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RELATIONSHIP BETWEEN AIR POLLUTION AND THE INCIDENCE OF SELECTED DISEASES AMONG CHILDREN AND ADOLESCENTS IN THE YEARS 2017-2023 IN SELECTED CITIES IN POLAND

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Abstract

The aim of this research is to examine the relationship between average annual air pollution concentrations in selected cities and the incidence of specific diseases among children and adolescents aged 0 to 18 in selected Polish cities - Gdańsk, Katowice, Poznań, and Lublin with varying levels of average annual air pollution [suspended particulate matter PM2.5 and PM10, benzo(a)pyrene, nitrogen dioxide]. The relationship between the incidence of selected diseases among children and adolescents (asthma, hypertension, food and skin allergies) from 2018 to 2023 and the quality of atmospheric air was examined. In Katowice, due to the presence of a developed industry, the permissible average annual concentrations of the analyzed air pollutants were exceeded in the initial period, unlike in Gdańsk and Lublin. However, the greatest challenge in Poland concerning air quality is the average annual concentration of benzo(a)pyrene. Nonetheless, there has been a significant decrease in recent years. Polish cities facing air pollution problems are undertaking various measures to improve air quality. Studies have shown significant connections between the concentrations of selected pollutants and the frequency of diseases such as bronchial asthma, hypertension, food and skin allergies. However, this impact varies from city to city.

Keywords: suspended dust PM2.5, suspended dust PM10, morbidity, bronchial asthma, children, benzo(a)pyrene, nitrogen dioxide

1. INTRODUCTION

Every year, approximately 47,000 Poles die as a result of air pollution [1,2]. One of the main public health problems in the world today is air pollution. Poland ranks third among the most polluted capitals in Europe in terms of average annual concentrations of suspended particulate matter PM10 [3]. It is estimated that polluted air causes around 7 million deaths annually worldwide. Nearly 300 million children globally live in areas where pollution levels exceed the standards by six times, and about 1.8

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million of them die due to smog, including one in ten under the age of five [4]. Children, due to their not fully developed respiratory and immune systems, as well as a significantly higher breathing rate per minute, are at a much greater risk of illness from polluted air compared to adults. During inhalation and air exchange, a higher dose of various pollutants enters the child's body [5,6].

Air pollution emissions in Poland primarily result from heating homes using coal and other solid fuels, including waste and plastics, often in stoves that do not meet emission standards. The municipal and household sector is the main source of air pollution emissions. Due to the low height of the emitters, emissions from these sources are referred to as "low emissions." This has a significant impact on air quality because the low placement of emission sources often leads to high concentrations of pollutants [mainly polycyclic aromatic hydrocarbons (PAHs), suspended particulate matter, dioxins, furans, and heavy metals such as mercury, cadmium, lead, as well as sulfur and nitrogen oxides] in the areas where people live, especially in densely populated regions [7-9].

Breathing polluted air has various health effects. Primarily, older adults, children, individuals with weakened immune systems, and those with pre-existing conditions can experience health impacts even on days when air pollution levels slightly exceed standards. The effects of air pollution on human health most commonly manifest as respiratory system issues. Wheezing, heavy breathing, coughing fits, asthma attacks, and bronchitis or pneumonia are among the first signs that appear with daily exposure to harmful emissions. The accumulation of toxic substances in the human body can also damage organs, lower resistance to infections, and contribute to problems with oxygen absorption in the blood. Inhaling polluted air negatively affects many aspects of daily human functioning, and diseases caused by air pollution are affecting an increasing number of people. Among the most serious conditions are cardiovascular diseases (heart attacks, hypertension, heart rhythm disorders, heart failure, and coronary artery disease), respiratory diseases (asthma and chronic obstructive pulmonary disease), cancer (including tumors of the central nervous system), allergic diseases (food and skin allergies), nervous system disorders, memory and concentration problems, chronic fatigue, worsening mental health, premature deaths-particularly related to respiratory and cardiovascular diseases, increased medication use, higher rates of school and work absenteeism, and lower birth weight in newborns [10-15].

