15. ASSESSMENT OF CHANGES IN PM2.5 CONCENTRATIONS AND HEALTH EFFECTS RESULTING FROM LONG-TERM EXPOSURE TO THESE CONCENTRATIONS IN POLAND IN THE PERIOD 2019-2023 IN THE LIGHT OF THE REVISION OF EU DIRECTIVES AND WHO GUIDELINES

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Air pollution, as a mixture of gases, aerosols, and suspended particulate matter (the dispersed phase of aerosols), is a significant factor influencing human health. Numerous published epidemiological studies (summarised, among others, in the regularly updated guidelines of the WHO[1,2,3,4]) have demonstrated an association between exposure to air pollution and a wide range of adverse health effects in the general population. The pollutants most commonly included in health impact assessments are particulate matter along with its content of heavy metals and polycyclic aromatic hydrocarbons, ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and carbon monoxide (CO). Findings from health risk assessment studies indicate that, in terms of health impact, exposure to airborne particulate matter – especially its finest fraction, PM2.5 (particles with a diameter of less than 2.5 micrometres) – is of greatest concern5. It is estimated

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[1] Air quality guidelines for Europe. WHO Regional Office for Europe. WHO Regional Publications, European Series, No. 23, Copenhagen, 1987

[2] Air quality guidelines for Europe, 2nd ed. WHO Regional Office for Europe. WHO Regional Publications, European Series, No. 91, Copenhagen, 2000

[3] Air Quality Guidelines. Global update 2005. Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide, WHO Regional Office for Europe, WHO Regional Publications, European Series, No. 91. Copenhagen, 2006

[4] WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021

[5] WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021

that long-term exposure to PM2.5 particulate matter contributes to 4.2 million premature deaths globally[6], accounting for approximately 8% of the total burden of disease[7,8]. In the case of Poland, estimates have ranged from around 50,000 premature deaths annually in previous years to slightly over 30,000 in recent assessments[9,10.]

Atmospheric particulate matter includes both primary particles (direct emissions into the atmosphere) and secondary particles (those formed as a result of chemical transformations in the atmosphere, long-range transport from arid regions, or the re-suspension of particles from surfaces). In both cases, the sources of the particles themselves and their precursors may be of natural origin (e.g. volcanic emissions, sea salt aerosol) or anthropogenic origin (e.g. fossil fuel combustion)[11]. In recent years, a number of additional measures have been undertaken in Poland to accelerate the reduction of anthropogenic emissions of suspended particulate matter into the atmosphere, including legal instruments (local legislation – so-called anti-smog resolutions, fuel quality regulations) and economic instruments (the „Clean Air" programme, local subsidy schemes).

This chapter presents the results of analyses concerning trends in annual average concentrations of PM2.5 particulate matter and the number of premature deaths attributable to population exposure to this pollutant in Poland over the past five years (2019–2023), with consideration of the country's administrative division into districts. Population exposure assessments were based on spatial distribution maps of PM2.5 particulate matter concentrations, developed using mathematical modelling of pollutant transformation and transport carried out by the Institute of Environmental Protection – National Research Institute, and corrected using objective estimation methods. These maps were made available

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[6] https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health.

[7] https://www.healthdata.org/research-analysis/health-risks-issues/air-pollution

[8] Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. Brauer, Michael et al. The Lancet, Volume 403, Issue 10440, 2162 – 220

[9] Soares, J., Plass, D., Kienzler, S., González Ortiz, A., Gsella, A., Horálek, J. (2023). Health Risk Assessment of Air Pollution: assessing the environmental burden of disease in Europe in 2021 (Eionet Report – ETC HE)

[10] Jakość powietrza w Polsce w roku 2022 w świetle wyników pomiarów prowadzonych w ramach Państwowego Monitoringu Środowiska (PMŚ). Skotak Krzysztof et al., GIOŚ, Warsaw, 2023

[11] Pyły drobne w atmosferze. Kompendium wiedzy o zanieczyszczeniu powietrza pyłem zawieszonym w Polsce. Biblioteka Monitoringu Środowiska, GIOŚ, Warsaw 2016

by the Chief Inspectorate for Environmental Protection (GIOŚ)[12]. Annual average concentrations at the district level were calculated as area-weighted means based on grid cell data from the maps. The estimation of premature deaths was carried out using a methodology aligned with that applied by the European Environment Agency, assuming a relative mortality risk increase of 8% per 10 µg/m³)[13] rise in concentration. An additional assumption was made to exclude health impacts below the threshold recommended by the WHO in its latest guidelines (i.e. 5 µg/m³)[14]. To assess variability in both annual average PM2.5 concentrations and the number of premature deaths across districts in the 2019–2023 period, the average annual rate of change was used. A summary of the results is presented in Table 15.1.

