Seeing Gray

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What is smog, what does it consist of, and where does it come from? How badly polluted is the air in Poland in relation to other countries in Europe?

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The problem of high concentrations of suspended particular matter in the air is garnering ever greater public attention, giving rise to numerous societal initiatives and websites meant to inform and warn society about the potential health risks. Personal air monitoring devices are also gaining popularity. And yet despite this rising societal awareness and numerous initiatives undertaken on the local and central governments, the problem of smog keeps resurfacing in Poland and elsewhere, usually during the colder part of the year when residential heating is required. Each time it provokes renewed debate about its causes and potential methods of mitigation.

The term "smog" refers to an occurrence of particularly high concentrations of airborne pollutants of anthropogenic origin (human-generated), usually in times of cold temperatures and calm wind conditions. The phenomenon that raises particular interest and discussion in Poland is known as "London smog," which is comprised of both particular matter particles and gaseous pollutants, including nitrogen oxides, sulphur oxides, and carbon monoxide, and usually occurs in the colder part of the year. Particular matter pollutants are solid particles suspended in the air. These particles are of varying composition and size, as a result of which they may be of varying harmfulness. A standard way of classifying them is in terms of a diameter, a parameter crucial for their ability for long-range transport from their original source and the effectiveness of removal from the atmosphere. Particles are usually classified into three groups: PM10 particles are smaller than 10 µm (micrometres) in diameter, the PM2.5 class includes those smaller than 2.5 µm in diameter, and the PM0.1 class includes those smaller than 0.1 µm. Particular matter pollutants are a mixture of organic and inorganic species. They may also include toxic substances, such as polycyclic aromatic hydrocarbons such as benzo[a]pyrene (BaP), heavy metals, dioxins and furan.

The question of size

Air pollution has a negative impact on human health, ranging from slight changes in the respiratory system all the way to significantly shorter lifespans. Those at highest risk are children, the elderly, and the ill (especially people who already have respiratory diseases). As we have mentioned, the impact on humans depends in large part on the size of the particles. The coarse particle fraction (PM10 particles, excluding the fine PM2.5 fraction) can be removed from the air by sedimentation processes and atmospheric precipitation within a few hours after their emission, whereas PM2.5 particles remain in the air for several days or even weeks. The longer persistence of PM2.5 particles is conducive to transport over longer distances and longer-term impact on humans. The size of particles is also important for how they penetrate the body. The coarse particular matter fraction may accumulate in the upper respiratory system, reaching the lungs, whereas fine PM2.5 particles can penetrate into the deepest parts of the lungs.

Many studies undertaken in both the United States and Europe have shown that when airborne particles concentrations surge, even against a relatively low background level, there is a corresponding increase in deaths due to respiratory and circulatory system diseases and more people require hospital treatment for bronchitis and asthma. In the EU countries, according to the results of a study carried out under the Clean Air for Europe (CAFE) program (http://europa.eu/scadplus/leg/en/lvb/l28026.htm), PM2.5 emissions caused by human activity shorten the average life expectancy by 8.6 months.

Long-term exposure to particular matter raises the risk of disorders of the lungs, heart, and also may lead to lung cancer. The standards in force in the European Union limit coarse particulate (PM10) exposure to a daily average of 50 µg/m^3 (which should not be exceeded more than 35 times a year), and an annual average limit of 40 µg/m^3. For fine particulates (PM2.5), the norm limits the annual average to 25 µg/m^3. The European Parliament Directive (http://www.epa.ie/pubs/legislation/air/quality/CAFE%20Directive.pdf) does not specify any particulate matter concentration threshold for informing the society, or for declaring an alarm. Under Poland's regulatory framework, these threshold levels for PM10 are 24-hour-average values of 200 µg/m^3 and 300 µg/m^3, respectively; the levels may differ in other European countries. An air quality report published by the European Environment Agency in 2017 concluded that in 2015, 10% of the population living in European cities (in the EU-28) was exposed to PM10 concentrations exceeding the permissible daily-average levels, and 53% to levels above WHO values. As for PM2.5, 7% of the population in European cities was exposed to concentrations exceeding the permissible annual-average levels, and 82% to levels above WHO values.

