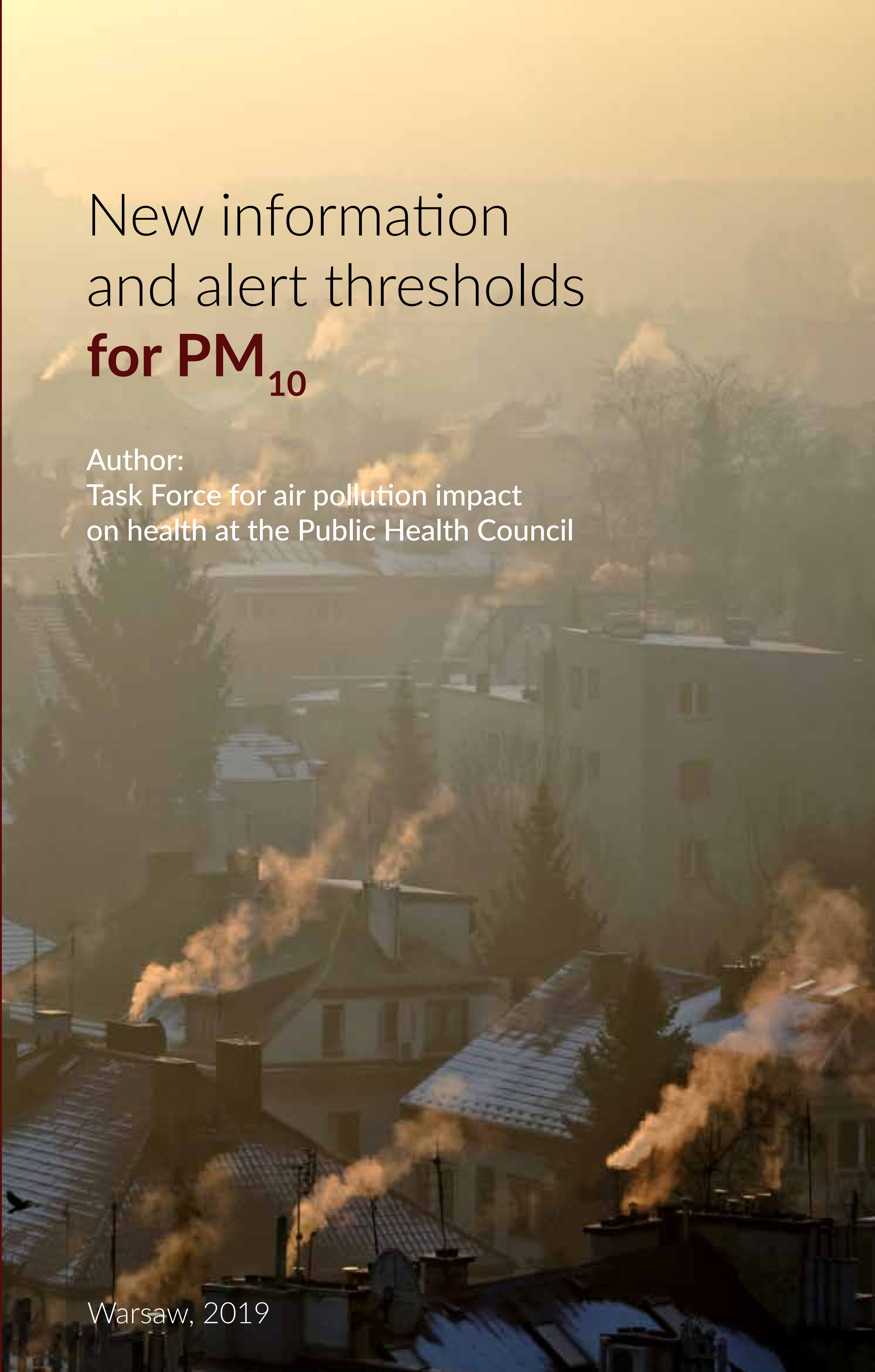

New information and alert thresholds **for PM_{10}**

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Warsaw, 2019

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1. Justification of the need to change the information and alert thresholds for PM_{10}

Pursuant to Directive 2008/50/EC, alert threshold means "a level beyond which there is a risk to human health from brief exposure for the population as a whole and at which immediate steps are to be taken by the Member States". The Directive also calls for drawing up action plans "indicating the measures to be taken in the short term where there is a risk of an exceedance of one or more alert thresholds in order to reduce that risk and to limit its duration". In Poland, an alert threshold is defined in the Environmental Protection Law (Journal of Laws of 2018, item 799) as a level beyond which there is a risk to human health even from brief exposure only.