Table 15.1 Annual mean concentration of PM2.5 and estimated number of premature deaths due to long-term exposure and medium-term rate of change in Poland for the period 2019-2023

Indicator	Value					Medium-term rate of change (%)		
	2019	2020	2021	2022	2023	mean	min	max
Exposed population (million)	38.383	38.089	37.908	37.766	37.637	-0.9%	-2.8%	5.4%
Annual mean concentration of PM2.5 from the State Environmental Monitoring stations (µg/m³)	18.9	16.9	19.2	16.6	14.5	-	-	-
Annual mean concentration of PM2.5 from model (µg/m³)	15.4	10.5	13.2	12.9	10.7	-8.6%	-15.8%	0.6%
Estimated number of premature deaths (person)	27,647	19,589	31,170	23,940	18,064	-12.1%	-100.0%	5.4%

The analysis of the annual average PM2.5 particulate matter concentrations in individual districts during the 2019–2023 period shows that among the 380 districts in Poland, only the cities of Gdańsk and Gdynia can be considered to have very good air quality. In these districts, the average PM2.5 concentration

[12] https://powietrze.gios.gov.pl/pjp/maps/modeling
[13] Soares, J., Plass, D., Kienzler, S., González Ortiz, A., Gsella, A., Horálek, J. (2023). Health Risk Assessment of Air Pollution: assessing the environmental burden of disease in Europe in 2021 (Eionet Report – ETC HE)
[14] WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021

remained below 5 µg/m³ – with Gdynia recording values below the level recommended by the WHO in its latest Guidelines in every year analysed. In Gdańsk, slightly higher concentrations were recorded in 2019 and 2021 (Fig. 15.1). It is worth noting that the current legally binding annual limit value for PM2.5—set at 20 µg/m³ to protect human health and applicable both in Poland and across the European Union—was exceeded, based on the 2019–2023 average, in only 13 districts. These include the cities with district rights of Świętochłowice, Chorzów, Piekary Śląskie, Rybnik, Zabrze, Siemianowice Śląskie, Bytom, Jastrzębie-Zdrój, Żory, Ruda Śląska and Nowy Sącz, as well as Rybnik district. The recently published Directive (EU) 2024/2881 of the European Parliament and of the Council of 23 October 2024 on ambient air quality and cleaner air for Europe (OJ L 2024/2881, 20.11.2024) introduces a significant tightening of this limit to 10 µg/m³. At present, this lower threshold is exceeded in more than half of all districts (299 out of 380).

The analysis of changes in annual average PM2.5 particulate matter concentrations across individual districts between 2019 and 2023 indicates a general improvement in air quality during this period. This positive trend may support the achievement of the new standards set by the European Union in the near future, as well as compliance with the values recommended by the WHO. However, success in this regard will depend on the intensity of actions undertaken to reduce air pollutant emissions, as well as on the pace of observed changes in pollutant concentrations in different regions of Poland. The results of the average annual rate of change in PM2.5 concentrations over the 2019–2023 period show a significant improvement in air quality in Poland. Among the 380 districts analysed, a positive average rate of change (indicating a slight deterioration in air quality) of +0.6% was observed in only one district—the city of Legnica. A high rate of improvement, exceeding –10% per year, was recorded in 93 districts, most notably in the city district of Nowy Sącz (–15.8%) and Nowy Sącz district (–15.0%) (see Fig. 15.2).

It is worth noting at this point that such a positive picture is not shown by the index of average relative changes calculated from year to year. In 19 out of the 380 districts in Poland, this indicator is positive. This results from significant fluctuations in annual concentrations. The highest average positive (i.e. adverse) year-on-year relative changes over the 2019–2023 period – exceeding 10% – were observed in five districts: Ząbkowice district (14.4%), the city of Wałbrzych (14.1%), Nakło district (12.8%), Wałbrzych district (12.7%), and Dzierżoniów district (11.2%). This occurred despite these districts having negative average annual