In June 2023, the Chief Inspectorate of Environmental Protection (GIOŚ) in Poland conducted an analysis of air quality measurement results. Compared to the previous five years, a significant improvement in air quality is evident. The GIOŚ analysis utilized pollution measurement data, primarily from sources related to heating homes and apartments: sulfur dioxide, suspended particulate matter PM10 and PM2.5, and benzo(a)pyrene. The analysis of the average annual concentrations of these air pollutants from monitored stations across Poland indicates a very favorable trend over the past few years. However, it is important to note that air pollution concentrations are also influenced by topographical and meteorological conditions in specific areas [16].

The northern part of Poland (the city of Gdańsk and the entire Pomeranian Voivodeship) is a region where the air quality is significantly better compared to other parts of the country. This is due to its geographical location, lower population density, favorable meteorological conditions, and fewer industrial facilities, which greatly influence the air quality (Fig. 1). The Lublin Voivodeship (including the city of Lublin), located in eastern Poland, is influenced by a continental climate, causing summer and winter to start earlier and last longer compared to other regions of Poland. The industry in the Lublin Voivodeship, primarily energy production, due to the high altitude of its emitters, largely exports pollution beyond the region's borders. Industrial plants with significant unorganized emissions or those emitted through low chimneys can also directly affect air quality in their vicinity (Fig. 1).

The Silesian Voivodeship (including the city of Katowice) is located in the southern part of the country. It is highly diverse in terms of its physical and geographical characteristics. The exploitation of the richest mineral resources in the country, along with related industrial activities and urbanization, has led to significant environmental degradation, including air quality issues. The Upper Silesian Industrial Region (GOP) is the largest industrial area in Poland, located in the northern part of the Upper Silesian Coal Basin. Current pollution levels are primarily the result of decades of industrial development (Fig. 1). Poznań, as well as the entire Greater Poland Voivodeship, located in the west-central part of Poland, falls within a temperate climate zone. Greater Poland is one of the warmest and driest regions in Poland.

It is predominantly an agricultural region, with the pharmaceutical, furniture, lighting equipment, household appliances, ceramics, glass, and plastic products industries dominating the area [17].

Fig. 1. Location of the analyzed cities in Poland

One of the sources of air pollution are the so-called microdusts that may be generated when sweeping, cleaning and washing streets. According to the European Waste Catalog, waste generated from polluted streets as a result of street cleaning is treated as one of the municipal waste streams that should be collected and disposed of in a comprehensive system. This type of waste is characterized by both variability in characteristics, but also in the amount generated throughout the year. This has a significant impact on the quality of atmospheric air in the immediate vicinity of the streets. This waste may constitute 10-15% of the mass of municipal waste. There is a significant relationship between street cleaning and the increase in microdust pollution in the air. Some studies conducted in this area have noted an increase in PM10 (particulate matter) levels and an increase in the share of minerals in the particulate matter, especially in the PM10 fraction [18].

The composition and amount of the fine fraction of microdust pollution from the streets present in the air is variable and depends mainly on the lifestyle of residents, the season and climatic and atmospheric conditions. Its highest content occurs in autumn, winter and spring, which is caused by the presence of ash from combustion from home furnaces [19].

The aim of this article is to assess the relationship between average annual air pollution concentrations in selected cities and the incidence of specific diseases among children and adolescents aged 0 to 18 in selected cities in Poland.

2. MATERIALS AND METHODS

The study selected 4 cities in Poland (Gdańsk, Katowice, Poznań, and Lublin) from four different regions (Pomeranian, Silesian, Greater Poland, and Lublin Voivodeships) with varying levels of industrialization, which impacts the scale of air pollution emissions (Fig. 1). The criteria for selecting cities were geographical diversity (east, west, north, south of Poland), diversity in terms of dominant economic activity (mining, agriculture, transport, industry) and demography (high population density). The cities selected for research are some of the largest cities in Poland, distinguishing themselves from the region.

Four types of pollutants were chosen for analysis - nitrogen dioxide (NO_2), particulate matter PM10, particulate matter PM2.5, and benzo(a)pyrene. Data on the concentrations of selected substances in the air were obtained from state monitoring conducted by the Chief Inspectorate of Environmental Protection (GIOŚ).

