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EXPOSURE TO PM2.5 AND PM10 POLLUTION AND THE RISK OF RESPIRATORY DISEASES IN UPPER SILESIA INHABITANTS

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Abstract
Background: Multiple studies confirm that PM2.5 and PM10 can affect lung growth and development in children and adolescents, the number of medical visits, and hospital emergency admissions due to asthma, respiratory symptoms, and upper and lower respiratory tract disorders. **Objective:** The objective of this study was the measurement-based assessment for determining whether the concentrations of PM10 and PM2.5 are within admissible limits or exceeded in the Upper Silesia urban area (Silesia province) and to examine the relationship between PM concentrations and the number of admissions in Primary Health Care due to respiratory diseases like asthma and chronic bronchitis for children, adolescents and adults. **Material and methods:** The data provided by the Voivodship Inspectorate for Environmental Protection in Katowice, National Health Fund - Silesian Department, and the District Sanitary-Epidemiological Station in Katowice for the period 2012-2017 was used in the statistical analysis. **Results:** The increase in the number of excessive levels of average daily PM10 concentration was observed in almost all measurement stations, both for the acceptable level, information, and alarm level. The increase in average annual PM2.5 concentrations was also observed. The results showed an increased prevalence of respiratory diseases (ICD-Diagnosis Code 10-CM: J017, J030, J034, J038, J040) during the study period in 14 of 20 cities of Silesia province, consistently higher for children than adults. **Conclusions:** In Silesia province, the air quality is poor and has deteriorated over the last few years. Exposure to ambient PM2.5 and PM10 was significantly associated with the development of respiratory tract diseases in children and adults.
Keywords: PM10, PM2.5, air pollution, respiratory tract disorders, asthma, chronic bronchitis

Background

The negative health effects of air pollution were known in ancient times, but it was only the severe smog episodes that occurred in the Meuse Valley (Belgium) in 1930 and in London in 1952 that initiated research into the effects of atmospheric pollution on human health (Ghio 2014). Particulate matter is a mixture of organic and inorganic substances, it is fine airborne particles that are part of the atmospheric aerosol. Its origin can be natural (particulate matter of natural origin is, for example, volcanic ash or mineral dust) or the result of human activity (such dust is formed in the process of fuel combustion and transformation of other airborne pollutants). The combustion of coal, wood, and biomass in individual heating systems, i.e. those in which it is not technically possible to install filters and dust collectors, leads to the formation of so-called low emissions. This issue encompasses combustion processes outside of the industry, including emissions at heights of up to 40 meters, coming mainly from domestic stoves and local boiler rooms, dangerous especially under unfavourable meteorological conditions (lack of wind and temperature inversion). Under this term there are also communication and transport emissions, as well as so-called unorganized emissions, i.e. emissions caused by fires, fieldwork, or dust from bulk material storage sites, as well as those caused by industrial accidents. Pollution is often accompanied by: polycyclic aromatic hydrocarbons (PAHs), including benzopyrene, heavy metals (including arsenic, cadmium, nickel, and lead), furans, sulphur, and asbestos. The exact composition

depends on the conditions under which the particulate matter was formed. Analyses of air quality and the relationship between air quality and human health usually distinguish two main fractions of particulate matter: PM10 dust - composed of particles up to 10 μm in diameter, and PM2.5 dust - composed of particles up to 2.5 μm in diameter (Maciołek et al. 2006). They have most significant influence on human health, because these particles can easily penetrate through the respiratory system (WHO 2013b) and the effect of exposure to particulate matter on the risk of infection in humans is proven (Ghio 2014).

PM10 - made up of particles up to 1 μm in diameter - is a much rarer distinction. Division of particulate matter according to the size of the particles that make it up is very important, because the smaller the particles, the greater the danger they pose to our health. Dust particles have a diameter of several or even several dozen times smaller than the diameter of a human hair, so they easily penetrate the respiratory tract along with inhaled oxygen. Finer dust fractions enter the bloodstream, and from there they have access to all internal organs. Standards for dust concentrations are presented as criterion values - permissible levels of substances in the air, target levels and long-term goal levels, alert levels, and levels for informing about the risk of occurrence of alert levels (Judy-Rezler, Toczko 2016).

The main source of PM10 in the air in European cities is emissions from combustion in individual heating systems of solid fuels such as coal, wood, and biomass, and road traffic, especially from diesel vehicles without particulate filters. The alert level for informing the public about the risk of concentrations for PM10 is 200 [μg/m3] for a 24-hour averaging period (Ghio 2014).