The question of source

Particular matter pollution arises from both natural and anthropogenic (human-caused) sources. The anthropogenic sources include fuel combustion, industrial processes, agriculture, and also other processes such as wearing of tires and roadway surfaces. Natural sources include marine aerosols, airborne dust from deserts, volcanic eruptions, and particles derived from biogenic processes. Sources of emission, and also the ways in which particles are created, may be classified as primary or secondary; the latter involve the oxidation of precursors (sulphur dioxide, nitrogen oxides, ammonia, volatile organic compounds) that in turn form aerosol particles.

In Poland, the greatest share of particulate emissions comes from residential heating, as well as from the power generation sector, that rely on combustion of fossil fuels (mainly coal). The share of individual fractions in particles emitted by individual sectors varies, depending on such factors as the technology involved, the specific nature of the source, and air pollution control methods employed. Worth noting here is the relatively high PM2.5 fraction content in the overall particular matter emitted by transportation sources.

Data collected by air quality monitoring stations show that the lowest particulate concentrations are found over the north and northwest of Europe (the Scandinavian Peninsula, Northern Ireland) and in regions situated at elevations above 800 m above sea level (Figure 5). Numerous analyses indicate that road transport and industry are the most significant sources of anthropological emissions for the continental part of Europe. Aside from that, an important natural source in the Mediterranean region is mineral dust transported from the Sahara Desert. Analysis of decades of particulate monitoring data seems to indicate a slight downward trend, especially in the case of stations monitoring concentrations along major urban transportation routes. Levels of PM10 concentrations registered by urban background stations remain on a constant level.

The WHO on smog

According to the World Health Organization (WHO), it is very hard to identify any specific level below which no health risk occurs. The levels currently recommended by the WHO were set based on research concerning PM2.5 pollution. An annual-average concentration on the level of 10 μg/m^3 is the lowest level for which an increase was identified, with 95% probability, in death rates from lung cancer and circulatory system diseases. The daily average value (25 μg/m^3), in turn, was set based on the annual-average value so as to prevent the occurrence of short-term increased concentrations. The levels for PM10 (annual-average value of 10 μg/m^3 and daily-average value of 50 μg/m^3) were set based on the PM2.5 values, given the assumption that the ratio of the PM2.5 fraction in the PM10 fraction is 0.5.

The WHO sums up the current state of knowledge as follows:

- Particular matter concentrations generally cause an increase in the mortality risk due to respiratory failure in infants under one; they have a negative influence on the pace of development of lung function and exacerbate asthma and causes other respiratory diseases, such as coughs and bronchitis in children.
- Fine particulates, PM2.5, pose a serious health hazard, causing increased rates of death due to diseases of the heart, vascular system, respiratory pathways, and lung cancer. Increased PM2.5 concentrations entail a higher risk of sudden incidents requiring hospitalization due to respiratory and circulatory problems.
- PM10 levels cause greater respiratory disease rates, as indicated by the number of hospitalizations due to respiratory disease.

The question of heat

An analysis of the origin of smog episodes in Poland in 2013–16, carried out at the request of the Chief Inspectorate of Environmental Protection, showed that high PM10 concentrations covering a significant part of the country occurred predominantly on days when the air temperature fell below zero centigrade (Celsius). This was related to an increase in surface-level emissions resulting from higher demand for residential heating. In nearly all cases, the pollution episodes occurred in conditions of stable or strongly stable atmospheric conditions and temperature inversion, and also with weak wind. These conditions hampered the dispersion of pollutants, leading to their accumulation near the surface.

Based on mathematical modelling results, the main cause of high PM10 concentrations in Poland was identified due to emissions from distributed residential heating sources. For most of the country, such emissions were 80% to 90% responsible for giving rise to a smog episode. In selected regions, especially near major transportation routes and in urban areas, sources related to road transport also contributed a significant share: from 10% to 30%, reaching 50% in agglomerations (,i.e. Warsaw). The influence of large point sources (industry and the