Information regarding the frequency of selected diseases among children and adolescents for the period from 2017 to 2023 was obtained from the National Institute of Public Health - National Institute of Hygiene (PZH-NIZP) in Warsaw, based on the annual MZ-11 report. This data pertains to the health status of children and adolescents aged 0 to 18 years, who were under the care of a primary care physician (family doctor) and were diagnosed with a specific disease (as of December 31 of each year) according to the ICD10 disease code (incidence rate per 10,000 people). The following disease categories according to ICD10 were included: bronchial asthma (J45), hypertension (I10-I15), allergic contact dermatitis caused by substances introduced into the body (L27), allergic food-induced gastritis, enteritis, and colitis (K52.2).

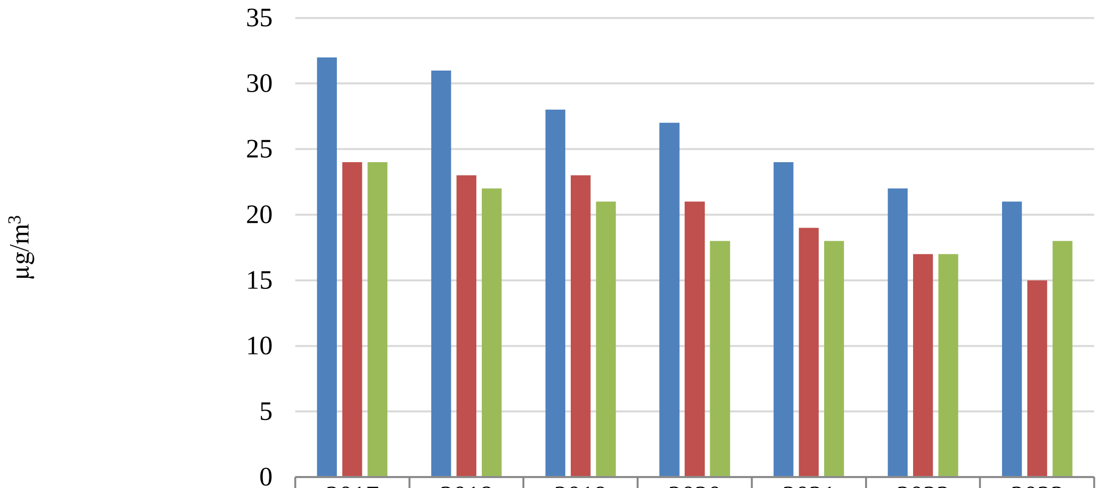
The Shapiro-Wilk test was used in statistical tests to check for normal distribution of random variables. The analyses also utilized Spearman rank correlation and Pearson correlation coefficients to interpret the strength of the relationship between pollutant concentrations and the frequency of certain diseases. The analyses were conducted using Statistica Soft. ver. 13.6.0.064 (0616).

3. RESULTS

3.1. Average annual concentrations of analyzed air pollutants

According to the Regulation of the Minister of the Environment dated August 24, 2012 (amended on December 11, 2020) on the levels of certain substances in the air for the protection of human health, the annual average concentration of nitrogen dioxide should not exceed 40 $\mu g/m^3$. For particulate matter PM2.5, the standard is up to 25 $\mu g/m^3$, for particulate matter PM10 up to 40 $\mu g/m^3$, and for benzo(a)pyrene up to 1 ng/m^3 [20].