Directive 2008/50/EC of the European Parliament and of the Council of May 21, 2008, on air quality and cleaner air for Europe established limit values for PM10 - an annual average concentration of 40 [μg/m3] and a 24-hour average concentration of 50 [μg/m3]. For PM2.5, the target value for annual average concentration was set at 25 [μg/m3]. The same document precisely defines PM as dust passing through a sorting hole, as defined in the reference sampling and measurement method for PM; PN-EN 12341:2014, with a 50% efficiency limit for aerodynamic diameter up to 10 μm (up to 2.5 μm). However, it is worth remembering that information about exceeded standards is announced when the daily concentration of PM10 reaches 200 [μg/m3] - this shows perfectly how often we all mistakenly think that the air is of good quality, while it is very polluted, and the alarm level (300 [μg/m3]) has not yet been reached (CAFE, 2008).

Therefore, the objective of this study was the measurement-based assessment for determining whether the concentrations of PM10 and PM2.5 are within admissible limits or exceeded in the Upper Silesia urban area (Silesia province) and to examine the relationship between PM concentrations and the number of admissions in Primary Health Care due to respiratory diseases like asthma and chronic bronchitis for children, adolescents and adults.

Material and methods

The data provided by the Voivodship Inspectorate for Environmental Protection in Katowice, National Health Fund - Silesian Department, and the District Sanitary-Epidemiological Station in Katowice for the period 2012-2017 was used in the statistical analysis.

Quantitative variables were described using means, standard deviations, and minimum and maximum values. The normality of distribution was assessed using the Shapiro-Wilk test. Correlations between variables were analysed using Pearson's correlation coefficient. Results were considered statistically significant at $p<0.05$. Data were processed using Statistica 13.3 (TIBCO Software, Palo Alto, United States) and Excel 2013 (Microsoft, Redmond, United States).

Results

The increase in the number of excessive levels of average daily PM10 concentration was observed in almost all measurement stations, both for the acceptable level, information, and alarm level. The increase in average annual PM2.5 concentrations was also observed. The results showed an increased prevalence of respiratory diseases; acute inflammation of the sinuses, nasal mucosa, tonsils and throat (ICD-Diagnosis Code 10-CM: J017, J030, J034, J038, J040) during the study period in 14 of 20 cities of Silesia province, consistently higher for children than adults.

In Silesia province, the air quality is poor and has deteriorated over the last few years. Exposure to ambient PM2.5 and PM10 was significantly associated with the development of respiratory tract diseases in children and adults ($p<0.05$). The increase in the number of excessive levels of average daily PM10 concentration and average annual PM2.5 concentrations (Tab I).

Table I. The relationship between the concentration of PM 2.5 and PM 10 and respiratory system diseases in 2012-2017.

PM/Year	First cases of age 0-18	Overall cases of age 0-18	First cases of age >19	Overall cases of age >19
PM10 (2012)	0.37	0.09	0.40	0.49
PM2.5 (2012)	0.27	0.15	0.36	0.40
PM10 (2013)	0.00	-0.30	0.06	0.00
PM2.5 (2013)	0.05	-0.06	0.16	0.17
PM10 (2014)	0.02	0.23	0.35	0.36
PM2.5 (2014)	-0.03	0.21	0.35	0.38
PM10 (2015)	0.46	0.24	0.50	0.23
PM2.5 (2015)	0.37	0.30	0.46	0.37
PM10 (2016)	0.64	0.23	0.56	0.23
PM2.5 (2016)	0.63	0.17	0.58	0.21
PM10 (2017)	0.36	0.21	0.45	0.45
PM2.5 (2017)	0.60	0.53	0.64	0.68

Interpretation of the correlation value

0.l	-	0.3	weak	correlation
0.3	-	0.5	moderate	correlation
0.5	-	0.7	high	correlation

0.7 - 0.9 very high correlation

Exposure to ambient PM2.5 and PM10 was significantly associated with the increase of respiratory tract diseases in children and adults in the Upper Silesia urban area (Figure 1). The increase in the number of excessive levels of average daily PM10 concentration and average annual PM2.5 concentrations was observed in almost all measurement stations during the study period (Figure 2).