rates of change in the range of -10% to -3%. The greatest relative decreases in annual average PM2.5 concentrations, exceeding 10%, were recorded in the following districts: the city of Nowy Sącz (-14.6%), Brzesko district (-12.6%), Oświęcim district (-11.7%), the city of Dąbrowa Górnicza (-11.5%), Będzin district (11.3%), Bieruń-Lędziny and Pszczyna districts (-10.9%), the city of Koszalin and Jaworzno (10.8%), as well as Chrzanów district (-10.5%), Bochnia district (-10.4%), and Nowy Sącz district (-10.1%).
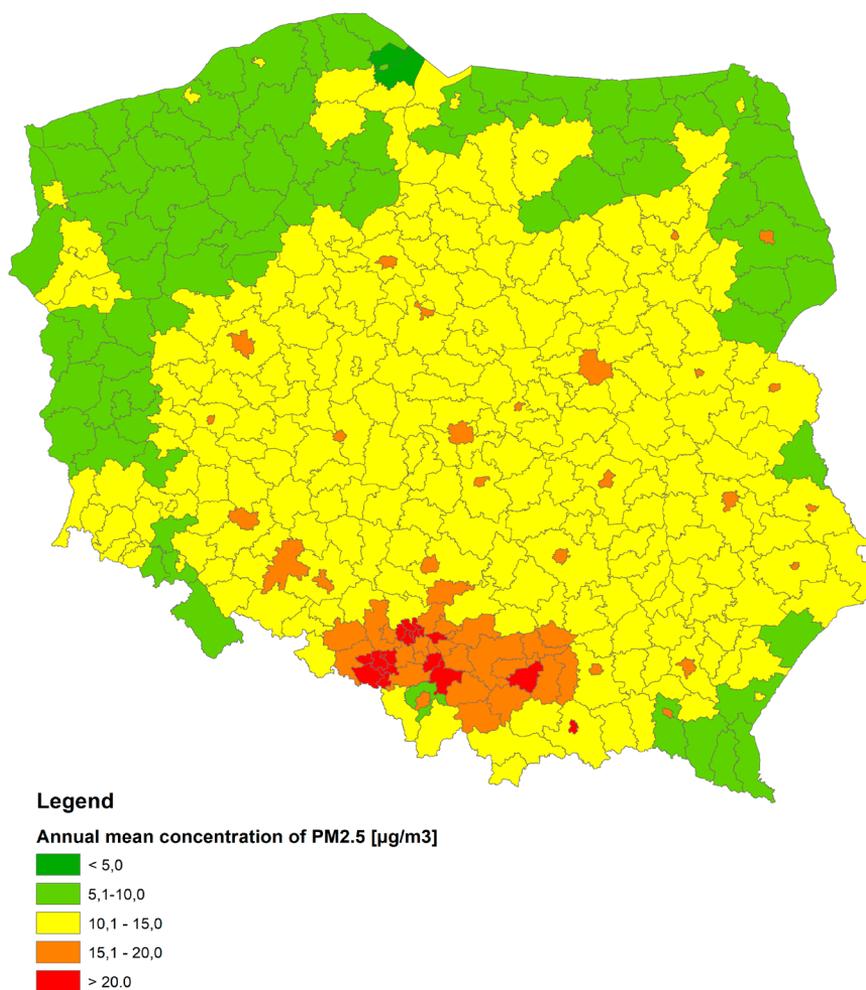

Legend

Annual mean concentration of PM2.5 [µg/m3]

- █ < 5,0
- █ 5,1-10,0
- █ 10,1 - 15,0
- █ 15,1 - 20,0
- █ > 20.0

Fig. 15.1. Annual average concentration of PM2.5 in the districts in the period 2019-2023

Legend

Medium-term rate of change of PM2.5 concentrations [%]