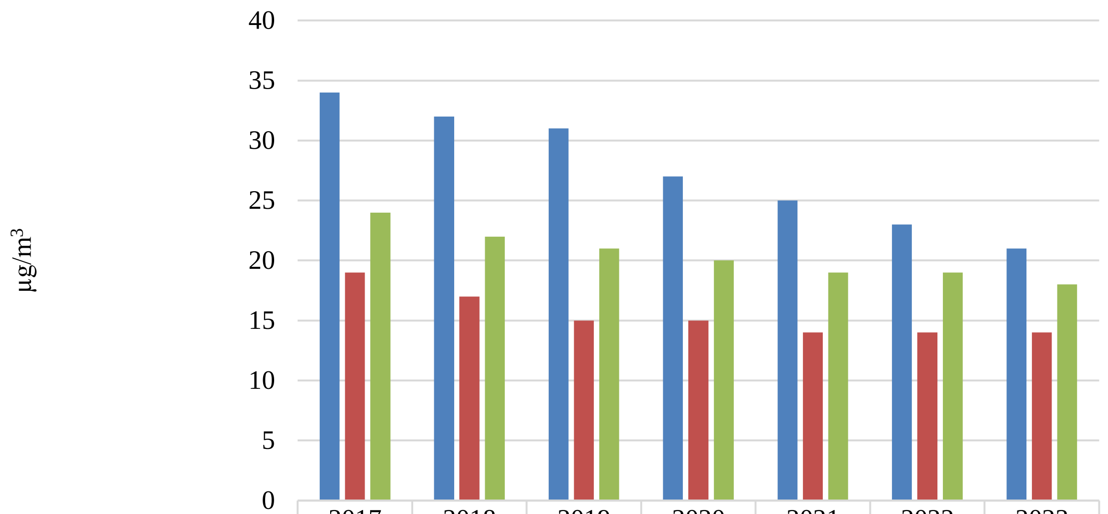
During the analyzed period in Gdańsk, there were no exceedances of the annual average concentrations of the air pollutants studied. For particulate matter PM2.5 and PM10, there was a decrease in their annual average concentrations between 2017 and 2023 by 9 and 11 µg/m³, respectively. The annual average concentrations of nitrogen dioxide also showed a downward trend of 6 µg/m³ (Fig. 2).



	2017	2018	2019	2020	2021	2022	2023
Suspended dust PM10	32	31	28	27	24	22	21
Suspended dust PM2.5	24	23	23	21	19	17	15
Nitrogen dioxide	24	22	21	18	18	17	18

Fig. 2. Average annual concentrations of selected air pollutants in Gdańsk in 2017-2023

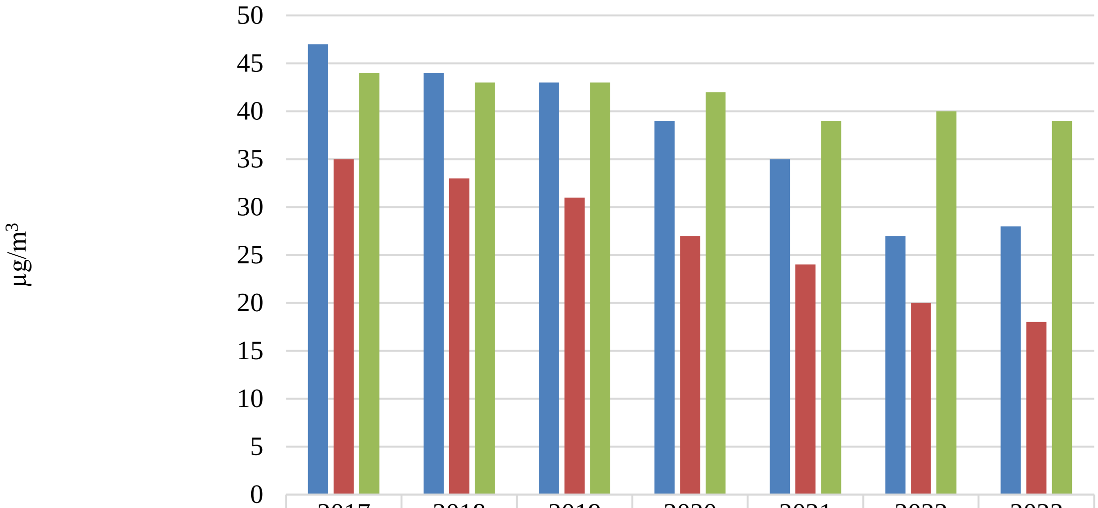
In Lublin and Gdańsk, between 2017 and 2023, no exceedances of the annual average concentrations of the analyzed air pollutants were observed. The annual average concentrations of particulate matter PM10 and PM2.5 show a downward trend. PM10 concentrations decreased by 13 µg/m³ during the analyzed period, and PM2.5 concentrations decreased by 5 µg/m³. The highest annual average concentration of nitrogen dioxide was 24 µg/m³ in 2017, and the lowest was 18 µg/m³ in 2023. The concentrations of this substance also indicate a declining trend (Fig. 3).