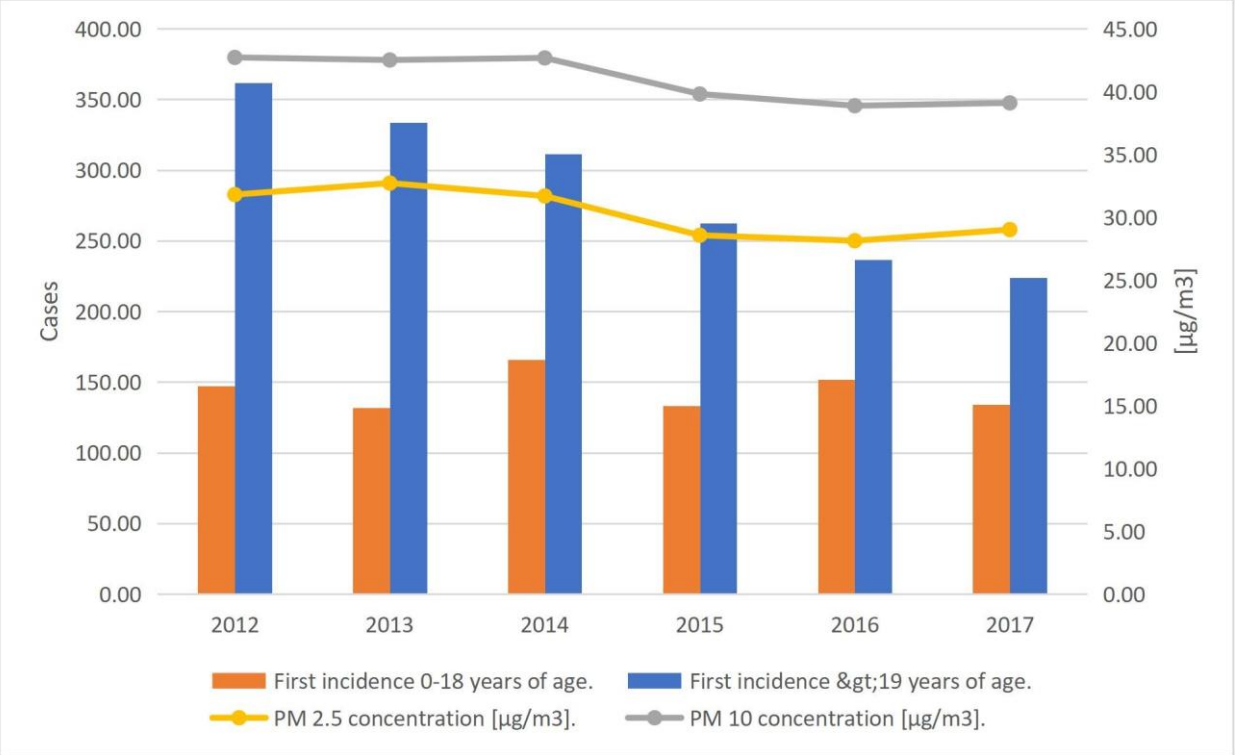

Figure 1. The number of first cases and PM concentration in the Silesian Voivodeship in 2012-2017.