Alert threshold levels should then be determined on the basis of the knowledge concerning the potential health impacts. Directive 2008/50/EC does not define information or alert thresholds for PM_{10}, leaving the Member States free to determine their own limit values. In Poland, pursuant to the Regulation of 24 August 2012 on levels of certain substances in ambient air (Journal of Laws of 2012, item 1031), the information threshold (daily average value) for PM_{10} is 200 µg/m^3 (four times the maximum permissible concentration), whereas the alert threshold is 300 µg/m^3 (six times the maximum permissible concentration). The analyses carried out (the results of which are presented further on in the study) reveal that concentrations exceeding 300 µg/ m^3 are not recorded too frequently, which means that the effectiveness of the existing alert threshold in terms of protecting human health is rather low due to the lack of risk awareness among citizens.

It is important to make clear that short-term measures alone are not the only or main direction that should be taken as far as health care policy is concerned. Avoiding highest daily concentrations will not lead to a significant decrease in the average annual concentration levels and, in particular, it will not allow the achievement of the WHO guideline values (20 µg/m^3 as the annual average for PM_{10})[1] which aim at reducing the health hazards connected with long-term exposure to PM_{10}. A considerable improvement of air quality can only be achieved by taking a mix of mid- and long-term measures to permanently reduce particulate matter emissions, especially from the municipal and housing sector. Alerts should be announced in order to motivate local authorities and citizens to take, as soon as possible, the widest possible range of actions to effectively minimize negative health impacts resulting from poor air quality.

In order to improve the effectiveness of the system for alerting about and responding to high concentrations of air pollutants, it is necessary to change the currently applied information and alert threshold values for PM_{10}. The results of our analysis enable the identification of the recommended values of these thresholds, taking into account the knowledge about the impact of particulate matter on human health. According to estimations from the European Environment Agency[2], every year 44.5 thousand people in Poland die prematurely as a result of exposure to fine particulate matter.

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1. WHO, 2005. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005. Summary of risk assessment. World Health Organization Press, Geneva, Switzerland.
2. EEA, 2018. Air quality in Europe — 2018 report. European Environment Agency, Copenhagen, Denmark.

2. Health impacts of particulate matter

There are a lot of well-documented studies on the impacts of air pollution on human health. In 2013, WHO carried out a broad review of these studies as part of the REVIHA-AP project (Review of evidence on health aspects of air pollution)[3] in order to provide the most reliable and evidence-based data concerning the issue. Harmful health effects of exposure to air pollution are usually analysed from two different points of view: as short-term effects (relating to short-term [hours/days] exposure to high concentrations) and as long term effects (relating to exposure measured in terms of years).

In the case of particular matter, the existence of both short- and long-term effects has been proven and the increased level of public health risk refers to premature deaths, incidence and prevalence of certain diseases as well as to hospital admissions. As part of the HRAPIE project ("Health risks of air pollution in Europe")[4], WHO experts selected a number of concentration – response functions (CRFs) that could be recommended for a quantitative assessment of health effects of exposure to particular matter and other air pollutants. Table 1 below presents the most important results with the relative risk (RR) values taken into account.

Pollutant metric	Health outcome	RR (95% CI) per 10 $\mu g/m^3$
$PM_{2.5}$, annual mean	Mortality, all-cause (natural), age 30+ years	1.062
PM_{10}, annual mean	Post-neonatal (age 1–12 months) infant mortality, all-cause	1.040
PM_{10}, annual mean	Prevalence of bronchitis in children, age 6–12 (or 6–18) years	1.080
PM_{10}, annual mean	Incidence of chronic bronchitis in adults (age 18+ years)	1.117
$PM_{2.5}$, daily mean	Mortality, all-cause, all ages	1.0123
$PM_{2.5}$, daily mean	Hospital admissions, cardiovascular diseases (CVDs) (includes stroke), all ages	1.0191
$PM_{2.5}$, daily mean	Hospital admissions, respiratory diseases, all ages	1.0190

Table 1. Selected coefficients of health risk associated with exposure to particulate matter. Source: WHO, 2013 – selected results of the HRAPIE project

As can be seen from the above RR values, health effects attributed to long-term exposure are much more harmful as compared with those attributed to short-term exposure, even with lower concentrations. However, these values indicate at the same time that short-term exposures, despite their limited duration, also pose a significant risk to human health.

