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PRACA ORYGINALNA
ORIGINAL PAPER

The relationship between asthma and hypertension in children and adolescents and atmospheric air pollution in Bielsko-Biała

Związek pomiędzy astmą i nadciśnieniem tętniczym u dzieci i młodzieży a zanieczyszczeniem powietrza atmosferycznego w Bielsku-Białej

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ABSTRACT

INTRODUCTION: Chronic diseases are among of the most serious phenomena and problems in the modern world. They include asthma, allergies and arterial hypertension. Even short-term exposure to polluted air increases the incidence of both hypertension and asthma. The aim of the study is to determine the relationship between the level of selected atmospheric air pollutants in the city of Bielsko-Biała in the years 2018–2022 (nitrogen dioxide, suspended dust PM2.5, PM10 and benzo(a)pyrene) and the incidence of asthma and hypertensive disease among children and youth from 0 to 18 years of age in Bielsko-Biała.

MATERIAL AND METHODS: Based on data from the Health Department – the Silesian Voivodeship Office in Katowice regarding the incidence of asthma and hypertensive disease, tables and graphs illustrating the incidence of these diseases were prepared. The annual average concentrations of selected air pollutants were also taken into account. Based on the Statistica program and Pearson correlation coefficients, the relationship between the occurrence of asthma, hypertensive disease and air pollution was examined.

RESULTS: The incidence of hypertension and asthma among children and adolescents in Bielsko-Biała is decreasing and amounted to 32.1/10,000 in 2018 and 18.7/10,000 in 2022 in the case of hypertensive disease, and 394.8/10,000 in 2018 and 319.9/10,000 in 2022 for asthma. The average annual concentration of PM10 and benzo(a)pyrene is also decreasing.

CONCLUSIONS: In the discussed period, the average annual concentrations of the analyzed substances were not exceeded. The decreasing incidence of both asthma and hypertension is related to the improvement in atmospheric air quality.

KEYWORDS

chronic diseases, hypertension, suspended dust PM10 and PM2.5, benzo(a)pyrene

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STRESZCZENIE

WPROWADZENIE: Choroby przewlekłe są jednym z najpoważniejszych zjawisk i problemów współczesnego świata. Należą do nich astma, alergie i nadciśnienie tętnicze (nadciśnienie). Nawet krótkotrwałe narażenie na zanieczyszczone powietrze zwiększa częstość występowania zarówno nadciśnienia, jak i astmy. Celem badań jest określenie zależności pomiędzy poziomem wybranych zanieczyszczeń powietrza atmosferycznego w mieście Bielsko-Biała w latach 2018–2022 (dwutlenek azotu, pyły zawieszone PM2,5 i PM10 oraz benzo(a)piren) a zachorowalnością na astmę i chorobę nadciśnieniową wśród dzieci i młodzieży w wieku od 0 do 18 lat w Bielsku-Białej.
MATERIAŁ I METODY: Na podstawie danych z Wydziału Zdrowia – Śląskiego Urzędu Wojewódzkiego w Katowicach, dotyczących zachorowalności na astmę i chorobę nadciśnieniową, przedstawiono tabele i wykresy ilustrujące częstość występowania tych chorób. Uwzględniono także średnie roczne stężenia wybranych substancji zanieczyszczających powietrze. Na podstawie programu Statistica i współczynników korelacji Pearsona zbadano związek pomiędzy występowaniem astmy i choroby nadciśnieniowej a zanieczyszczeniem powietrza.
WYNIKI: Liczba zachorowań na nadciśnienie tętnicze i astmę wśród dzieci i młodzieży w Bielsku-Białej maleje i wynosi 32,1/10 000 w 2018 r. i 18,7/10 000 w 2022 r. w przypadku choroby nadciśnieniowej oraz 394,8/10 000 w 2018 r. i 319,9/10 000 w 2022 r. w przypadku astmy. Maleje także średnioroczne stężenie PM10 i benzo(a)pirenu.
WNIOSKI: W omawianym okresie nie nastąpiło przekroczenie średniorocznych stężeń analizowanych substancji. Zmniejszająca się zapadalność na astmę i nadciśnienie tętnicze ma związek z poprawą jakości powietrza atmosferycznego.

