Air pollution, health risks and costs

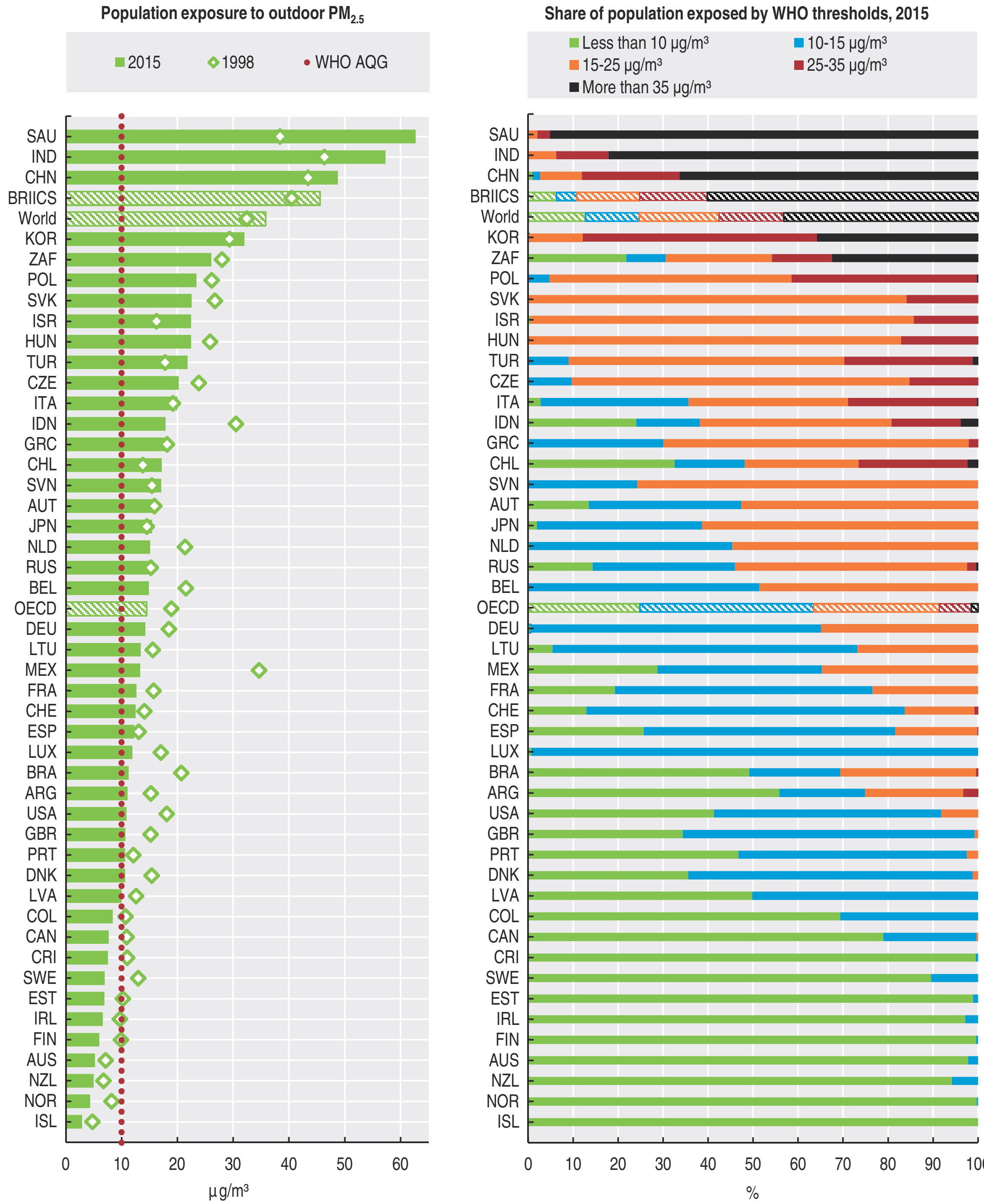
Air pollution is the single greatest environmental health risk worldwide. Reducing risks to human health from degraded air quality, then, is central for improving people's lives and well-being. Fine particulate matter ($PM_{2.5}$), in particular, is the most serious pollutant globally from a human health perspective. Chronic exposure even to moderate levels of $PM_{2.5}$ substantially increases the risk of heart disease and stroke, the leading causes of death in OECD countries. It also increases the risk of respiratory diseases, including lung cancer, chronic obstructive pulmonary disease and respiratory infections (WHO, 2016; Burnett et al., 2014; Brauer et al., 2016). Other pollutants of most concern are small particulates (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2). Emissions from transport, industry, electricity generation, agriculture and domestic (household) sources are the main contributors to outdoor air pollution (EEA, 2016a; Caiazzo et al., 2013).