- < -7,50
- -7,49 - -5,00
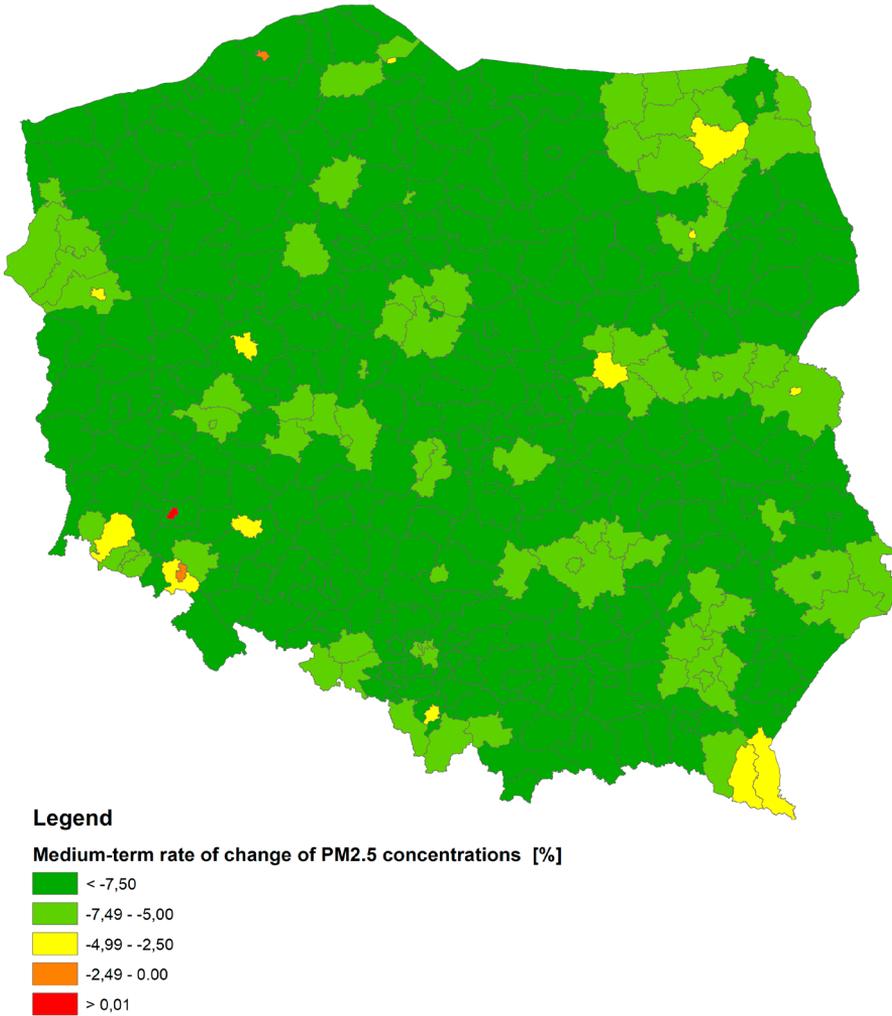- -4,99 - -2,50
- -2,49 - 0.00
- > 0,01

Fig. 15.2. Medium-term rate of change of PM2.5 concentrations in the districts in the period 2019-2023

Improvements in air quality have a tangible impact on reducing the health effects resulting from exposure to specific pollutants. The estimated annual average number of premature deaths attributable to long-term exposure to PM2.5 concentrations exceeding µg/m³ during the 2019–2023 period exceeds 24,000. These health impacts are not evenly distributed over time and space, as their magnitude depends on the level of pollution, the size of the exposed population, and that population's vulnerability, defined by the mortality rate from natural causes. Due to population density, the highest number of premature deaths is observed

in the largest city districts, namely: the Capital City of Warsaw, Kraków, Łódź, Wrocław, Poznań, and Katowice—each of which recorded, on average, over 300 premature deaths annually during the 2019–2023 period. Notably, in these six districts alone, premature deaths accounted for over 18% of the national total, despite the population of these districts constituting only 12% of the country's total population. An exception to this trend is found in the cities of Gdynia and Gdańsk, where, despite their large populations, the low concentration of PM2.5 does not result in any significant number of premature deaths (0 cases in Gdynia, 9 in Gdańsk). Only a few premature deaths (no more than 6 annually) were recorded in the least populated districts (with populations not exceeding 25,000), such as Bieszczady, Nowy Dwór, Sejny, Lesko, and Gołdap (see Fig. 15.3).

A different picture emerges when looking at the indicator of premature deaths per 100,000 inhabitants. The highest values (exceeding 140 cases per 100,000 inhabitants) are observed in the south of Poland, in the cities of Chorzów, Świętochłowice, Siemianowice Śląskie, Bytom, Piekary Śląskie, and Sosnowiec, as well as in Wodzisław district. The lowest values (not exceeding 18) are recorded in the cities of Gdynia, Gdańsk, and Świnoujście, and in the districts of Puck, Nowy Dwór, Police, Bieszczady, and Koszalin (see Fig. 15.4)

The analysis of the obtained results regarding the medium-term rate of change in the number of premature deaths caused by long-term exposure of residents in individual districts to PM2.5 particulate matter between 2019 and 2023 indicates, in many cases, significant and positive changes. The most positive changes were observed in Gdańsk, where concentrations fell below the expected values and the number of premature deaths attributed to air pollution has now dropped to 0, and in Gdynia, where no changes were observed due to the absence of health effects throughout the entire analysis period. High negative rates of change in the number of premature deaths – exceeding -10% annually – are seen in 257 districts, most notably in Nowy Dwór district (-48%) and in Żary, Elbląg and Żagań districts (each exceeding -23% per year). Unfortunately, the slowest rate of decline in the number of premature deaths among all districts in Poland is generally found in cities with district rights (19 of the 25 districts with the lowest rate of change are such cities), with increases observed in the cities of Legnica (5.4%) and Wałbrzych (1.7%), and virtually no change in Wrocław and Łomża (values below 0.1%) (see Fig. 15.5).