SŁOWA KLUCZOWE

choroby przewlekłe, nadciśnienie, pyły zawieszone PM10 i PM2,5, benzo(a)piren

INTRODUCTION

Currently, 9 out of 10 people around the world breathe polluted air, which causes approximately 7 million deaths annually [1]. According to the analysis of the European Commission, inhaling polluted air causes approximately 47,000 deaths among Polish residents every year, including 36,500 due to PM2.5 suspended dust [2].

Exposure to even relatively low levels of air pollution for many months or years causes the occurrence of:

- respiratory diseases, including asthma, chronic obstructive pulmonary disease, lung cancer
- circulatory system diseases (including hypertension)
- mortality due to cardiovascular and respiratory diseases
- gradual weakening of the immune system, especially in sensitive people, those treated for chronic diseases or diagnosed with diseases at an advanced stage [3,4,5].

The main source of air pollution in Bielsko-Biała (as well as in the entire Silesian Voivodeship) is anthropogenic emissions from the municipal and residential sector in the autumn-winter period (surface emissions), with a smaller share being emissions from transport (linear emissions) and industrial activity (point emissions). The main local sources of pollution are the chimneys of individually heated houses, while road transport affects the concentration of pollutants, especially in areas directly adjacent to roads with significant volumes of traffic. Industrial plants with significant fugitive emissions or emissions through low emitters may also directly affect the air quality in individual regions of the voivodeship.

The city area can be divided into two different types in terms of ventilation, i.e. into "well-ventilated" areas, where there are, for example, hills, and "less ventilated" areas, which are valley areas, where the percentage of the frequency of a lack of wind and weak winds is much higher, thus reducing the possibility of air exchange and purification in the city. The general quality of air in Bielsko-Biała is influenced by many factors, creating this phenomenon with a complex multi-parameter system, very difficult to model and forecast. However, the most important factors are those related to the formation, migration and local accumulation of pollutants at low altitudes above ground level. The geographical location of the city favors the ventilation of the urban area because the height of the terrain falls from the south to the north and from the west to the east. Nevertheless, there are local depressions in the area, and for this reason, appropriate spatial development is important, especially in urbanized areas. Another factor that directly causes the occurrence of increased concentrations of pollutants in the air are climatic and meteorological conditions. Favourable meteorological conditions (air temperature, wind speed and direction) cause an increase or decrease in the concentration of pollutants in the atmospheric air at the measurement height (approx. 2 m above ground level) [6].

Arterial hypertension (hypertension) affects approximately 20–30% of the world's population and in most cases it is primary. This disease is one of the main risk factors responsible for the epidemic of heart and vascular diseases in Poland, Europe and the world. According to the World Health Organization (WHO), increased blood pressure is the first cause of death in the world. It is one of the main independent risk factors for coronary heart disease, stroke, heart failure,

peripheral arterial atherosclerosis and renal failure. Arterial hypertension affects 3–5% of children and adolescents aged 0 to 18 years. The frequency of diagnosis of this condition in teenagers aged 14–18 is similar to the prevalence of hypertension in young adults and is approximately 10–13%. In Poland, it affects 4% of men aged 18–24, 6% aged 25–34 and 14% aged 35–44. In women, the corresponding frequencies are 2%, 4% and 10%. Secondary hypertension occurs more often in younger children, before the pubertal growth spurt. The incidence of essential hypertension (primary hypertension) increases rapidly during adolescence and mainly affects boys. This is caused by the physiological increase in blood pressure in boys. During this period, hypertension is diagnosed 3–4 times more often in boys than in girls [7].

Air pollution is associated with the development of hypertension, atherosclerosis and related complications. The mechanism of the influence of polluted air on the development of cardiac ischemia, strokes and cardiac arrhythmias has already been described in many works. Oxygen radicals have a significant impact, leading to inflammation and damage to the endothelium [8,9]. Air pollution increases blood pressure through the mechanism of causing systemic inflammation, oxidative stress, epigenetic changes and dysfunction of the vascular endothelium in addition to other hemodynamic parameters [10,11,12]. A detailed description of the impact of polluted air on the development of cardiac ischemia, hypertension, heart failure and cardiac arrhythmias was presented in a review by Głuszek and Kosicka [13].