Air pollution causes millions of avoidable deaths every year. It is therefore urgent to implement policies that reduce emissions of air pollutants and limit the population's exposure to air pollution. Emissions can be reduced by substituting dirty fuels for cleaner ones, focusing development on cleaner industries, reducing consumption of polluting products and adopting cleaner technologies. Behavioural and lifestyle changes are also important. Policies that provide incentives across a broad spectrum of firms and consumers (e.g. emission or energy taxes) tend to be more cost-efficient than those that target a specific product, fuel or technology (e.g. subsidies for electric cars).

Both the sources of air pollution and severity of exposure vary across and within countries. Hence it is important to tailor policies to specific local circumstances. For example, more stringent measures are required in densely populated areas or for emission sources located upwind from urban areas. Such spatially heterogeneous policies help achieve environmental objectives at lower costs than measures that apply uniformly to sources in all locations and to populations at all risk levels. Cost-efficient implementation of air pollution policies deserves attention because it allows a faster transition of countries towards a greener growth model. At the same time, it generates more economic opportunities (jobs, exports, etc.).

Progress can be assessed by measuring the exposure of population to air pollutants, and by assessing the health consequences and their economic costs. The costs of air pollution mainly arise from its detrimental impact on human health. These take the form of shorter life expectancy, increased healthcare costs and reduced labour productivity. Further consequences include reduced agricultural output and damage to ecosystems.

Figure 10.1. **Population exposure to air pollution by $PM_{2.5}$ exceeds guideline in many countries**



Note: These estimates are for chronic outdoor exposure to $PM_{2.5}$. Internationally comparable measures of average $PM_{2.5}$ concentrations are derived from satellite observations, chemical transport models and ground monitoring stations. Population exposure to air pollution is calculated by weighting concentrations with populations in each cell of the underlying gridded data. These estimates include pollutants from both anthropogenic and natural sources. There is a possibility of over-estimates or under-estimates in certain locations. While satellite observations are less precise than in-situ monitoring, the two data sources are complementary. They allow estimates of concentrations in locations not covered by ground monitoring networks; they also improve the comparability of estimates between different locations.

Source: OECD (2017a), "Exposure to air pollution", *OECD Environment Statistics* (database); OECD calculations based on van Donkelaar et al. (2016) and CIESIN (2016).