3. WHO 2013. http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2013/review-of-evidence-on-health-aspects-of-air-pollution-revihaap-project-final-technical-report
4. WHO 2013. Health risks of air pollution in Europe – HRAPIE project: Recommendations for concentration– response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide. WHO Regional Office for Europe, Copenhagen, Denmark.

3. Methodology

3.1 Materials and data

The analyses were carried out for the period between 2015 and 2017. PM_{10} and $PM_{2.5}$ concentrations served as exposure indicators (data obtained from the State Environmental Monitoring), whereas hospital admissions and deaths were used as health indicators (data obtained from the Central Statistical Office (CSO)) and the National Health Fund). The analyses were carried out taking into account the zones which are subject to air quality assessment in line with the Regulation of the Minister of the Environment of 2 August 2012 on zones subject to air quality assessment, Journal of Laws of 2012, item 914.

Information on particulate matter concentrations was extracted from the database held by the Chief Inspectorate of Environmental Protection (CIEP) for all available manual urban -background monitoring stations, verified average daily values were taken into account by applying the criterion of 75% completeness of measurement series in a year. The analyses revealed that the vast majority of exceedances of limit values for average daily PM_{10} concentrations occur during the heating season, which is why further analyses were limited to the first and fourth quarter of each year. Health risk was calculated taking into account the RR for $PM_{2.5}$. The PM_{10} values were converted into $PM_{2.5}$ values on the basis of the average monthly share of $PM_{2.5}$ in PM_{10} for stations in which both fractions of particulate matter are monitored in parallel.

For stations where $PM_{2.5}$ concentrations were not monitored an agreed conversion factor was used (by applying the criterion of belonging into a given CIEP zone and the criterion of similarity of the location characteristics). It was assumed that daily concentrations of $PM_{2.5}$ with no effects on human health are those lower than 2.5 µg/m^3 (concentrations resulting from non-anthropogenic emissions according to EEA).

Health-related data included the number of patients admitted hospitals by reasons for admission in line with the ICD10 classification: cardiovascular diseases (codes: I00 – I99) and respiratory diseases (codes: J00 – J99). CSO data concerning the annual mortality rates per poviat for people aged 30 years and over were also used. 95% of the total number of deaths was taken into account assuming that in the case of people over 30 years old, 5% of deaths are from unnatural causes.

3.2 Scenarios related to potential values of alert thresholds for daily PM_{10} concentrations

Analyses were carried out for six potential values of alert thresholds, i.e. 50, 75, 100, 150, 200 and 300 µg/m^3 respectively. The calculations consisted in converting all concentrations exceeding the alert threshold adopted in a given scenario into the value of that threshold (e.g. 50 µg/m^3) and then calculating the health impact resulting from a potential reduction of concentrations as compared with the baseline scenario (i.e. the one calculated for actual concentrations).

It was assumed that the alert system will operate on the basis of average results obtained from all monitoring stations located in a given zone, e.g. for the 100 µg/m^3 scenario, the alert is announced in the whole zone when the average daily concentration measured by these stations exceeds 100 µg/m^3. Simulations were run to assess the frequency of alerts for all scenarios taking into account PM_{10} concentrations recorded during the heating seasons of the years 2015 – 2017 in all zones. The results are presented in Table 2 and Figure 1 below.

Daily PM_{10} concentrations [µg/m^3] – threshold value	average	median	percentile 25	percentile 75	Min	Max
50	43.5	42.3	28.8	54.6	13.3	87.3
75	16.3	13.7	8.4	19.4	3.0	48.7
100	6.8	5.5	2.5	8.7	0.3	25.7
150	1.64	0.67	0.00	2.25	0.00	10.67
200	0.49	0.00	0.00	0.58	0.00	3.33
300	0.05	0.00	0.00	0.00	0.00	0.67

Table 2. Statistics concerning the number of days in exceedance of daily PM_{10} concentrations (threshold values). Own analysis based on CIEP data.