	2017	2018	2019	2020	2021	2022	2023
Suspended dust PM10	34	32	31	27	25	23	21
Suspended dust PM2.5	19	17	15	15	14	14	14
Nitrogen dioxide	24	22	21	20	19	19	18

Fig. 3. Average annual concentrations of selected air pollutants in Lublin in 2017-2023

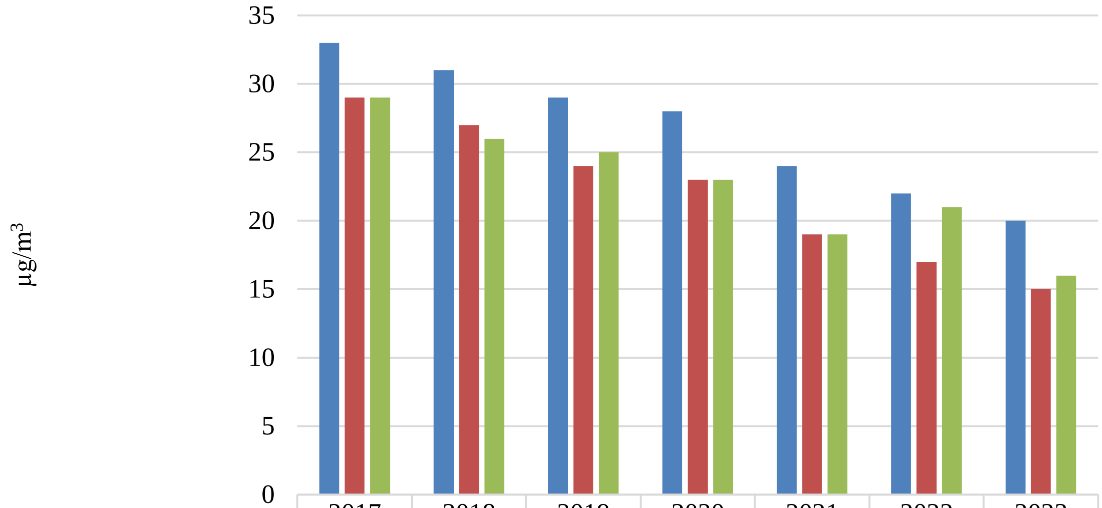
In Katowice, all of the discussed air pollutants exceeded the permissible limits. For particulate matter PM10, exceedances were observed until 2019, reaching up to 47 µg/m³ (in 2017). Exceedances of the permissible levels for PM2.5 concentrations were recorded until 2020, with a maximum of 35 µg/m³. The annual average concentrations of nitrogen dioxide also exceeded the established standards during the period 2017-2020, reaching 44 µg/m³ (Fig. 4). For all three analyzed air pollutants in Katowice—PM10, PM2.5, and NO_2 a downward trend in concentrations was observed.



	2017	2018	2019	2020	2021	2022	2023
Suspended dust PM10	47	44	43	39	35	27	28
Suspended PM2.5	35	33	31	27	24	20	18
Nitrogen dioxide	44	43	43	42	39	40	39

Fig. 4. Average annual concentrations of selected air pollutants in Katowice in 2017-2023

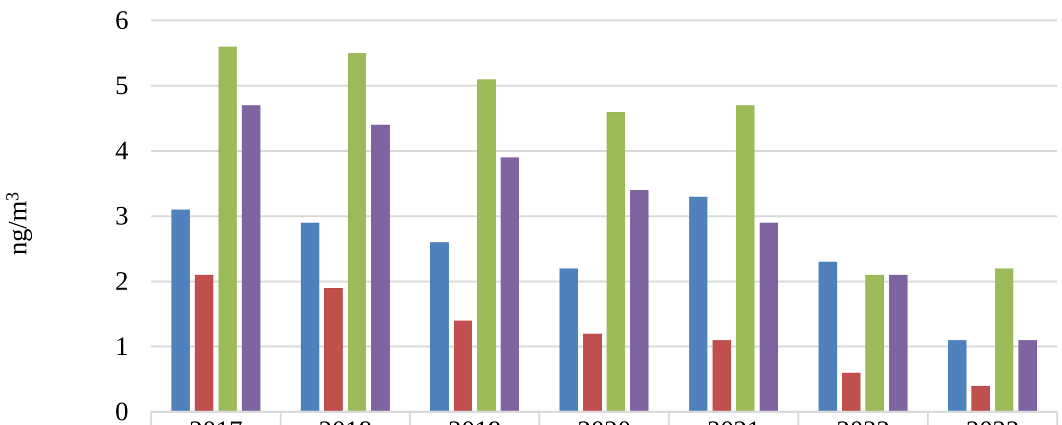
In Poznań, no exceedances of the standards for annual average concentrations of particulate matter PM10 and nitrogen dioxide were observed. Both showed a decreasing trend between 2017 and 2023. PM10 concentrations decreased by 13 µg/m³ during this period, as did nitrogen dioxide concentrations, which also dropped by 13 µg/m³. The annual average concentration of PM2.5 exceeded the standards in 2017 and 2018, by 4 µg/m³ and 2 µg/m³, respectively. From 2019 to 2023, the annual average concentrations of PM2.5 showed a downward trend (Fig. 5).