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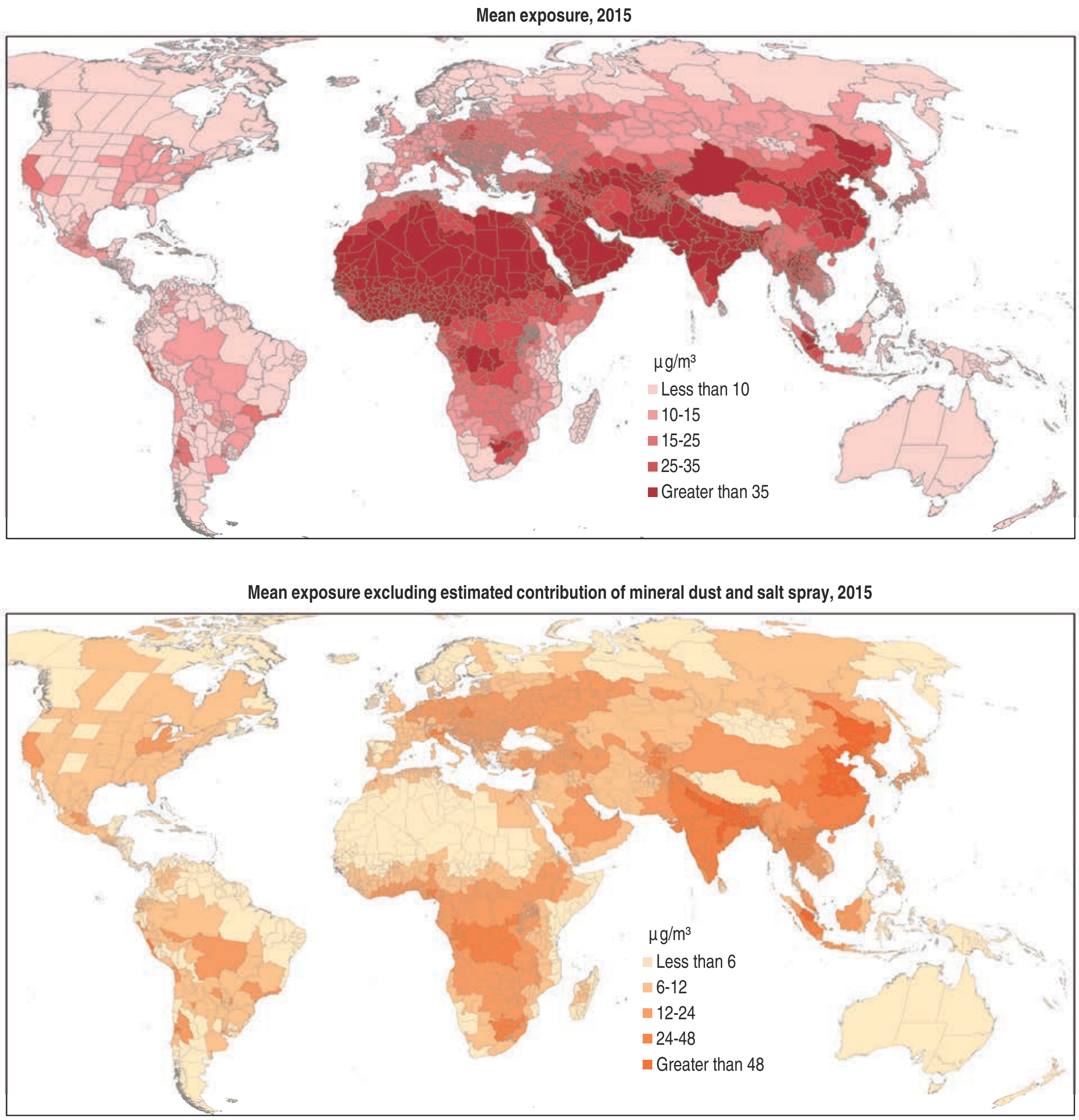
Figure 10.2. **Population exposure to air pollution by $PM_{2.5}$**



Source: OECD (2017a), "Exposure to air pollution", *OECD Environment Statistics* (database); OECD calculations based on van Donkelaar et al. (2016) and CIESIN (2016). Administrative boundaries: FAO (2015).