According to the definition proposed by the international team of experts GINA (Global Initiative for Asthma), bronchial asthma is a heterogeneous disease, usually characterized by chronic inflammation of the respiratory tract, with respiratory symptoms such as wheezing, shortness of breath, feeling of tightness in the chest and cough, which vary in time and intensity, including variable airway obstructions. The etiology of asthma is multifactorial; its development is influenced by both environmental and individual factors (including genetics). Environmental factors with a potential impact on the development of asthma include allergens and exposure to infectious agents [14].

Asthma is a chronic respiratory disease characterized by variable airway obstructions, bronchial hyperresponsiveness, and airway inflammation. Air pollution has a negative impact on asthma treatment outcomes in both adults and children. Road traffic-related air pollution (TRAP), exposure to polluted air, including nitrogen dioxide, suspended particulate matter PM2.5 and PM10, in addition to passive smoking (second-hand smoke exposure – SHS), are important risk factors for the development of asthma, mainly in children. Exposure to external pollutants can trigger asthma symptoms, exacerbate and deteriorate lung function. The prevalence of asthma is estimated at 1–18% of the population in various countries. 13% of the global incidence of childhood asthma is attributable to TRAP. Exposure to PM2.5, PM10 and NO_2 is associated with a higher incidence of asthma until the age of 20. Each year, 4 million new cases of asthma in children can be attributed to NO_2 pollution. PM2.5 dust is responsible for 16 million cases of asthma in children each year. This dust increases the frequency of visits to the emergency room due to asthma exacerbation in both adults and children. Annually, 9–10 million asthma emergency room visits worldwide can be attributed to PM2.5. Although particles are detected in many organs, the respiratory system is usually the first line of entry into the body. Particulate matter penetrates deep into the lungs and increases the frequency and severity of asthma attacks, exacerbating bronchitis and other lung diseases [15,16]. Inhaled particulate matter can cause oxidative stress in the lungs, as well as interact with various components of the immune system and enhance the allergic inflammatory response. Dust particles enter the circulatory system through the obstruction layers of the alveoli and absorb on their surface many toxic substances floating in the air, such as heavy metals, polycyclic aromatic hydrocarbons (PAHs) and organic/inorganic ions [17].

The aim of the study is to determine the relationship between the level of selected average annual concentrations of atmospheric air pollutants (nitrogen dioxide, PM2.5 and PM10 particulate matter and benzo(a)pyrene) and the incidence of asthma and hypertension. The study area covered the city of Bielsko-Biała and the population group of children and adolescents aged 0 to 18 years who were residents of the city registered from the moment of birth, therefore the statistical data did not change during the study. These are data on the health status of children and adolescents under the care of a primary care physician (family doctor).

MATERIAL AND METHODS

The article takes into account data from the Chief Inspectorate for Environmental Protection (Główny Inspektorat Ochrony Środowiska – GIOŚ) showing the average annual concentrations of the above-mentioned pollutants for the period from 2018 to 2022 in the analyzed city. The next stage was to prepare appropriate graphs presenting the average annual concentrations of the analyzed substances. Statistical data from the Health Department of the Silesian Voivodeship Office in Katowice regarding the number of cases of asthma