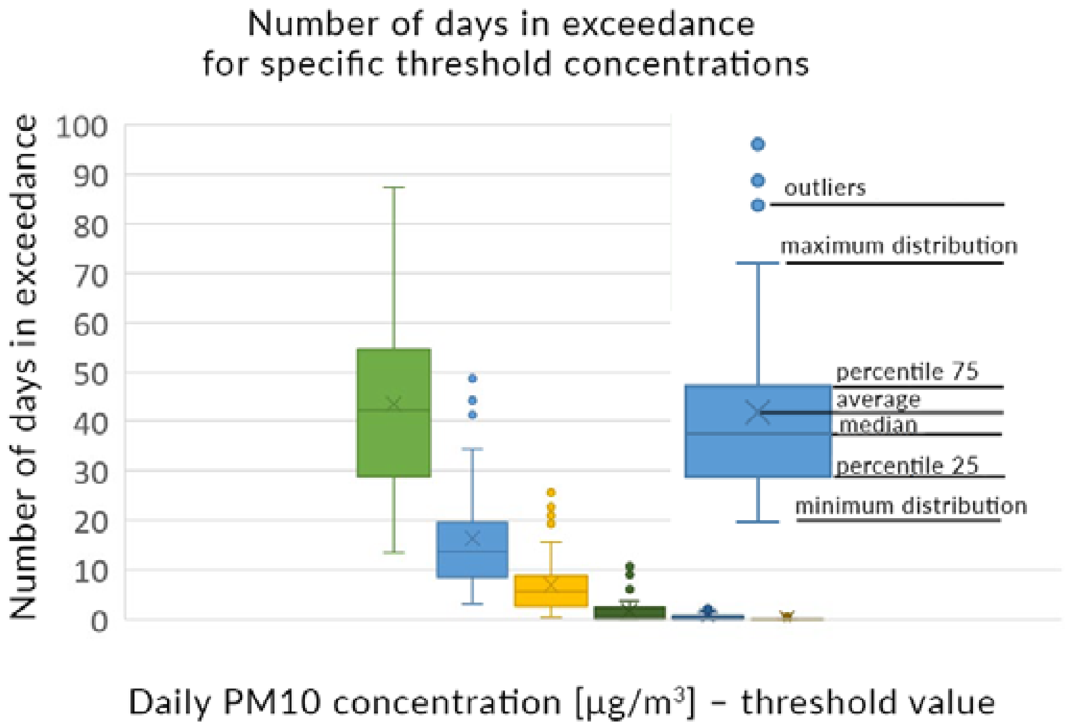

Figure 1. Number of days in exceedance of daily PM_{10} concentrations (threshold values). Own analysis based on CIEP data.

The results show that for the 50 µg/m^3 threshold, the average frequency of potential alerts is 43 per year – alerts would be announced 13 times per year in the zone with the best air quality and 87 times in the zone with the worst air quality. For the 300 µg/m^3 threshold, alerts would not be announced more often than twice every three years (the maximum value for the zones from the three-year average: 0.67). The number of alerts depends on the concentration levels recorded in a given zone – in the most polluted parts of the country alerts could potentially be announced over ten times more often than in the zones with the best air quality. The analyses revealed that the highest frequency of potential alerts would be observed in the agglomeration of Rybnik-Jastrzębie, agglomeration of Cracow, agglomeration of Upper Silesia and in the zone of Silesia, whereas the lowest frequency would be recorded in the zone of Podlasie, the city of Koszalin and the agglomeration of Białystok.

3.3 Results of health impact analyses

Using the RR ratios established for hospital admissions due to cardiovascular and respiratory diseases (short-term exposure to $PM_{2.5}$) and for total mortality (long-term exposure to $PM_{2.5}$), calculations were carried out to determine the number of hospital admissions and deaths that could potentially be avoided if the recorded daily concentrations did not exceed the proposed alert thresholds. Results are presented in Table 3.

Daily PM_{10} concentration [µg/m^3] not exceeding	Analysis of short-term effects during the heating season		Analysis of long-term effects
	Avoided hospital admissions for cardiovascular diseases	Avoided hospital admissions for respiratory diseases	Avoided deaths, all-cause, age 30+ years
2,5	11 706	17 034	45 598
50	2 896	4 000	6 988
60	**1 775**	**2 383**	4 200
75	1 341	1 808	3 259
80	**1 166**	**1 535**	2 759
100	677	892	1 669
150	206	261	522
200	76	93	196
300	14	16	38

Table 3. Number of hospital admissions and deaths that could potentially be avoided in Poland depending on the scenario in which the selected daily PM_{10} concentrations are not exceeded.