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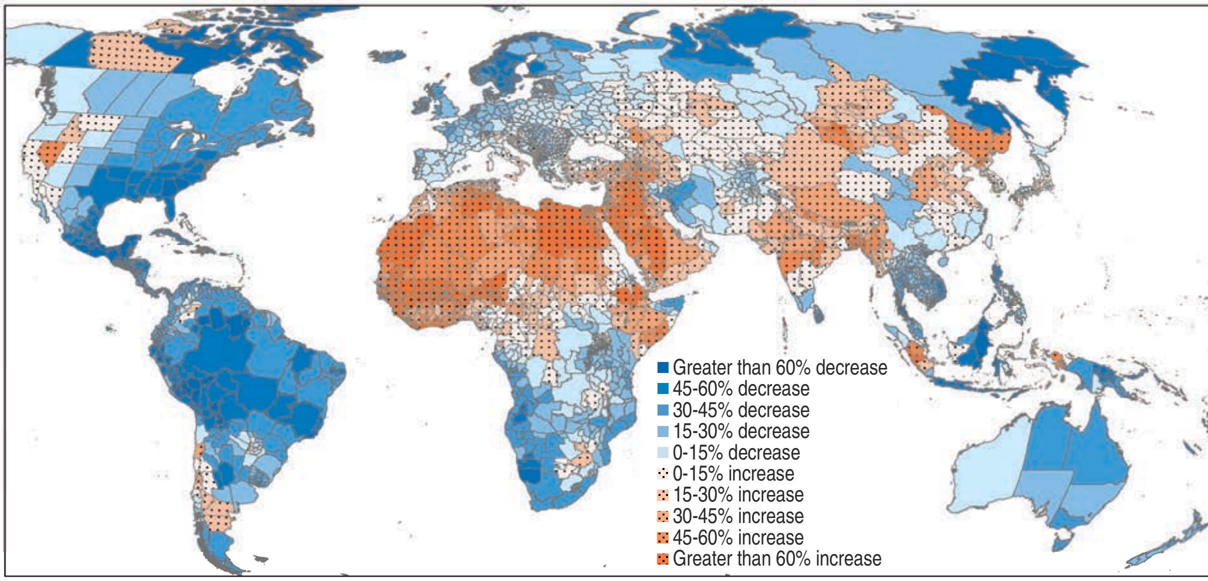
Main trends and recent developments

Human exposure to $PM_{2.5}$ remains dangerously high

Despite commendable improvements in reducing exposure, the populations of most OECD countries remain chronically exposed to harmful levels of $PM_{2.5}$ (Figure 10.1). Less than one in three OECD countries meet the WHO Air Quality Guideline for annual average $PM_{2.5}$ exposure of 10 micrograms per cubic metre (µg/m^3). Even this value is not a "safe"

Figure 10.3. **Change in population exposure to air pollution by $PM_{2.5}$ (1998-2015)**



Source: OECD (2017a), "Exposure to air pollution", *OECD Environment Statistics* (database); OECD calculations based on van Donkelaar et al. (2016) and CIESIN (2016). Administrative boundaries: FAO (2015).

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level; the 10 µg/m^3 guideline is still associated with elevated risk of the diseases listed previously (WHO, 2016). Progress in most OECD countries contrasts with steady increases in $PM_{2.5}$ exposure in the People's Republic of China (hereafter China) and India from already very high, to even more extreme levels.

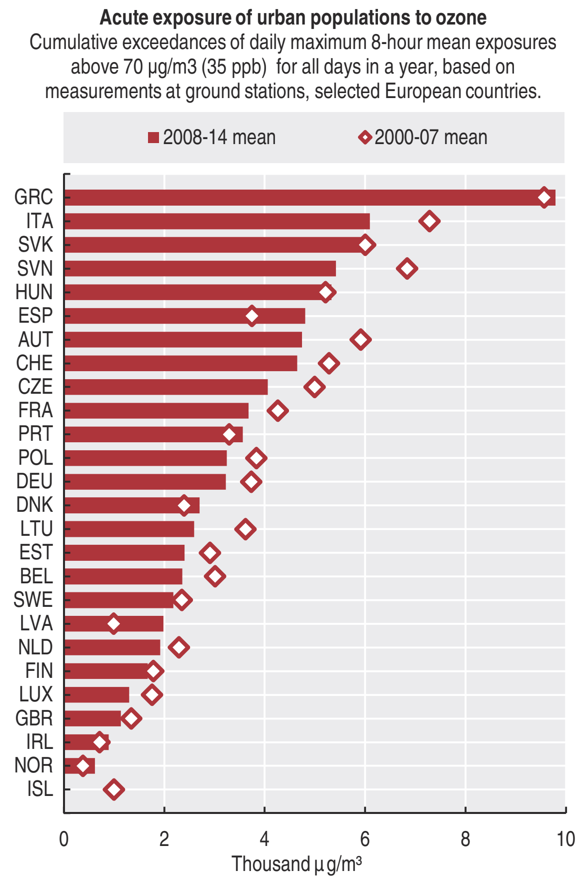
There has been little improvement in population exposure to air pollution by ozone