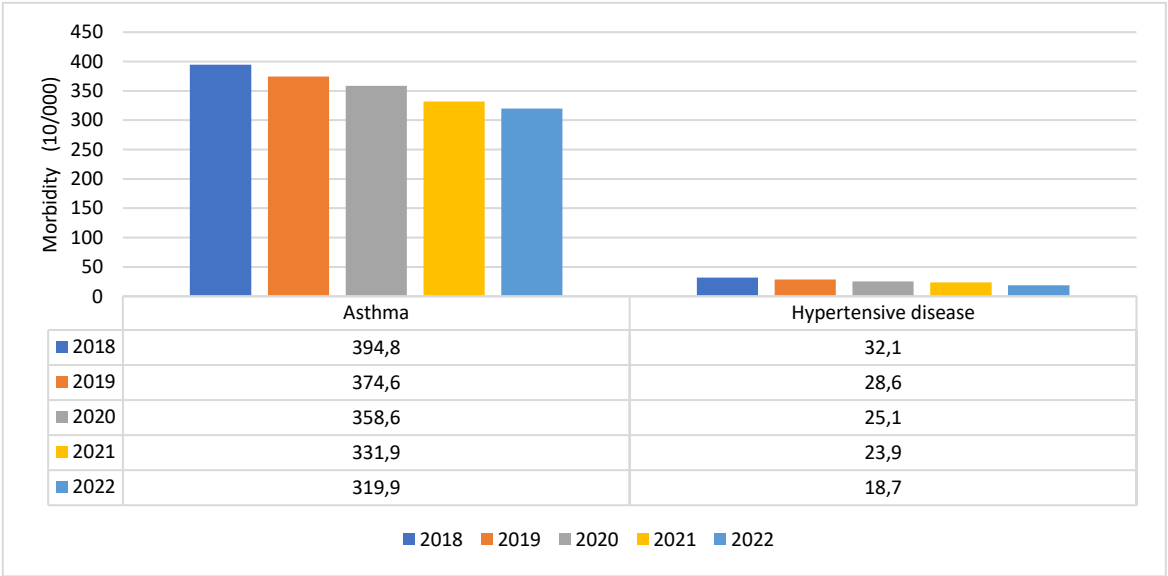
(J45–J46) and hypertension (I10–I15) among the studied population group of Bielsko-Biała residents were also used, taking into account the incidence rate per 10,000 children and adolescents. In order to examine the relationship between the occurrence of asthma and hypertension and air pollution, Pearson correlation coefficients were calculated using the Statistica software version 13.6.0.064 (0616) program and their significance was checked.

RESULTS

The incidence of hypertensive disease among children and adolescents up to 18 years of age is decreasing and ranged from 32.1/10,000 in 2018 to 18.7/10,000 in 2022. In the case of asthma, the incidence rate is also decreasing and ranged from 394.8/10,000 in 2018 to 319.9/10,000 in 2022 (Figure 1).

The classification criteria in accordance with Art. 89 of the Act of April 27, 2001 – Environmental Protection Law (Journal of Laws of 2021, item 1973, as amended) for PM10 suspended dust in order to protect human health states the average annual permissible level of 40 µg/m^3. In the years 2018––2022, this concentration decreased and ranged from 37 µg/m^3 in 2018 to 24 µg/m^3 in 2022 (Figure 2). In the case of PM2.5, this criterion is 20 µg/m^3 (annual average concentration) to protect human health. The highest (32 µg/m^3) concentration was recorded in 2018 and the lowest (23 µg/m^3) in 2022 (Figure 2). The classification criteria for nitrogen dioxide to protect human health is a permissible level of 40 µg/m^3 per calendar year. During the period in question, the average annual concentration of the substance decreased from 32 µg/m^3 (2018) to 25 µg/m^3 (2022; Figure 2).

In order to examine the relationship between the occurrence of asthma and hypertensive disease and air pollution, the Pearson correlation coefficients were calculated using the Statistica program and their significance was tested. It was concluded that there is a very strong positive correlation between the concentration of PM10 and the occurrence of the above-mentioned diseases. The Pearson correlation coefficient in the case of asthma and PM10 was 0.9824 (p-value = 0.003) and in the case of PM10 and hypertensive disease it was 0.9828 (p-value = 0.07), which in both cases indicates a very strong positive correlation, i.e. a decrease in the value of PM10 results in a decrease in the incidence of asthma and hypertensive diseases. Similar results were obtained when examining the relationship between nitrogen dioxide and the above-mentioned diseases. The Pearson correlation coefficient for nitrogen dioxide and asthma was 0.8878 (p-value = 0.05) and for nitrogen dioxide and hypertensive disease 0.8462 (p-value = 0.07). At a significance level of 0.05, the first result is statistically significant, the second is not, but in the case of such a small sample, we can assume a significance level of 0.1. In both cases there is a strong positive correlation. In the case of the relationship between the PM2.5 concentration and the occurrence of the above-mentioned diseases, statistically insignificant results were obtained, which may be due to the short observation period (5 years) and the fact that the PM2.5 standards were still exceeded (Table I). To sum up, it can be said that improving air quality (especially decreasing PM10 and nitrogen dioxide values) reduces the incidence of hypertension and asthma.