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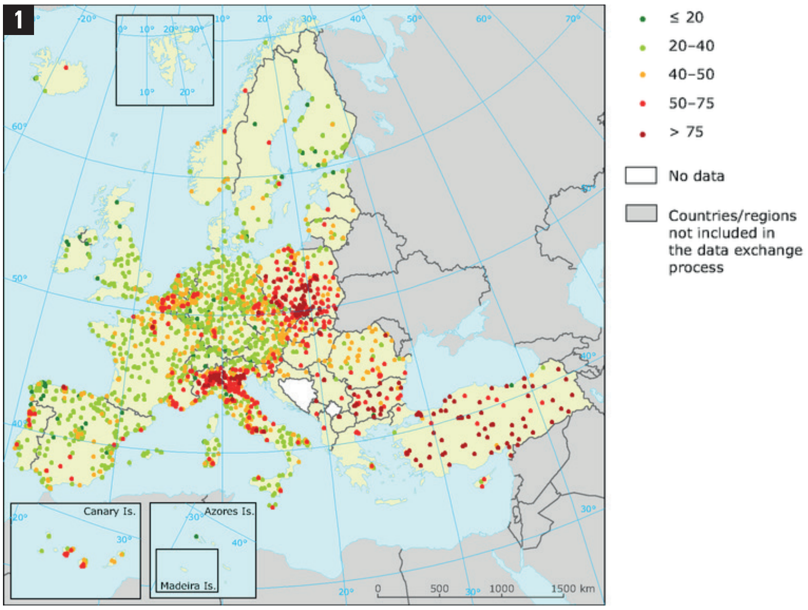

Fig. 1. Highest PM10 levels in Europe in 2012, expressed as the 90.4 percentile of PM10 concentrations calculated based on daily-average monitoring station data (in μg/m³)

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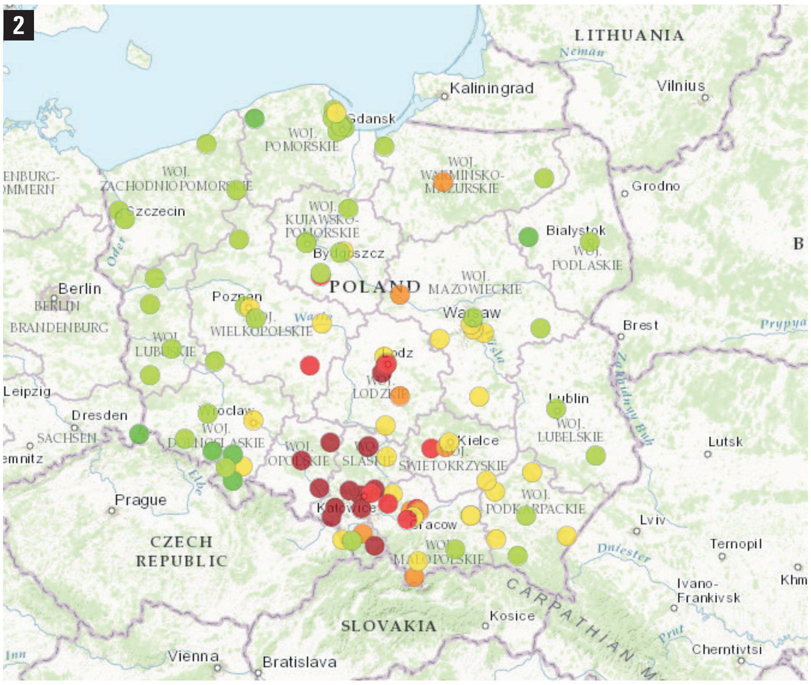

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power sector) was smallest in regions where high PM10 concentrations occurred.

In the case of certain episodes, there was a visible influence of trans-boundary sources contributing to high PM10 levels (generally up to a 10% share). This mainly applied to the border areas along the south of the country and sources from the Czech Republic (mainly Moravian Silesia, including the industrial region of Ostrava) and Slovakia. In specific cases, this contribution reached 50%. Air masses transported from Germany generally did not contribute to the PM10 threshold values being exceeded over a larger area of Poland. In regions that showed the highest percentage share of emissions originating from sources situated to the west of Poland, PM10 concentrations were generally not high. Analyses carried out using air quality modelling and back trajectory analysis indicate that in the case of certain episodes, emission sources located in southern Poland (mainly Silesia) contribute to high concentrations in the border regions of Slovakia and the Czech Republic.

Particularly unfavourable smog conditions occurred in the period of winter 2017, when PM10 levels in cities in southern Poland reached record levels, with the maximal hourly value recorded during the day over 1000 μg/m³.