Exposure to ground-level ozone (O_3) has serious consequences for human health, contributing to, or triggering, respiratory diseases. These include breathing problems, asthma and reduced lung function (WHO, 2016; Brauer et al., 2016). Ozone exposure is highest in emission-dense countries with warm and sunny summers. In Europe, exceedances of a 70 µg/m^3 exposure level in urban areas changed little between 2000-07 and 2008-14. However, some countries with high levels like Italy, Slovenia and Austria appear to be making progress (Figure 10.4). Almost all European countries exceed this O_3 exposure level at some point each year. Determining the causes of O_3 trends is difficult because ozone results from complex interactions between different phenomena. The most important determinants are background atmospheric chemistry, climate, anthropogenic and biogenic emissions of ozone precursors such as volatile organic compounds, and the ratios between different emitted chemicals.

Air pollution is estimated to cause around 0.5 million premature deaths, with a welfare cost equivalent to 3.6% of GDP in the OECD area each year

In OECD countries, exposure to outdoor $PM_{2.5}$ and ozone can be attributed to an estimated 500 000 premature deaths (GBD, 2015). The annual welfare cost associated with these premature deaths can be calculated in terms of what the population would be willing to pay to avoid the fatalities. This amounts to USD 1.7 trillion, equivalent to 3.6% of GDP for the OECD area (Figure 10.5b). Cardiovascular disease from exposure to outdoor particulates

Figure 10.4. **Population exposure to air pollution by O_3 has seen little improvement**



Note: For acute exposure, WHO recommends a maximum daily 8-hour mean exposure limit of 100 µg/m³ to provide adequate protection of public health. Establishing longer-term health responses to O_3 is complex. There is insufficient evidence to recommend a guideline value for chronic exposure. For some countries the values shown in this figure are not representative of the entire population.

Source: Eurostat (2017), *Urban Population Exposure to Air pollution by Ozone* (database).

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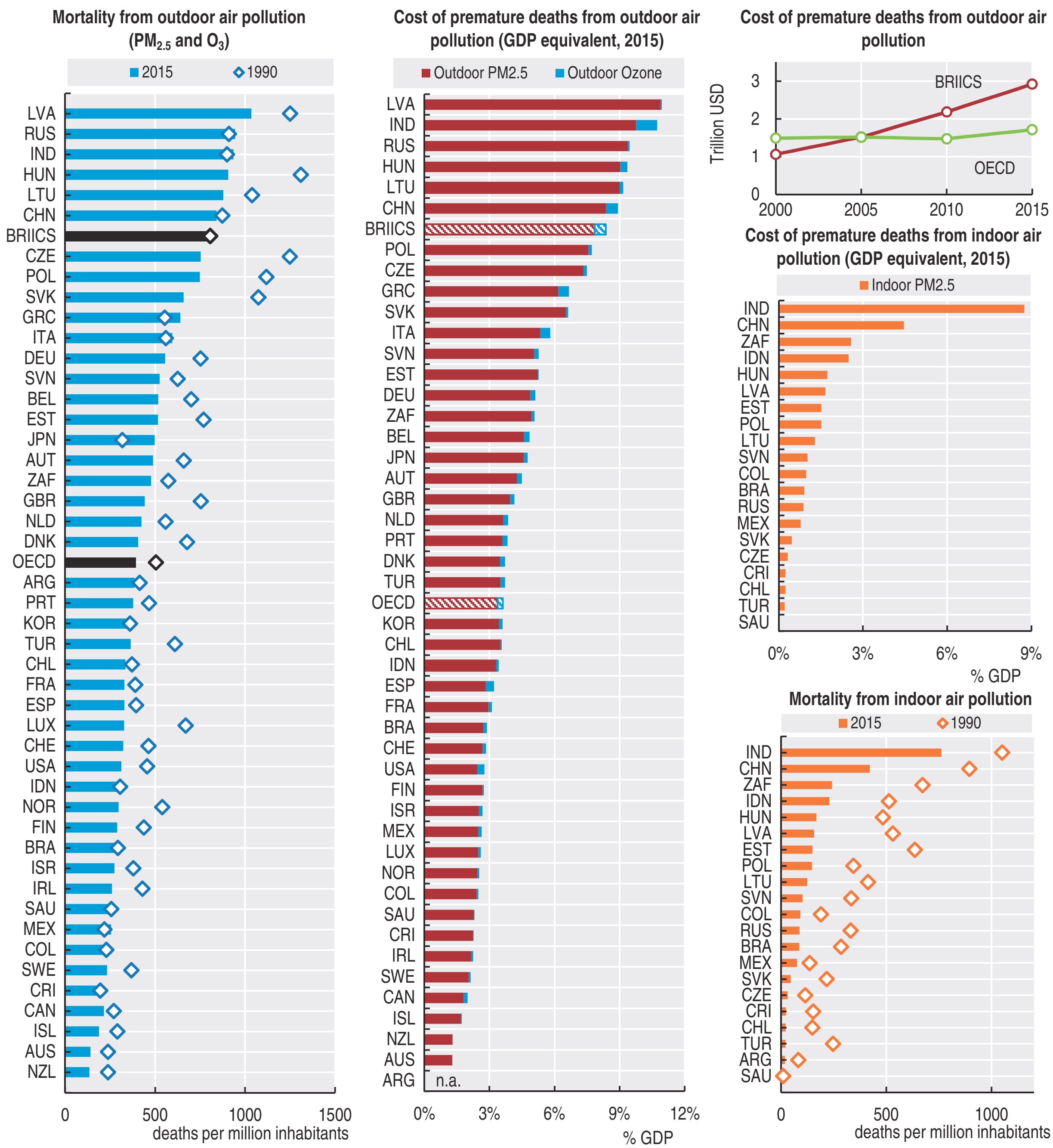
causes most of these deaths. Globally, GBD (2015) estimates exceed 4.4 million deaths annually. In some non-OECD economies, such as India, the health risks and welfare costs of exposure to indoor air pollution come close to those of exposure to outdoor air pollution (Figure 10.5d, Figure 10.5e).