	Asthma	Hypertensive disease
2018	394,8	32,1
2019	374,6	28,6
2020	358,6	25,1
2021	331,9	23,9
2022	319,9	18,7

Fig. 1. Incidence of children and adolescents aged 0–18 with asthma and hypertension in 2018–2022 in Bielsko-Biała (incidence per 10,000). Source: Author's compilation based on data from Health Department of Silesian Voivodeship Office in Katowice.

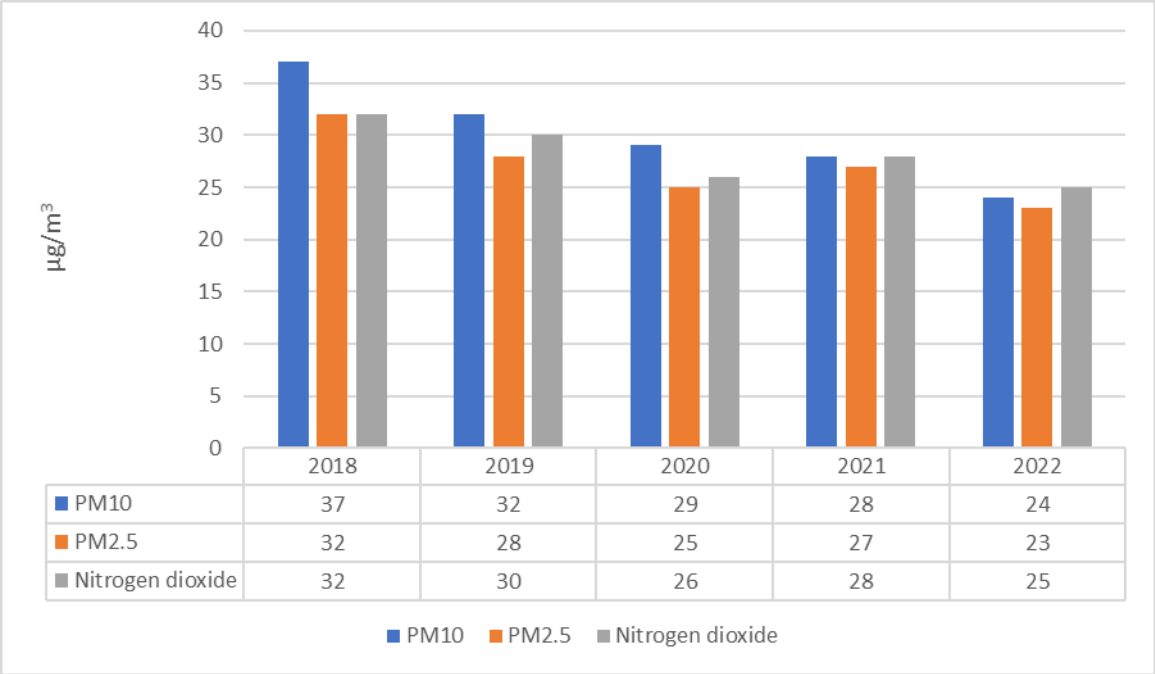


Fig. 2. Average annual concentrations of suspended dust PM10, suspended dust PM2.5 and nitrogen dioxide. Source: Author's compilation based on data from Chief Inspectorate of Environmental Protection (GIOŚ).

Table I. Correlations between PM2.5 and PM10 suspended dust, nitrogen dioxide and bronchial asthma and hypertensive disease

Variable	PM10	PM2.5	Nitrogen dioxide
Asthma	0.9824 p = 0.003	0.6588 p = 0.227	0.8878 p = 0.05
Hypertensive disease	0.9828 p = 0.07	0.6000 p = 0.285	0.8462 p = 0.07

Correlation coefficients in red are statistically significant $p < 0.05$ N = 5. Source: Author's study.

The average annual permissible concentration of benzo(a)pyrene in accordance with the Regulation of the Minister of the Environment of August 24, 2012 on the levels of certain substances in the air for the protection of human health (target level) should not exceed 6 ng/m^3 in a calendar year. During the period in question, it had a decreasing tendency and amounted to 5.2 ng/m^3 in 2018 and 3.1 ng/m^3 in 2022 (Figure 3).

