people (especially the elderly and very young) who live close to busy roads;
2. children whose schools lie close to major roadways; and
3. people who spend much of their time travelling through or working in environments with heavy traffic, such as traffic wardens and police, street traders and some commuters.

In addition, urban planning and development – which determine patterns of residence and mobility and the availability of public transport and non-motorized transport options – are equally strong factors in shaping exposure. Although the available data and models do not allow precise estimation and prediction of exposure patterns, traffic can be concluded to be responsible for an increasing proportion of population exposure to air pollution.

Exposure to transport-related air pollution is often combined with exposure to pollutants from other sources typical for urban areas, such as emissions from community combustion (particularly for heating and cooking) or industry. This complicates both the assessment of risk and the design of effective measures for risk reduction.

## Trends

The available data and models restrict the possibility for precise estimates and predictions of exposure patterns. Trends in exposure are difficult to establish because relevant research programmes do not exist. As a result, population-level estimates do not adequately reflect extreme personal exposures.

Owing to trends in urban emissions, however, traffic may conceivably be responsible for an increasing proportion of the population's exposure to air pollution, despite a decrease in pollution levels.

## Contribution of traffic to pollution levels

Pollution levels (concentrations) are crucial determinants of exposure, often independent of the behaviour or choices of exposed individuals. Emissions from traffic sources contribute significantly to pollution. Most of the relevant available data originate from

the countries belonging to the European Union (EU) before May 2004. The patterns observed in these countries may be generalized to the other Member States in the Region, however, since they are following transport patterns seen in the EU.

## Facts

In the 1990s, the introduction of technological measures – such as improvements in fuel quality and abatement techniques such as catalytic converters and engine designs – led to improvement in overall air quality in most cities, even though road traffic increased. Average background ozone concentrations in urban areas increased, however, probably owing to reduced titration of ozone caused by decreasing emissions of nitric oxide gas.

In most urban areas in the countries belonging to the EU before May 2004, road transport is the most important source of nitrogen oxides, carbon monoxide, benzene, black smoke (except in cities where coal is widely used for domestic heating) and ultrafine PM (with a diameter of less than 1.0  $\mu\text{m}$  – PM1.0) in ambient air. Tailpipe emissions of primary particles by road transport contribute up to 30% of fine PM (PM2.5), and non-tailpipe emissions (from, for example, the resuspension of road dust and wear on brake-linings) is the most important source for coarse PM (PM10). Road transport is also the main contributor to emissions of nitrogen dioxide and benzene in many cities, and the major reason for non-compliance with current EU air-quality standards.

Concentrations of transport-related air pollution vary between areas of a city. In a belt along urban highways that can be 0.2–0.5 km wide, concentrations of nitric oxide, black smoke and PM2.5 are much higher than background levels. The gradient is less pronounced for nitrogen dioxide, while PM2.5 and PM10 have an even smoother spatial distribution. In “street canyons”, with heavy traffic and limited dispersion of emissions, levels of all traffic-related pollutants are much higher than the urban background.

## Trends

Current policies should result in improved air quality. In 2010, the concentration of traffic-related pollutants is expected to be roughly 50% of that in 1995, and 90% of the urban population in the countries belonging to the EU before May 2004 is expected to live in areas meeting the EU air-quality limit values for nitrogen dioxide (hourly value), carbon monoxide, benzene and lead.

Nevertheless, increasing traffic congestion and the growth of traffic volume in urban areas are undermining the benefits to urban air quality resulting from the introduction of cleaner fuels, more stringent emission limits for new vehicles, and road management. Unless additional measures are taken, annual nitrogen dioxide and

24-hour and annual PM10 levels are expected to exceed current EU limit values for 20%, 70% and 50% of the urban population, respectively, mainly as a result of road transport emissions.

At urban and rural background locations, average ozone concentrations are expected to increase further, owing to decreasing nitrogen oxide emissions and possibly to an increase in hemispheric background concentrations of ozone. In addition, the relative contribution of non-tailpipe emissions of road traffic to PM10 concentrations is expected to increase in coming years.

Further, alternative vehicle technologies are unlikely either to become important in the market in the next decade or to have a significant impact on air quality. Consequently, a large proportion of the European population is expected to continue living in areas with high PM and nitrogen dioxide levels, mainly owing to road-traffic emissions.

Trends in transport development in the eastern half of the WHO European Region are following the patterns in western countries, posing the risk of an increased contribution of traffic to air pollution.

## Conclusions

Owing to continuing urbanization and the expansion of urban areas, an increasing share of the population is likely to live in areas with higher levels of traffic-related pollutants, even though overall air pollution levels are in general falling. Greater exposure to traffic-related air pollutants is probably resulting from the increasing share of commuting by passenger vehicles and the increasing time spent on roads with heavy and congested traffic.

## Factors determining emissions

There is no smoke without combustion. This section shows how this fact, combined with behaviour and development trends of societies, affects the volume and patterns of emissions, which in turn affect air quality.

## Facts

Internal combustion engines and conventional fuels are the dominant contributor to transport-related air pollution. To counter this, current regulations (such as the EU emissions standards called Euro 0 through Euro IV) and further future legislation (Euro V and Euro VI) will further reduce tailpipe emissions of regulated pollutants.

The volumes of transport in the western half of the WHO European Region are very high. Those in central Europe are much lower – one third of the western level for passenger transport and one tenth of that for freight transport – but were expected to increase soon after the enlargement of the EU. In the countries of eastern Europe,

the Caucasus and central Asia, long-distance public and freight transport broke down between 1990 and 1998.