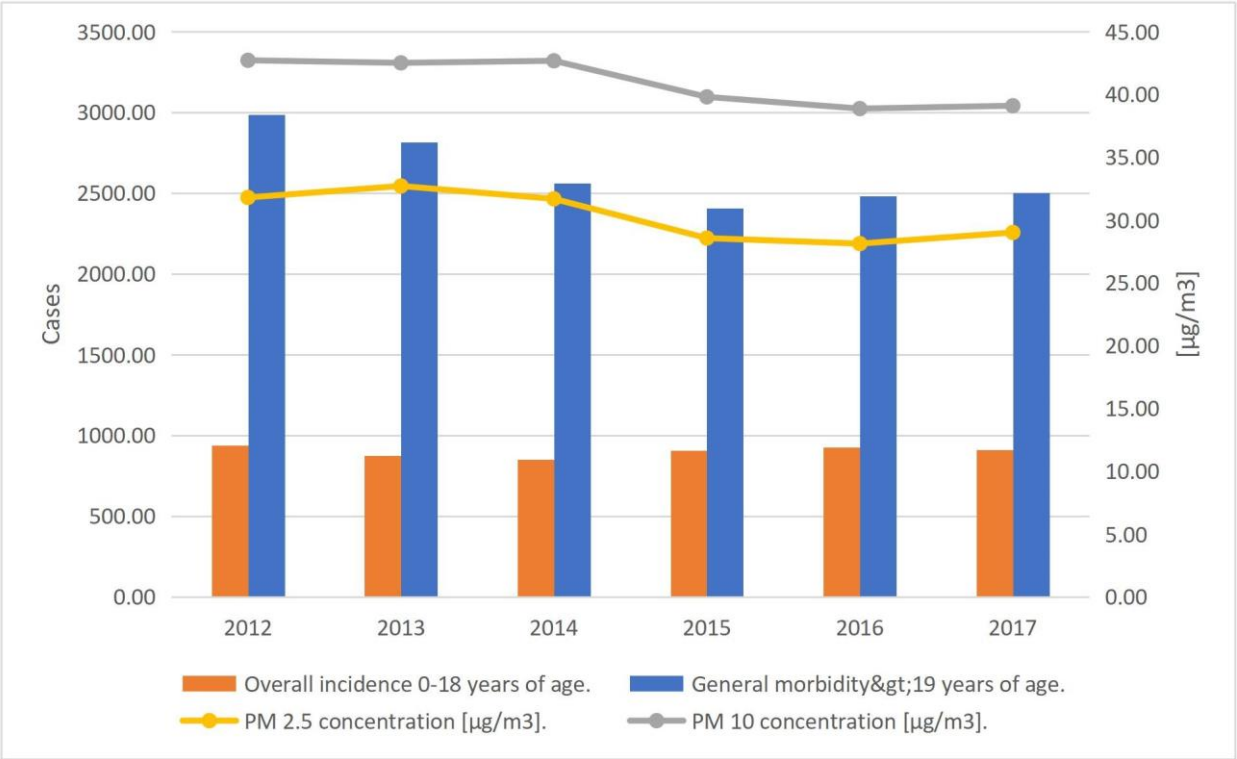

Figure 2. The total number of cases and PM concentration in the Silesian Voivodeship in 2012-2017.

Detailed data on the number of first respiratory episodes and the overall incidence of these entities are presented in Table II.

Table II. Number of first and overall cases by age group of patients (0-18 years and >19 years) for each county and city in 2012-2017

City	Year	First cases of age 0-18	Overall cases of age 0-18	First cases of age >19	Overall cases age >19
Częstochowa	2012	112	698	136	1393
	2013	97	672	138	1388
	2014	91	695	104	1426
	2015	92	656	85	1252
	2016	59	645	72	1231
	2017	85	648	104	1415
Tarnowskie Góry	2012	88	713	239	1624
	2013	74	606	139	1613
	2014	65	421	121	1488
	2015	91	660	180	1690
	2016	128	724	198	1747
	2017	180	861	161	1868
Wodzisław	2012	119	885	197	2563
	2013	65	796	186	2648
	2014	58	821	224	2863
	2015	118	818	243	2299
	2016	128	910	215	2286
	2017	110	894	248	2377
Bielsko Biala	2012	147	947	492	2565
	2013	106	984	263	2392
	2014	296	1121	312	2273
	2015	133	1007	242	2147
	2016	163	1030	267	2348
	2017	175	1100	176	2236
Częstochowa	2012	215	**1751**	564	4487
	2013	162	1612	496	4948
	2014	173	1105	472	4470

	2015	131	1469	279	4349
	2016	155	1441	262	4379
	2017	118	1425	441	4463
Gliwice	2012	178	1175	320	3327
	2013	149	875	415	2911
	2014	184	1069	371	2521
	2015	146	1251	379	2334
	2016	163	1129	340	2440
	2017	129	1094	213	2436
Katowice	2012	276	1080	849	**7210**
	2013	**311**	1176	**943**	5996
	2014	303	1154	788	4870
	2015	223	910	640	4632
	2016	255	1034	436	4877
	2017	217	1020	384	4799
Żory	2012	42	272	99	727
	2013	90	291	89	639
	2014	156	436	98	593
	2015	132	484	53	561
	2016	162	495	104	540
	2017	60	244	65	427

According to the above table, the highest number of cases in the 0-18 age group was recorded in the Częstochowa district, and in the 19+ group in the Katowice district. The former group had a total of 1,751 cases in 2012, and the latter 7210 also in the same period.

Discussion

Air pollution has a particularly significant impact on environmental degradation, human health and quality of life (Sygulska et al. 2018). Our study confirmed that in Silesia province, in Poland, the air quality is poor; the increase in the number of excessive levels of average daily PM10 concentration and average annual PM2.5 concentrations was observed in almost all measurement stations. The impact of suspended particulate matter on human health has been the subject of intense research over decades (Fenger 2009, Anderson 2009, Chang et all 2015, Li et al 2016). Multiple studies highlighted the relation between particulate matter and the occurrence of health effects in terms of respiratory and cardiovascular diseases (Kelly 2015). Particulate matter can be a serious pathogen, settling on the walls of the alveoli hindering gas exchange, irritating the epidermis and mucous membranes, inflammation of the upper respiratory tract, and causing allergic diseases, asthma, cancers of the lungs, throat, and larynx. Some particulate matter accumulates in the respiratory tract, and the toxins it contains damage cell membranes and causes inflammation. There is no concentration threshold below which the negative health effects of dust on human health do not occur The immune system is not always able to mount a fully effective defence which leads to the removal of all dust from the body. Their presence in the respiratory tract is a risk factor for many conditions, including chronic obstructive pulmonary disease. Even with a small increase in dust in the air, there is a noticeable increase in the number of people with mild symptoms of diseases (mainly cardiovascular and respiratory diseases and asthma), an increase in the consumption of medicines, visits to doctors, medical home visits, hospital emergency admissions and a marked increase in school and work absenteeism days; days of limited activity (Brown 2013; Linares 2009; Praznikar and Praznikar 2012).