The question of regulation

Routine monitoring of PM10 and PM2.5 airborne particular matter levels is carried out in Poland by the State Environmental Monitoring Service. The quality of measurements depends on a method employed, location (representativeness) of the observation site as well as the completeness of measurement time series. A specific methodology for airborne particulate measurements is set forth by the European Parliament directive and by national regulations.

We should perhaps stress that the commercially available low-cost air monitoring sensors that gain have been gaining greater popularity, particularly those intended to measure PM10 and PM2.5, are not

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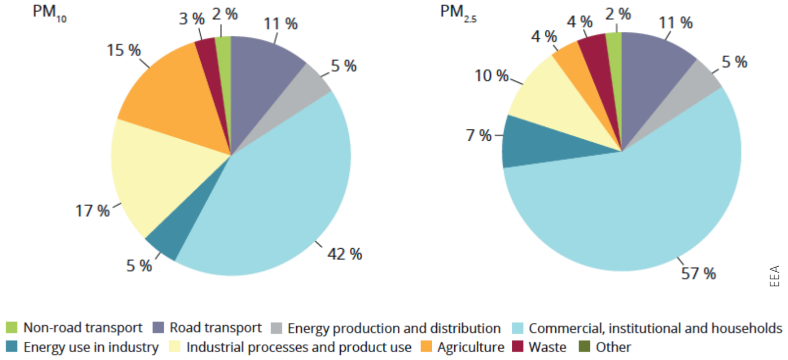

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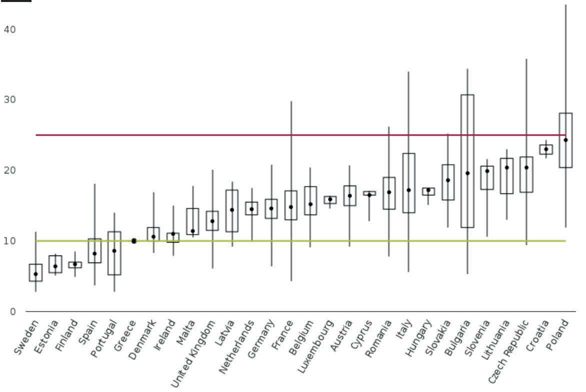

devices that operate in line with the reference methodology. Given the lack of compliance, such sensors cannot be treated as a source of reliable measurements, and so it cannot be reliably ascertained on the basis, of their readings whether air quality norms were exceeded.

Given the negative impact of PM2.5 particles on human health, the European Parliament directive introduces additional air quality norms for urban background areas in cities with more than 100,000 residents and urban agglomerations. In these areas, a permissible PM2.5 value was defined, called the concentration exposure threshold, calculated based on the average exposure for a city with over 100,000 residents. Moreover, each member state, based on its own domestic average exposure index – calculated using the average exposure index for a city with more than 100,000 residents and agglomerations and the criteria set forth in the above directive – has set its own national PM2.5 reduction target. In Poland, the average exposure index for a city with more than 100,000 residents and urban agglomerations is calculated for 30 cities and agglomerations based on data from 32 air quality monitoring stations. Compared to other European countries, the level of particular matter pollution in Poland remains on a high level.

The question of household combustion

In both Poland and Europe, a slight downward trend is evident in particular matter pollution levels. The exposure to above-norm concentrations significantly nevertheless increases in the winter months and relates to the occurrence of unfavourable meteorological conditions – mainly temperature inversion and of weak wind. When the temperature drops, there is higher demand for energy and the intensity of household combustion increases. In Poland, household combustion of solid fuels, frequently in low-efficiency furnaces (inefficient combustion) leads to significant particular matter emissions, is a factor significantly contributing to the occurrence of smog episodes. Such a breakdown of emission sources is the reason why Poland stands out negatively against the backdrop of other countries in Europe.

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Fig. 2.
Air quality index in Poland at 8:00 UTC 9/01/2017. Orange color means daily-average value was exceeded, while red and dark red denote that public-information and alarm levels were exceeded.

Fig. 3.
Contribution to PM10 and PM2.5 in 2015 (average for EU-28).

Fig. 4.
Yearly-average PM2.5 concentrations in EU countries (highest, lowest, and average values, in μg/m^3). Rectangle represents 25th and 75th percentiles. The red line shows the value recommended by the EU, the green line that recommended by the WHO.