In the 15 countries belonging to the EU before May 2004, passenger cars cover 80% of their mileage on urban and suburban roads; lorries cover about 80% of their mileage on suburban roads and motorways. In addition, the motorway network in the EU expanded by 2.7% per year in the 1990s. Urban and suburban road extension is marginal, while traffic volume is in general rising, leading to higher traffic density and congestion in cities.

Volumes of urban public transport have not changed substantially in recent years, as a consequence of urban development. Motorcycles and mopeds have the potential to increase traffic flow in cities, but also have high emissions of various hydrocarbons, carbon monoxide and PM, which are harmful to health.

Many urban trips cover distances of less than 6 km. Since the effectiveness of catalytic converters in the initial minutes of engine work is small, the average emission per distance driven is very high in urban areas. Poorly maintained vehicles, lacking exhaust after-treatment systems, are responsible for a major part of the emissions.

## Trends

Road transport will continue to grow in the EU in the next decades. The eastern half of the Region is following the transport pattern in the western half: more private cars and more goods transport with lorries.

As to technological issues, conventional diesel and petrol engines will dominate for at least the next 10–20 years. The market share of diesel-fuelled vehicles will continue to increase. Emissions per vehicle kilometre driven will decrease. Alternative vehicle technologies – the use of fuel cells and electric and hybrid vehicles – are unlikely to become important on the market before 2015.

A number of promising technologies are candidates for lowering vehicle emissions, including particle traps, a system to reduce nitrogen oxide emissions, preheated catalytic converters and electronic vehicle controls. For further emission reductions, new engine and aftertreatment technologies may require fuels that are free of metals and have zero sulfur content and a low content of PAHs.

By 2020, in the EU, 20% of conventional fuels should be replaced by such substitutes as biofuels, natural gas and hydrogen. The main driving force for this initiative is policy on climate change.

## Conclusions

In urban areas, congestion and the large number of short trips made under cold-start conditions offset the decrease in emissions per vehicle. Road transport is likely to remain a significant contributor to air pollution in cities in coming decades.



## Next steps for policy, action and research

Estimates based on the evidence from accumulated research indicate that tens of thousands of deaths per year could be linked to ambient air pollution in European cities, shortening life expectancy by an average of up to a year. This is similar to the number of deaths from traffic accidents.

The available evidence justifies a range of action to protect health from the harmful effects of transport-related air pollution. Nevertheless, further research is needed, both to increase the understanding of causal links between transport and health and to make action more effective. Policies must consider all the aspects of transport and mobility – both negative and positive – if their implementation is to maximize health benefits for people in the WHO European Region.

## Action

Despite the remaining needs for research, the expected health benefits justify measures to reduce exposure to transport-related air pollution. For example, traffic management significantly reduces the exposure of the residents of urban areas.

Better integration of environmental and health considerations in urban planning can lead to, for example:

- siting offices and commercial areas in ways that reduce the need for motorized transport;
- preventing traffic congestion;
- creating green areas;
- siting non-residential functions around urban highways; and
- separating pedestrians and bicyclists from road traffic.

Urban planning may aim at integrative measures that lower emission rates, such as promoting highly efficient, service-oriented and clean public transport and improving traffic flow. Revitalizing railway systems for freight transport can reduce not only road travel but also the risk of increased air pollution due to the spread of urban areas.

The development of technologies likely to lower the emission levels of conventional vehicles should be promoted. Control mechanisms of proven effectiveness (such as mandatory car inspections to eliminate gross polluters and badly maintained vehicles) should be more widely used. Further, alternative vehicle technologies and substitute fuels hold the potential for substantial future reductions in emissions of hazardous air pollutants. They should be further explored and developed.

## Research

Some of the knowledge needed to form the basis of effective action is still lacking. More research is needed:

1. precisely to quantify the harmful effects of transport-related air pollution, particularly on vulnerable groups such as children, elderly people and people already suffering from chronic disease;
2. to estimate population exposure, which must reflect the spatial and temporal variability of personal exposures and the conditions in the microenvironments where people live and work;
3. to track trends in populations' exposure to air pollution in general and to transport-related air pollution in particular, which may be rising;
4. adequately to quantify the associations between exposure and adverse health effects, which includes making a comprehensive risk assessment of health impact, evaluating long-term health effects and measuring and/or modelling exposure;
5. to determine what constituents of traffic emissions are responsible for the observed health effects in human populations, which includes making studies of the role of diesel emissions and new pollutants, such as trace elements from catalytic converters; and
6. to assess the public health benefits of various measures to improve air quality, particularly those addressing transport-related air pollution, in order to support policies.

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While transport is a vital part of modern life, policy-makers in the WHO European Region face the difficult challenge of reducing the related risks to health and the environment and meeting countries' requirements for effective transport systems. Diseases related to the air pollution caused by road transport affect tens of thousands of people in the Region each year. Policies for more effective action need to be based on a better understanding of the role of various pollutants in harming health and the determinants of exposure.

This booklet helps to meet this need. It summarizes the results of a systematic review of the literature and a comprehensive evaluation of the health hazards of transport-related air pollution. It identifies the key facts emerging from the accumulated evidence, and uses them to suggest both topics for further research and well-justified short-term action to protect health. It can help policy-makers play their part in making and implementing transport policies in the European Region that maximize the benefits to health.

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