	2017	2018	2019	2020	2021	2022	2023
Suspended dust PM10	33	31	29	28	24	22	20
Suspended dust PM2.5	29	27	24	23	19	17	15
Nitrogen dioxide	29	26	25	23	19	21	16

Fig. 5. Average annual concentrations of selected air pollutants in Poznań in 2017-2023

In all analyzed Polish cities between 2017 and 2023, a decline in the annual average concentration of benzo(a)pyrene was observed. However, exceedances of the permissible limits for this substance were recorded in all cities during specific years. Only in Gdańsk, in 2022 and 2023, did benzo(a)pyrene concentrations fall within the allowable range: 0.6 ng/m³ in 2022 and 0.4 ng/m³ in 2023. The lowest concentrations of this substance were observed in Gdańsk, where they did not exceed 2.1 ng/m³. The highest annual average concentrations of benzo(a)pyrene, reaching 5.6 ng/m³, were recorded in Katowice (Fig. 6).

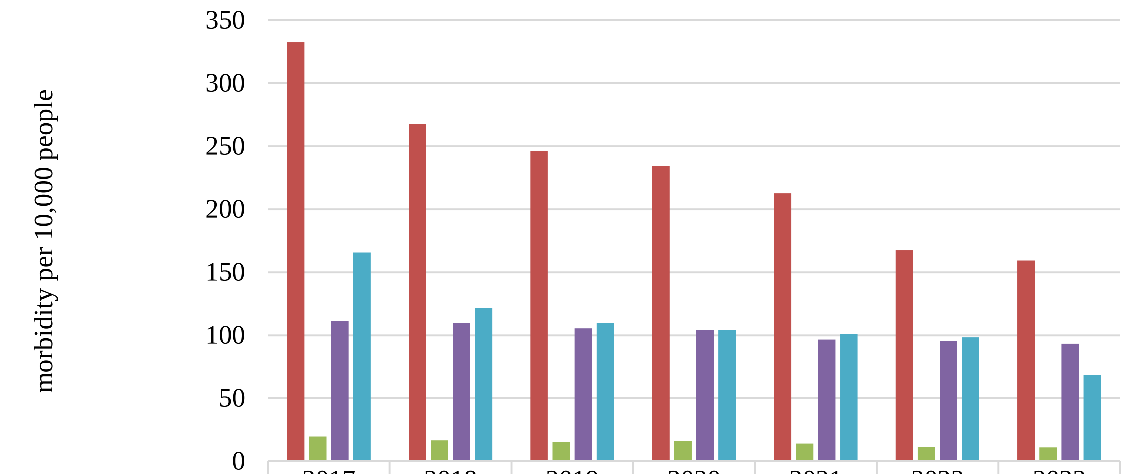


	2017	2018	2019	2020	2021	2022	2023
Lublin	3,1	2,9	2,6	2,2	3,3	2,3	1,1
Gdańsk	2,1	1,9	1,4	1,2	1,1	0,6	0,4
Katowice	5,6	5,5	5,1	4,6	4,7	2,1	2,2
Poznań	4,7	4,4	3,9	3,4	2,9	2,1	1,1