The correlation between the concentration of benzo(a)pyrene and the incidence of asthma and hypertensive disease was also examined. In both cases, there was a statistically significant strong positive correlation, in the case of the relationship between the concentration of benzopyrene and the incidence of asthma, the correlation coefficient was 0.9746 (p-value = 0.005), while in the case of the relationship between the concentration of benzopyrene and the incidence of hypertensive disease, the correlation coefficient was 0.9935 (p-value = 0.001). Therefore, in both cases, the correlation is very strong; as the concentration of benzopyrene decreases, we observe a decline in the incidence of both diseases (Table II).

In the discussed period from 2018 to 2022, the average annual concentrations of PM10 and nitrogen dioxide were not exceeded. In the case of PM2.5 suspended dust, the average annual concentration is exceeded from 3 to 12 µg/m^3, but a significant decrease in this pollution can be observed. It is also similar in the case of benzo(a)pyrene, where in each analyzed year there is an average annual concentration exceedance of 5.2 to 3.1 ng/m^3, but its concentration has a decreasing tendency (Figure 3).

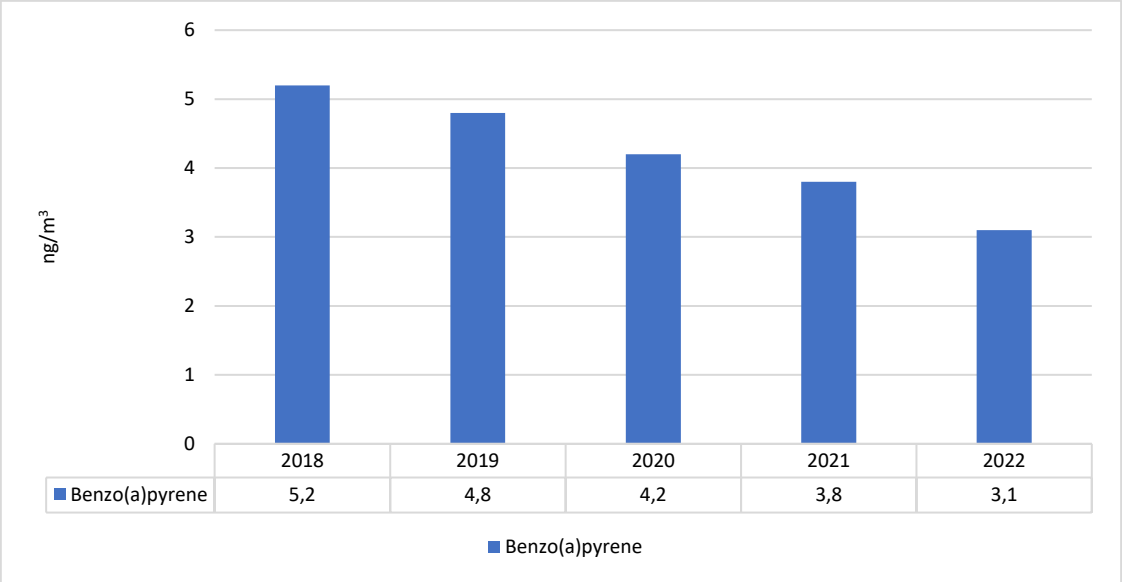


Fig. 3. Average annual concentrations of benzo(a)pyrene. Source: Author's compilation based on data from Chief Inspectorate of Environmental Protection (GIOŚ).

Table II. Correlations between benzo(a)pyrene and bronchial asthma and hypertensive disease

Variable	Benzo(a)pyrene
Asthma	0.9746 p = 0.005
Hypertensive disease	0.9935 p = 0.001

Correlation coefficients in red are statistically significant $p < 0.05$ $N = 5$. Source: Author's study.

CONCLUSIONS

Over the analysed period, there was a decrease in the incidence of both bronchial asthma and hypertension, which amounted to 394.8/10,000 and 32.1/10,000 in 2018 and 319.9/10,000 and 18.7/10,000 in 2022, respectively, with a decrease in the average annual concentrations of PM10 particulate matter and with variable average annual concentrations of PM2.5 particulate matter and nitrogen dioxide.

Significant improvement in air quality has a direct impact on the decrease in the number of illnesses (Figure 2 and Figure 3) as evidenced by the significant correlations that were found. The above data on the incidence of asthma and hypertensive disease indicate that air pollution, which is a serious problem in the civilized and industrialized world, has a very large impact on the human body. Their health consequences are most often long-lasting and concern the development of the chronic diseases described above, which may lead to a shorter lifespan. Children and teenagers are more likely to experience serious breathing problems during periods when air pollution levels are high.