In recent times, numerous reports have appeared in the media and press concerning the most polluted cities in Europe, often highlighting cities in Poland. These rankings are based on various data sources and estimates. Frequently, they take into account only information from monitoring stations, thus excluding cities where no air quality monitoring is conducted.
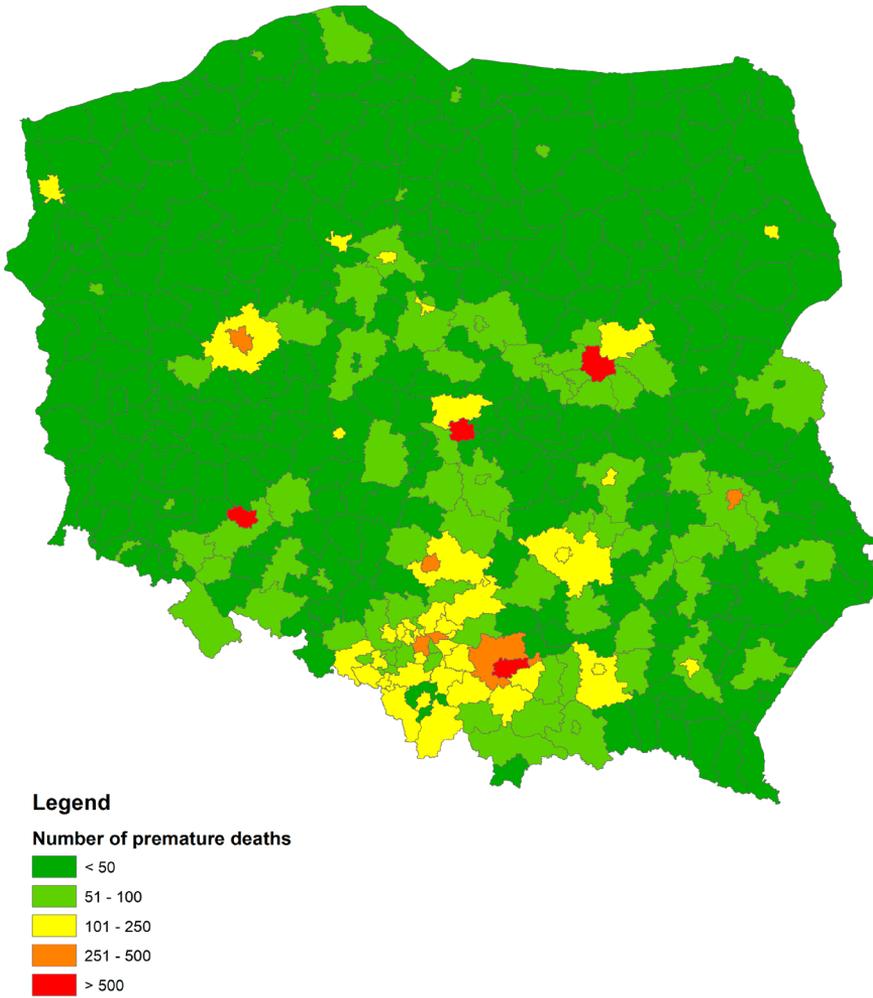
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Number of premature deaths

- █ < 50
- █ 51 - 100
- █ 101 - 250
- █ 251 - 500
- █ > 500

Fig. 15.3. Average number of premature deaths resulting from long-term exposure to PM2.5 concentrations in the districts in the period 2019-2023

Moreover, concentration values derived from monitoring stations do not sufficiently reflect spatial variations in pollution levels within cities. This may lead to an underestimation of risk if stations are located in areas with low concentrations, or an overestimation if they are placed in the most polluted spots, such as near busy roads. It is important to note that air quality monitoring stations in Polish cities are generally located in densely populated areas with potentially the highest concentrations, in order to identify exceedances of air quality standards and thereby indicate the need to develop corrective measures (Air Quality Programmes).