The welfare cost from premature deaths is projected to more than double in OECD countries by 2060

According to OECD (2016) annual welfare costs from premature deaths are projected to more than double in OECD countries without more stringent policy action. They are expected to reach USD 3.5 trillion in 2060 (equivalent to 5% of GDP in 2060). In non-OECD economies, costs are projected to increase tenfold. This could reach USD 15-22 trillion in 2060 (equivalent to 7-10% of their GDP in 2060).

Furthermore, the costs to the economy, including through reduced labour productivity, are projected to add an extra USD 3.3 trillion by 2060 (OECD, 2016). Potential benefits of pollution mitigation would thus be very significant.

Figure 10.5. **Air pollution weighs heavily on population's health and welfare**



Source (mortality): GBD (2015), *Global Burden of Disease Study 2015 Results*. Mortality data on indoor air pollution from GBD are available for only some countries. They draw on WHO information and national household surveys.

Source (costs): OECD calculations using methodology adapted from OECD (2014). A standard value-of-statistical-life (VSL) estimate is used to calculate the costs of premature mortalities. The country-specific costs presented here account for differences in income levels and income elasticities across countries (elasticity of 0.8 for high-, 0.9 for middle- and 1 for low-income countries). Nevertheless, the underlying VSL estimate might be less reliable when applied to countries with different standards of living or extrapolated over time. VSL also captures non-market values that are unrelated to expenditures and therefore not an integral part of the calculation of GDP. Consequently the cost estimates are compared with GDP only for illustration.