Studies in Europe show a significant association between PM2.5 exposure and respiratory infections in children (Gehring et al. 2010). Children and infants are particularly vulnerable to particulate air pollution, as their immune, respiratory and central nervous systems are not yet fully developed (Zyska et al. 2018). The results of this study also showed that exposure to ambient PM2.5 and PM10 was significantly associated with the development of respiratory tract diseases, like acute inflammation of the sinuses, nasal mucosa, tonsils and throat, in children and adults, but higher for children than adults. Relative to adults, children often spend more time outdoors, and due to their smaller lung capacity, they also breathe more frequently, thus inhaling - much more than adults - an amount of air relative to their body weight, and their protective barriers such as mucous membranes and epithelia are not yet fully formed. As we mentioned before exposure to air pollutants significantly increases the incidence of respiratory infections, including pneumonia, particularly in children (Sygulska et al. 2018). It is estimated that in 60-90% of children presenting to the doctor, the immediate cause of the illness was a viral respiratory infection (Tranda et al. 2000). Other publications suggest a link between PM2.5 and bronchiolitis in infants (Karr et al. 2009). PM10, as larger particles, is deposited in the upper

respiratory tract and bronchial tree. When deposited on the surface of the upper respiratory tract, they are removed fairly quickly if clearance mechanisms such as mucociliary clearance (i.e., the rate at which the upper airway epithelium is cleared of pollutants) and macrophage function are not impaired (Geiser, Kreyling 2010). In the case of asthmatics, the pro-inflammatory effects of the finest fractions of particulate matter, and substances in the dust, such as transition metals, may be crucial (Kawecki, Nawrocki 2013). It is the content of these components, rather than the total dust concentration, that may therefore determine the strength of the association between exposure to dust pollution and asthma incidence (Jedrak 2017).

In addition to children, the following are considered particularly vulnerable to the harmful effects of particulate matter: seniors (because the risk of heart attacks and strokes increases in old age) (Anoop et al. 2013, Szu-Ying 2014), pregnant women (smog exposure can lead to premature birth, fetal damage, low birth weight of the baby and susceptibility to pneumonia in infancy) (Malley 2017; Liu 2017), physically active people (during physical exertion the demand for oxygen increases, leading to inhalation of even higher amounts of dust) and people suffering from cardiovascular and respiratory diseases including allergies (because of the possibility of aggravation of disease symptoms) (Judy-Rezler, Toczko 2016).

The link between air pollution levels and mortality was recognized as early as at least the 1930s, and certainly since the so-called Great London Smog of December 1952. The very high concentrations of particulate matter and sulphur dioxide occurring at that time caused approx. 4,000 deaths in a matter of days, it is now estimated that the total number of victims of the Great London Smog is about 12,000, as the elevated mortality rate continued for several weeks after the smog subsided (Davis 2002). Although the study of mortality rates was not the purpose of our study.

There are many well-known examples of how improvements in air quality translate into improvements in population health, particularly when it comes to respiratory diseases and disorders. This is well illustrated by the already-cited case of Utah Valley, where, in the mid-1980s, due to a steel mill strike, air pollution concentrations dropped significantly, and with them not only total mortality but also the number of hospitalizations for bronchitis and asthma exacerbations. A particularly strong (about twofold) decrease in hospitalizations was observed among children under the age of five (Pope 1991).

The state of the environment is one of the factors that greatly affect our sense of safety. Smog, which occurs most often in urbanized areas, affects the quality and comfort of population life. Despite significant improvements in recent decades, there are some regions in Europe, especially East - Central Europe, where air pollution continues to harm human health and the environment (WHO 2016a).

Conclusions

1. In Silesia province, the air quality is poor and has deteriorated over the last few years.
2. Exposure to ambient PM2.5 and PM10 was significantly associated with the increase of respiratory tract diseases in children and adults in the Upper Silesia urban area.
3. It is necessary to implement further measures to reduce the levels of PM10 and PM2.5 dust in human living spaces and educate the public about the harmfulness of these substances to health, with particular attention to the harmfulness associated with an increased risk of upper respiratory tract infections.

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