This pattern is also demonstrated by the data presented in Table 15.1, where average PM2.5 concentrations calculated from monitoring station data are higher than the area-weighted averages derived from modelled data corrected using objective estimation methods (maps show concentrations consistent with measurements in the vicinity of the stations and their representative zones). This further confirms the validity of the station placements within the State Environmental Monitoring (Państwowy Monitoring Środowiska) system (as they are located in areas of highest health risk while ensuring high population representativeness for each station).
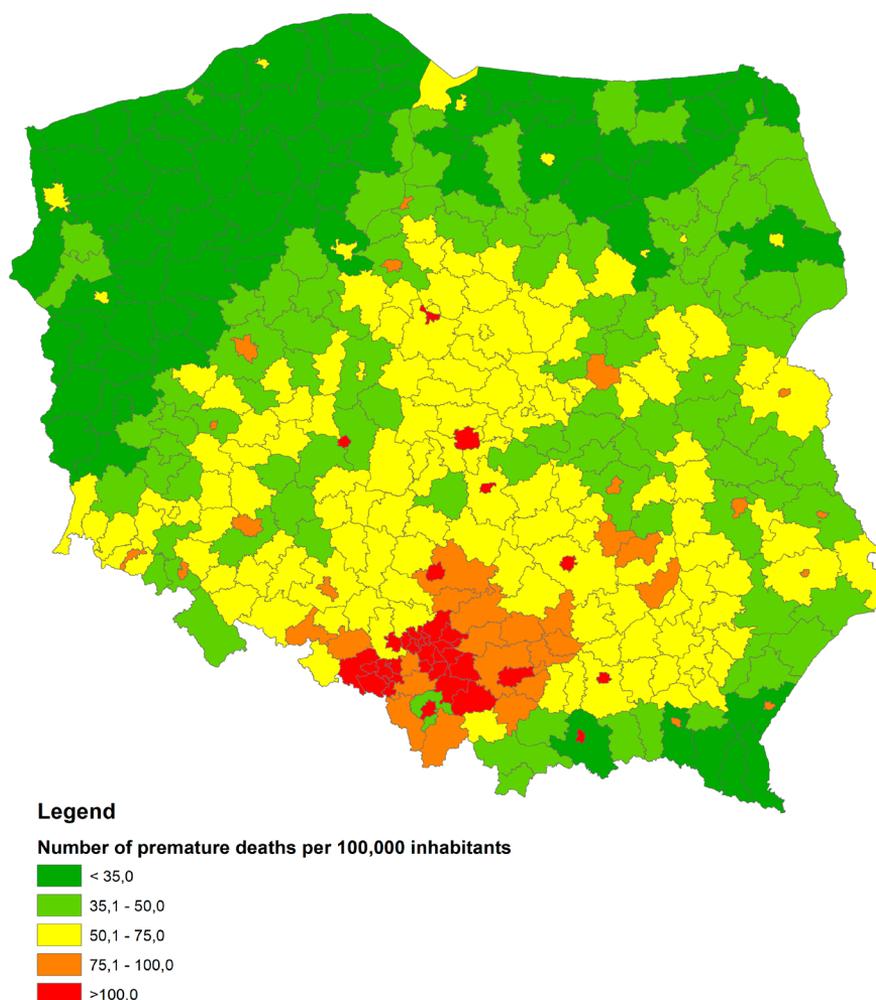

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Number of premature deaths per 100,000 inhabitants

- < 35,0
- 35,1 - 50,0
- 50,1 - 75,0
- 75,1 - 100,0
- >100.0

Fig. 15.4. Average number of premature deaths per 100,000 inhabitants resulting from long-term exposure to PM2.5 concentrations in districts in the period 2019-2023
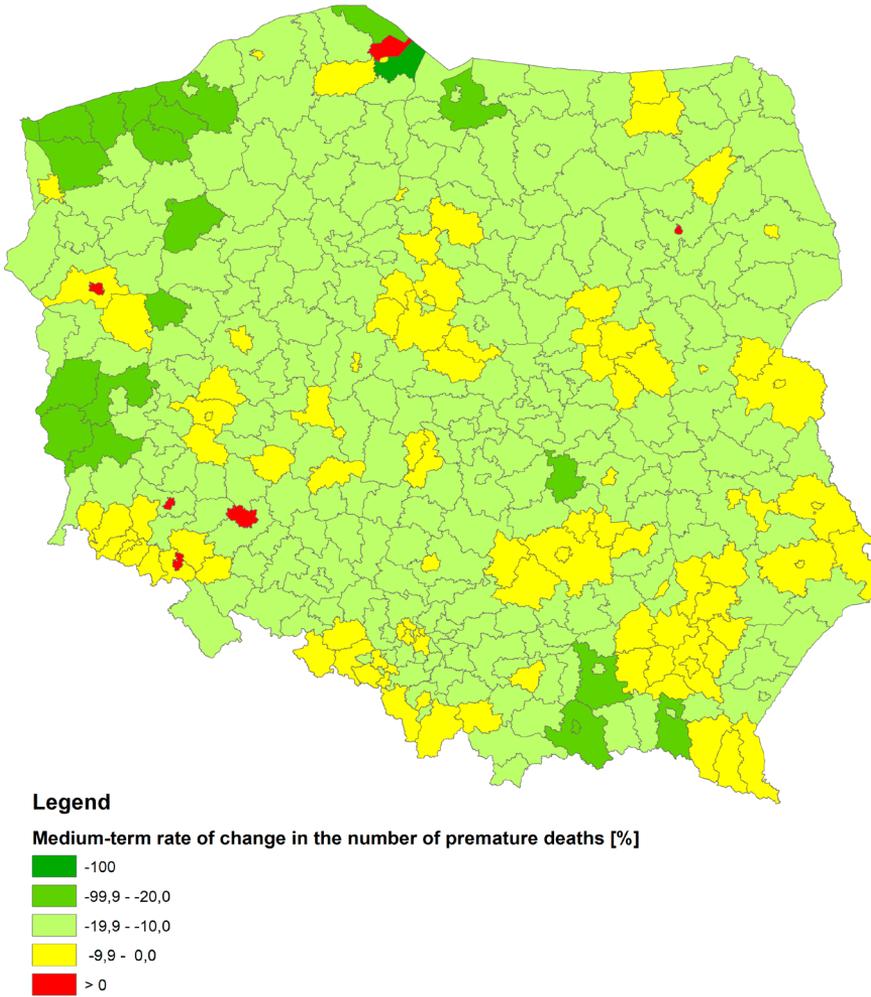
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Medium-term rate of change in the number of premature deaths [%]