Fig. 6. Average annual concentrations of benzo(a)pyrene in the analyzed cities in 2017-2023

3.2. Epidemiology of selected diseases

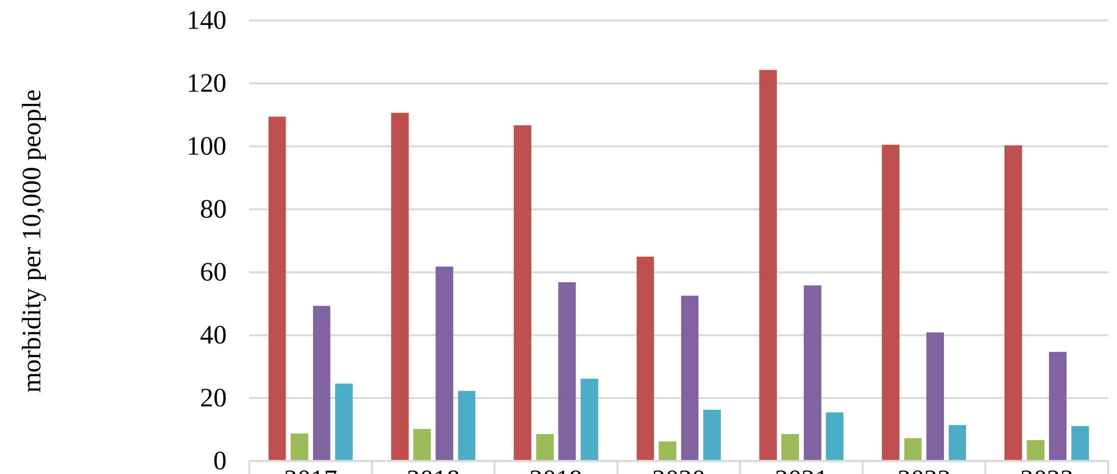
During the studied period of 2017-2023, the frequency of asthma, food allergies, and skin allergies among children and adolescents in Gdańsk has shown a decreasing trend. In the case of asthma, the highest incidence was observed at 332.5 per 10,000 people. By 2023, it had decreased by 52.1% compared to 2017. Hypertension affected a maximum of 19.5 per 10,000 individuals, with a decrease in incidence of 44.1%. For food allergies, the highest incidence was 111.4 per 10,000, and for skin allergies, it was recorded at 165.6 per 10,000 (Fig. 7). The frequency of food allergies decreased by 16.3%, while skin allergies decreased by 58.6% during the analyzed period.



	2017	2018	2019	2020	2021	2022	2023
Bronchial asthma	332,5	267,6	246,5	234,5	212,6	167,4	159,3
Hypertension	19,5	16,6	15,2	16,1	14,1	11,4	10,9
Food allergies	111,4	109,6	105,4	104,1	96,7	95,5	93,2
Skin allergies	165,6	121,5	109,5	104,3	101,1	98,4	68,5

Fig. 7. Epidemiology of individual diseases among children and adolescents from Gdańsk in 2017-2023