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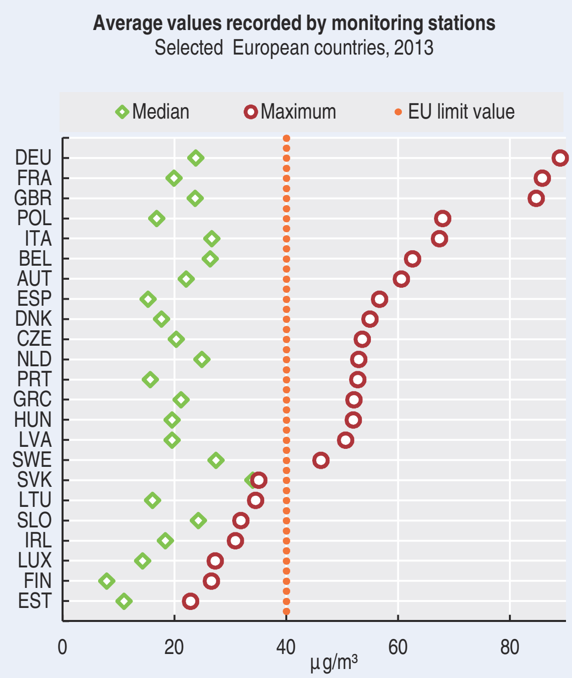
Box 10.1. **Nitrogen dioxide is a persistent problem in cities**

Along with fine particulates and ozone, nitrogen dioxide (NO_2) is the other major constituent of the air pollution mix in OECD countries. Like ozone, NO_2 causes respiratory problems such as bronchitis symptoms in asthmatic children and reduced lung function growth. In 2013, some monitoring stations in Germany, France and the United Kingdom, recorded annual average concentrations over twice the WHO guideline and EU legal limit values. Most European countries have at least one city where the average considerably exceeds limits. NO_2 is predominantly emitted by vehicles. In Paris, for example, road vehicles emit an estimated 62% of NO_2 (Airparif, 2014).

Reducing motor vehicle emissions in densely populated areas could make the greatest impact on NO_2 exposure. Strategies include modal shifts, electrification of vehicle fleets and reduced urban congestion. The public health benefits of more efficient transport are compounded by reductions of other pollutants; in the case of Paris, road traffic generates more than half of particulate emissions.

Figure 10.6. **NO_2 concentrations exceed limits in cities**



Source: EEA (2016b), *Attainment Situation for NO_2.*

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Measurability and interpretation

Exposure to air pollution is assessed against three outdoor air pollutants with the most significant health impacts:

- **Population exposure to outdoor $PM_{2.5}$** is derived using pollutant concentration estimates. These use chemical transport models (which, in turn, rely on several emissions databases), satellite-based measurements of aerosol optical depth and measurements from ground stations. This hybrid approach has the advantage of being available for areas that lack a sufficient density of ground-based air monitoring stations. It is also more comparable between different areas than estimates derived from ground-based measurements stations alone. The estimates include particulates originating from both natural and anthropogenic sources. Population exposure is calculated by weighting concentrations with population in each cell of the resulting gridded concentration data.

- **Population exposure to ground-level ozone** Acute O_3 exposure estimates in urban areas are average ground station measurements weighted by neighbouring population. The indicator refers to the annual sum of daily maximum 8-hour mean concentrations above a threshold (70 $\mu g/m^3$ or 35 parts per billion) at urban background stations in agglomerations and calculated for all days in a year. Current WHO air quality guidelines for ozone (O_3) are 8-hour mean concentrations of 100 $\mu g/m^3$.
- **Concentrations of NO_2** measured at ground-based monitoring stations.

The health impacts from exposure to air pollution are then evaluated:

- **Cost of outdoor air pollution:** The cost of the health impact of air pollution is evaluated in terms of what the population at large would be "willing to pay" to avoid premature deaths from exposure to outdoor air pollution (the cost estimates take only $PM_{2.5}$ and O_3 into account). These welfare costs are calculated using estimates of the "Value of a Statistical Life". These, in turn, are derived from a meta-analysis of a large number of studies of individual willingness-to-pay to reduce the risk of premature mortality. Cost estimates represent the cost of premature mortalities. They exclude any morbidity impacts (labour productivity losses, treatment costs and willingness to pay to avoid pain and suffering from illness). They also exclude impacts other than those on human health (e.g. on built structures, agricultural productivity, ecosystem health). The social cost of air pollution is thus greater than the cost of mortalities presented in this chapter. Yet the available evidence suggests that mortality costs account for the bulk of the total costs to society. See also *Glossary*.