- -100
- -99,9 - -20,0
- -19,9 - -10,0
- -9,9 - 0,0
- > 0

Fig. 15.5. Medium-term rate of change in the number of premature deaths resulting from long-term exposure to PM2.5 concentrations in districts in the period 2019-2023

Below is a summary of the analysis results for the 66 largest cities in Poland (cities with district rights), which are home to nearly one-third of the country's population (12.5 million residents), taking into account the level of exposure to PM2.5 particulate matter, the associated health impacts, and the rate of change over the period 2019–2023.

The results obtained for the period 2019–2023 (to minimise the effect of year-to-year variability, annual average concentrations for each district have been calculated as five-year averages) indicate that, among Poland's largest cities, the

most polluted in terms of PM2.5 are, in order: Świętochłowice, Chorzów, Piekary Śląskie, Rybnik, Zabrze, Siemianowice Śląskie, Bytom, Jastrzębie-Zdrój, Żory, Ruda Śląska, and Nowy Sącz. These cities do not comply with the applicable average annual limit value of 20 μg/m³ for PM2.5 concentrations. It should be emphasised that the stricter limit value set out in the revised Directive 2024/2881 (10 μg/m³) is met in only five cities: Gdynia, Gdańsk, Świnoujście, Sopot, and Zielona Góra, while the value recommended by the WHO is met only in Gdynia and Gdańsk. The annual average concentrations in these five cities indicate the best air quality over the past five years (see Fig. 15.6).

Despite air quality problems in the majority of Polish cities (in light of the tightened criteria under Directive 2024/2881), which require intensified efforts to improve air quality, the observed rate of change in many cities indicates the potential for significant improvement in a relatively short period. A positive rate of change (i.e. decreasing concentrations) was recorded in all cities except Legnica, which saw a slight increase of 0.6% over the 2019–2023 period. Among the cities with the poorest air quality, the largest reduction in annual average PM2.5 concentrations was observed in Nowy Sącz (nearly 16%), followed by Piekary Śląskie and Rybnik (over 9%), as well as Żory, Zabrze, and Jastrzębie-Zdrój (over 8%). It is worth noting that a significant medium-term rate of change, exceeding 9% over the 2019–2023 period, was found in 23 of the 66 cities assessed. Among the cities with a strong chance of achieving the tightened EU limit due to their high rate of improvement are Suwałki (-6.8% with an annual average PM2.5 concentration of 11.0 μg/m3), Koszalin (-12.6% with 11.2 μg/m3), and Elbląg (-11.1% with 11.5 μg/m3) (see Fig. 15.6).