The analyses show that the relationship between the alert threshold value and the number of potentially avoidable hospital admissions/deaths is non-linear (exponential decay) and for high threshold values, especially due to the low number of cases, health benefits at national level are minimal. The greatest improvement of general population health indicators was achieved for the lowest value of a potential alert threshold (50 µg/m³) – assuming 100% for the best case scenario (BSC), i.e. a situation where maximum daily concentrations of PM_{10} are not exceeded anywhere in the country. Calculations were carried out for potential benefits (in %):

- 100% BCS is achieved with the threshold value for PM_{10} of 50 µg/m³
- **81%** BCS is achieved with the threshold value for PM_{10} of **60** µg/m³
- **75%** BCS is achieved with the threshold value for PM_{10} of **63** µg/m³
- **53%** BCS is achieved with the threshold value for PM_{10} of **80** µg/m³
- **50%** BCS is achieved with the threshold value for PM_{10} of **82** µg/m³
- 34% BCS is achieved with the threshold value for PM_{10} of 100 µg/m³
- 25% BCS is achieved with the threshold value for PM_{10} of 116 µg/m³
- 12% BCS is achieved with the threshold value for PM_{10} of 150 µg/m³
- 4% BCS is achieved with the threshold value for PM_{10} of 200 µg/m³

The analysis shows that with the alert threshold for PM_{10} of 82 µg/m³, population health could be improved by around 50% (understood as a 50% reduction of negative health impacts) as compared with the baseline scenario with the threshold value of 50 µg/m³.

Figures 2 and 3 present a comparison between the frequency of PM_{10} threshold exceedances and the number of hospital admissions/deaths attributable to exposure to specific concentrations of particulate matter.

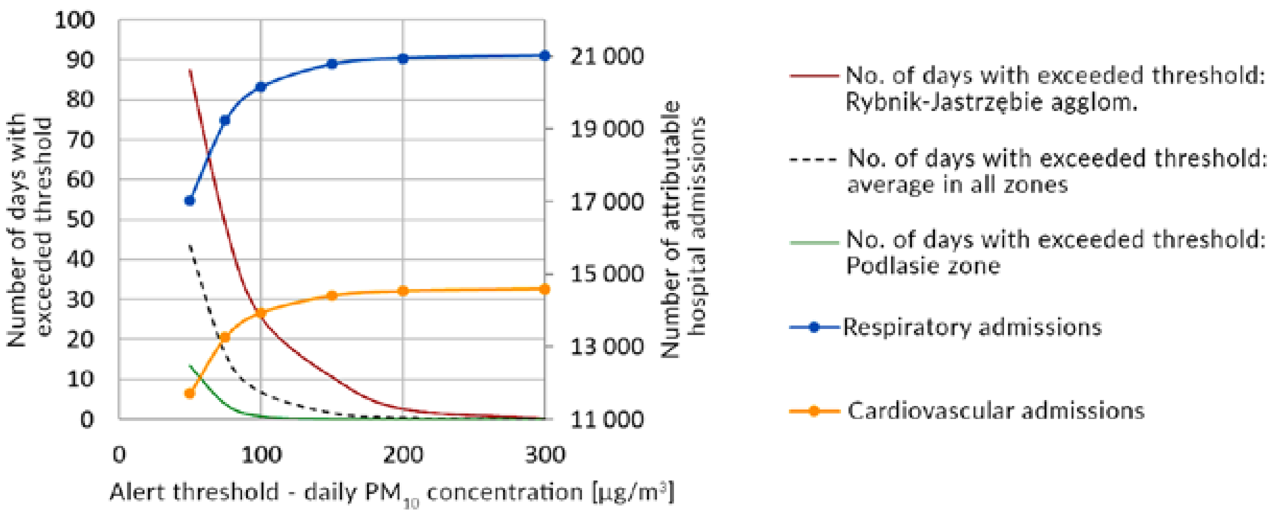

Figure 2. Number of days with exceeded daily concentrations of PM_{10} (threshold values) vs. number of hospital admissions attributable to short-term exposure to particulate matter in ambient air.