Exposure indicators provide only a partial view of air pollution severity and consequences aggregated across the entire population. Importantly, there is generally no "safe level" of exposure for many pollutants. Even where guideline or target exposures are met, substantial public health and economic benefits can be realised through further improvements in air quality.

Better estimates are needed for exposure to both outdoor and indoor air pollution. Particular attention should be paid to exposure of sensitive groups and quantitative impact on human health (and associated distributional and equity issues). Although many important gaps remain, available data are improving. This heightened quality is driven by two trends. First, epidemiological evidence of the severity of the impacts of air pollution on human health is increasingly strong. Second, hybrid approaches to measuring pollutant concentration present new opportunities to use different types of data from several different sources. This allows for more robust estimates of pollutant concentrations.

Sources

Airparif (2014), "The State of the Air (Paris)", *www.airparif.asso.fr/etat-air/air-et-climat-quelques-chiffres*.

Brauer, M. et al. (2016), "Ambient air pollution exposure estimation for the global burden of disease 2013", *Environmental Science and Technology*, Vol. 50/1, pp. 79-88.

Burnett, R.T. et al. (2014), "An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure", *Environmental Health Perspectives*, 122: 397-403.

Caiazzo, F. et al. (2013), "Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005", *Atmospheric Environment*, 79: 198-208.

CIESIN (2016), Gridded Population of the World, version 4 (GPWv4), Center for International Earth Science Information Network, *http://dx.doi.org/10.7927/H4X63JVC*.

EEA (2016a), Air Quality in Europe – 2016 Report, *www.eea.europa.eu/publications/air-quality-in-europe-2016*.

EEA (2016b), Attainment situation for NO_2, *www.eea.europa.eu/data-and-maps/daviz/attainment-situation-for-annual-limit-1#tab-chart_1*.

Eurostat (2017), *Urban Population Exposure to Air Pollution by Ozone* (database), *http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tsdph380* (accessed in February 2017).

FAO (2015), Global Administrative Unit Layers (GAUL) 2014 version, FAO-GeoNetwork, Food and Agriculture Organization of the United Nations, *www.fao.org/geonetwork/srv/en/metadata.show?id=12691 (accessed in March 2016)*.

GBD (2015), "Global Burden of Disease Study 2015 Results", Institute for Health Metrics and Evaluation, Seattle, United States, *http://ghdx.healthdata.org/gbd-results-tool* (accessed in February 2017).

Mackie, A., I. Haščič and M. Cárdenas Rodríguez (2016), "Population Exposure to Fine Particles: Methodology and Results for OECD and G20 Countries", *OECD Green Growth Papers*, No. 2016/02, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5jlsqs8g1t9r-en*.

OECD (2017a), "Exposure to air pollution, *OECD Environment Statistics* (database), *http://dx.doi.org/10.1787/env-data-en* (accessed in March 2017).

OECD (2017b), "Green growth indicators", *OECD Environment Statistics* (database), *http://dx.doi.org/10.1787/data-00665-en* (accessed in March 2017).

OECD (2016), *The Economic Consequences of Outdoor Air Pollution*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264257474-en*.

OECD (2014), *The Cost of Air Pollution: Health Impacts of Road Transport*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/9789264210448-en*.

van Donkelaar et al. (2016), Global Estimates of Fine Particulate Matter using a Combined Geophysical-Statistical Method with Information from Satellites, Models, and Monitors, *Environmental Science and Technology*, *http://dx.doi.org/10.1021/acs.est.5b05833*.

WHO (2016), Ambient Air Quality and Health (factsheet), World Health Organization, Geneva, *www.who.int/mediacentre/factsheets/fs313/en*.

Further reading

Roy, R. (2016), "The cost of air pollution in Africa", *OECD Development Centre Working Papers*, No. 333, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5jlqzq77x6f8-en*.

US EPA (2011), *The Benefits and Costs of the Clean Air Act from 1990 to 2020,* United States Environmental Protection Agency, Washington, DC, *www.epa.gov/cleanairactbenefits/feb11/summaryreport.pdf*.

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