In 2023, GIOŚ prepared an analysis of the results of air quality measurements. Compared to the five previous years, significant improvement can be seen. The GIOŚ analysis used the results of measurements of pollutants that largely come from heating houses and apartments: nitrogen dioxide, suspended dust PM10 and PM2.5 (from all automatic measurement stations in Poland) and benzo(a)pyrene in suspended dust PM10 (from manual stations). The analysis of the average values of the above-mentioned air pollution concentrations from the analyzed measurement stations in Poland indicates a very favorable situation over the last few years. Nonetheless, it should be borne in mind that the concentration of pollutants in the air is also influenced by the meteorological conditions prevailing in a given period in a specific area [18].

The exceedances of the average annual permissible level in 2022 in relation to nitrogen dioxide were local and occurred only in the areas affected by road transport in the centers of 4 agglomerations (including Upper Silesia). Significant improvement in air quality also occurred in relation to air pollution with PM10 suspended dust. In 2022 alone, exceedances of the average daily permissible level of PM10 suspended dust occurred in 14 zones, while in 2021 these exceedances occurred in 25 zones. Similar improvement occurred with respect to PM2.5. The number of zones in which the average annual permissible level of PM2.5 suspended dust (20 $\mu g/m^3$) was exceeded decreased from 29 zones in 2021 to 11 zones in 2022 throughout the country. The assessment results for 2022 in relation to both PM10 and PM2.5 suspended dust showed that in 2022, in most areas of Poland, their concentrations were the lowest since the beginning of measurements.

DISCUSSION AND SUMMARY

One of the most frequently studied risk factors for asthma is air pollution resulting from the increased risk of asthmatic attacks through various mechanisms, including direct irritation of the respiratory tract, toxic effects on the respiratory epithelium, bronchial hyperresponsiveness, and modification of the immune response. Some epidemiological studies indicate a significant role of pollution levels, primarily PM10 particulate matter, in the occurrence of asthma exacerbations, and consequently with a greater number of visits to outpatient clinics or emergency rooms, but there are also reports that do not confirm such a relationship. Contradictory results between different studies may to some extent be the consequence of differences in the way these studies were conducted, or they may result from different levels of pollution and the dominant substance.

Asthma and hypertension are chronic diseases that have many causes for changes in their incidence. In addition to exposure to environmental factors (including air pollution), they include smoking, alcohol abuse, obesity, lack of physical activity, genetic predisposition, various types of mental disorders that are both a cause and an effect, as well as chronic stress. The author of this article considered only air pollution as an environmental factor that affects the change in the incidence of the discussed diseases.

By breathing polluted air with increased concentrations of dust and gases, the human body is potentially exposed to a change in the frequency of chronic diseases, mainly respiratory diseases. This is confirmed by numerous international studies. A study of a group of 146,397 young children from Utah, combined with the results of air monitoring (where the average annual permissible concentration of benzo(a)pyrene and PM2.5 and PM10 dust was repeatedly exceeded) from 1999–2016 showed that already a week after an increase in PM2.5 concentration by 10 $\mu g/m^3$, the number of reports of acute respiratory infections increased, which grew for up to three weeks and lasted for up to 28 days from the rise in concentration. The increment in the number of reports of respiratory diseases was 32% for children between 2 and 18 years of age [19]. However, other international studies have not provided a clear answer as to whether there is a relationship between the average annual concentrations of air pollution and the incidence of asthma among children and adolescents in 2014–2019 in Germany, Switzerland and France [15,17].

The biggest air pollution problem in the Silesian Voivodeship, as well as in the entire country, is the high content of benzo(a)pyrene in PM10 suspended dust; nevertheless, in this case, the concentrations of this pollutant and the areas of their exceedances have significantly decreased. The number of zones in which exceedances occurred decreased from 39 in 2021 to 32 in 2022 [20].

Currently, changes in climate policy regarding air quality involve prevention through the implementation of modern industrial technologies that ensure lower emissions of gases and dust into the atmosphere. The sources of air pollution are clearly related to human economic activities, therefore strategies should be developed to increase cooperation between developed and developing countries to counteract the health effects of air pollution.

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