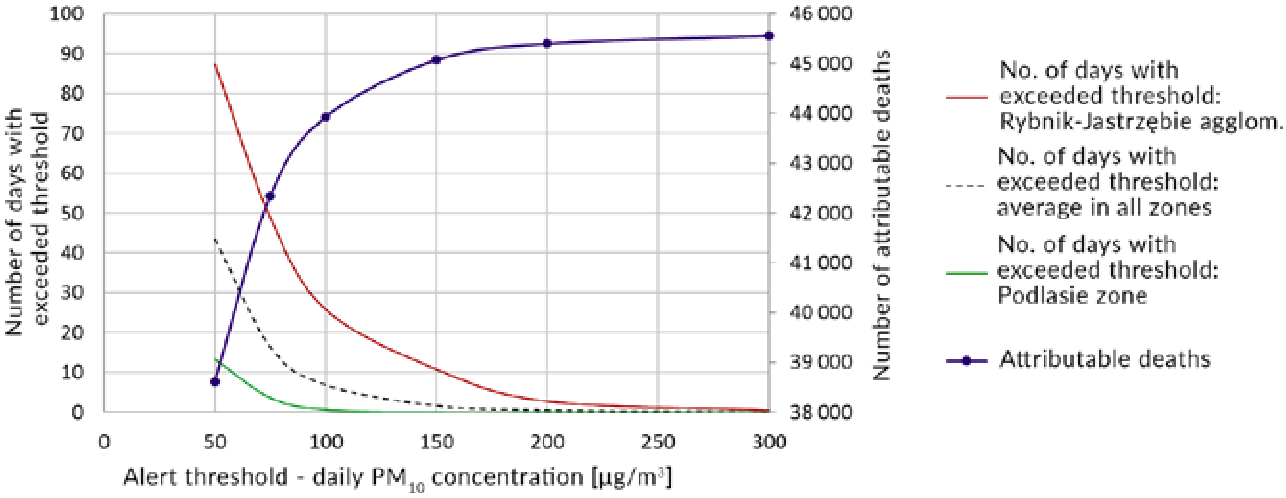

Figure 3. Number of days with exceeded daily concentrations of PM_{10} (threshold values) vs. number of deaths attributable to long-term exposure to particulate matter in ambient air.

The analyses show that in the case of alert thresholds for which 25%, 50% and 75% BCS can be achieved respectively, the potential number of days with exceeded concentrations – at national level – will be as follows:

- 63 µg/m^3 (75% BCS) 26 days on average (min: 6, max: 67)
- 82 µg/m^3 (50% BCS) 13 days on average (min: 2, max: 39)
- 116 µg/m^3 (25% BCS) 4 days on average (min: 0, max: 18).

4. Conclusions and recommendations

The analyses were carried out in order to find out what reduction of negative health impacts can potentially be achieved assuming that certain average daily concentrations of PM_{10}, i.e. the suggested alert thresholds, are not exceeded. It was demonstrated that the currently applied alert level (300 µg/m^3), due to very low frequency of recorded exceedances, does not contribute to a reduction of the existing health risk associated with air pollution.

Following the analysis of health impacts and potential frequency of alerts, it is recommended that:

- A new value of 60 µg/m^3 should be set as the information threshold for daily PM_{10} concentration, which corresponds to the achievement of 81% of the maximum, potentially possible, reduction of negative health impacts.
- A new value of 80 µg/m^3 should be set as the alert threshold for daily PM_{10} concentration, which corresponds to the achievement of 53% of the maximum, potentially possible, reduction of negative health impacts.

It must be pointed out that setting new information and alert thresholds for PM_{10} is the first step towards reducing risk to human health resulting from air pollution. Only a well-functioning alert system offering a catalogue of short-term remedial measures and recommendations for the general public will indeed contribute to reducing negative health impacts. This catalogue should be created using the examples and experiences of other EU countries in which such systems have been successfully implemented, as well as on the basis of short-term measures that have been proposed so far in Poland and the effectiveness of which has been confirmed (e.g. those included in Air Quality Plans).

Taking into account the conclusions of the audit conducted by the Supreme Audit Office to assess measures taken by public bodies in relation to air quality improvement[5], in order to ensure effectiveness of the proposed measures it is necessary to precisely define the entities and persons responsible for their implementation, the rules for their financing as well as mechanisms for monitoring compliance.

In view of the fact that the elimination of short-term pollution peaks only can contribute to a reduction of health impacts by 15% – 20%, short-term measures should be part of a programme aimed at a drastic reduction of long-term average exposure to air pollutants.

5. Supreme Audit Office, 2018. Information on audit results. Air quality protection (P/17/078), Ref. No. 150/2018/P/17/078/LKR