The level of health risk in the analysed cities is indicated by the average premature mortality rate per capita. The highest values of this rate, averaged over the 2019-2023 period and exceeding 150 deaths per 100,000 inhabitants, were observed in the most polluted cities, namely Chorzów, Świętochłowice, Siemianowice Śląskie, and Bytom, where the medium-term rate of change in premature deaths remains insufficient (not exceeding 10%). The best premature mortality rates per capita (fewer than 50 cases per 100,000 inhabitants) were recorded in cities with the lowest annual average PM2.5 concentrations – specifically Gdynia, Gdańsk, Świnoujście, Zielona Góra, Sopot, Suwałki, and Koszalin. In these cities (except for Sopot), the medium-term rate of change in the number of premature deaths exceeds 10% (see Fig. 15.7). It is worth emphasising that a high rate of change (above 10%) in premature deaths caused by long-term exposure to PM2.5 was observed in 40% of cities with district rights (27 out of 66), including one of the most polluted cities – Piekary Śląskie. In addition to the cities mentioned above, very high and positive indicators reflecting a significant rate of reduction in the health impacts of PM2.5 exposure were recorded in Nowy

Sącz (20.6%), Elbląg (19.1%), Dąbrowa Górnicza (16.5%), and Przemyśl (15.2%). A negative rate of change in the number of premature deaths (i.e. an increase over the 2019–2023 period) was observed only in Legnica (5.4%) and Wałbrzych (1.7%), while no change (around 0.1%) was recorded in Wrocław and Łomża.
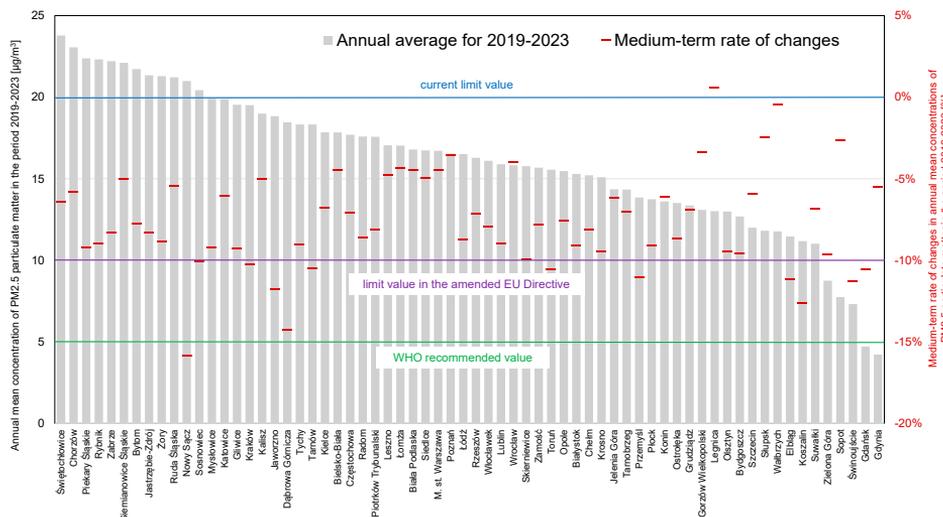

Fig. 15.6. Average annual PM2.5 concentration and medium-term rate of change in concentrations in cities with district rights in 2019-2023 compared to permissible levels and WHO recommended values
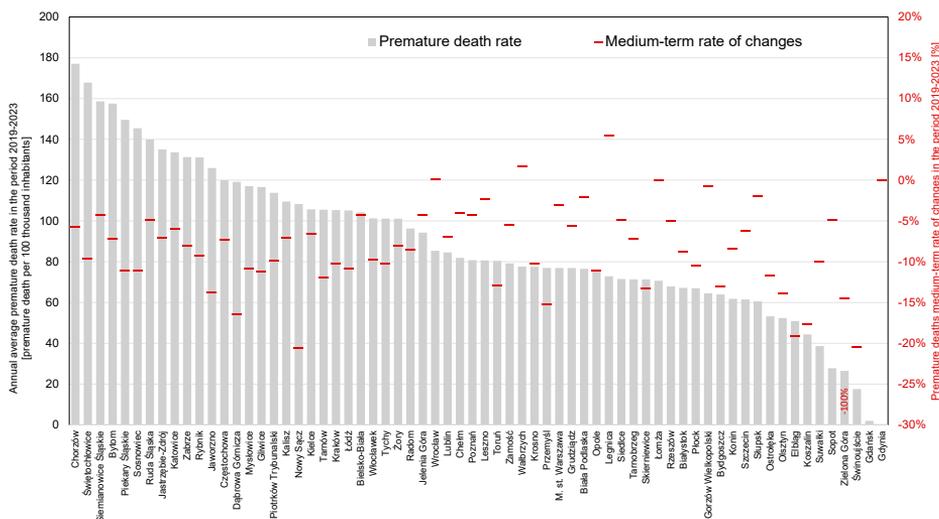

Fig. 15.7. Average annual rate of premature deaths per 100,000 inhabitants due to exposure to PM2.5 and medium-term rate of change in the number of premature deaths in cities with district rights in 2019-2023