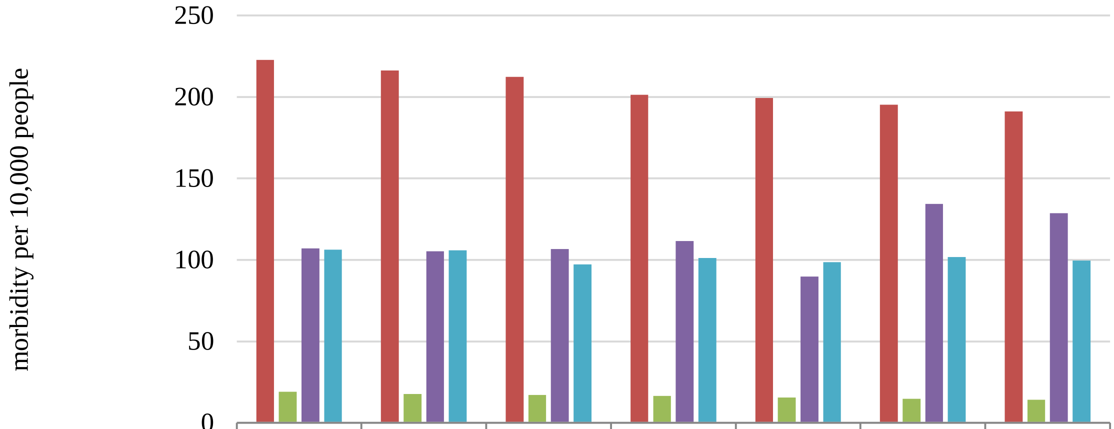
The incidence of all analyzed conditions among children and adolescents living in Lublin during the discussed period does not show clear trends. All the analyzed diseases had a lower frequency of occurrence in 2023 compared to 2017. However, there were some fluctuations in individual years. In the case of bronchial asthma, the highest incidence was observed in 2021 (124.3 per 10,000). As for hypertension, the highest number of cases was recorded in 2018 (10.2 per 10,000) (Fig. 8). The incidence of bronchial asthma and hypertension decreased in 2023 compared to 2017 by 8.3% and 25.0%, respectively. For food allergies, the highest incidence was observed in 2018 (61.8 per 10,000). The highest incidence of skin allergies was recorded in 2019 (26.1 per 10,000). The incidence of food and skin allergies decreased in 2023 compared to 2017 by 29.6% and 54.9%, respectively.



	2017	2018	2019	2020	2021	2022	2023
Bronchial asthma	109,4	110,7	106,7	64,9	124,3	100,5	100,3
Hypertension	8,8	10,2	8,6	6,2	8,6	7,2	6,6
Food allergies	49,3	61,8	56,8	52,5	55,8	40,9	34,7
Skin allergies	24,6	22,3	26,1	16,3	15,5	11,4	11,1

Fig. 8. Epidemiology of individual diseases among children and adolescents from Lublin in 2017-2023

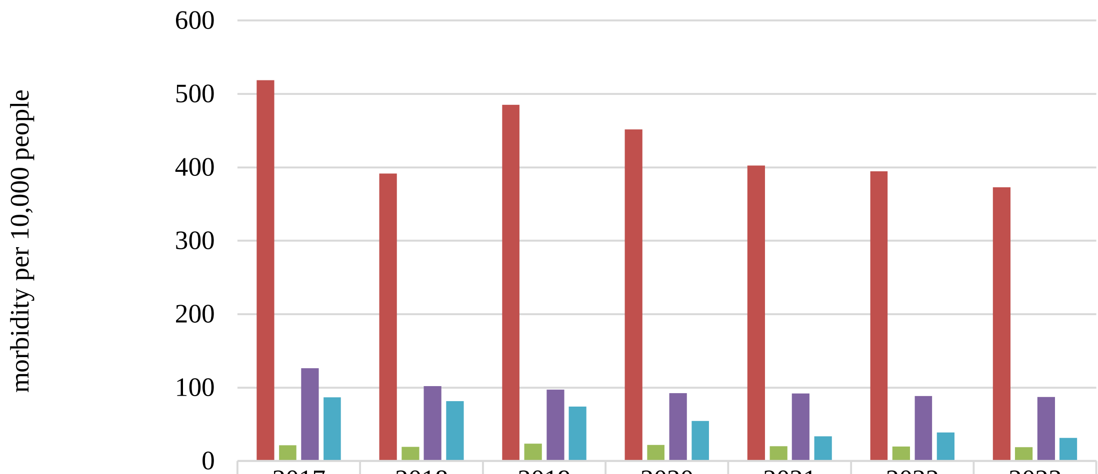
The incidence of the analyzed conditions among children and adolescents living in Katowice shows a downward trend in bronchial asthma and hypertension. The decrease in incidence in 2023 compared to 2017 was 14.2% and 26.2%, respectively. The incidence of food allergies remained relatively stable until 2020. In 2021, a slight decrease in incidence was observed, followed by an increase, and in 2023, it was 20.1% higher compared to 2017. The frequency of skin allergies showed slight fluctuations, with a small decrease of 6.3% in 2023 compared to 2017 (Fig. 9).



	2017	2018	2019	2020	2021	2022	2023
Bronchial asthma	222,8	216,3	212,4	201,4	199,3	195,2	191,1
Hypertension	19,1	17,7	17,1	16,5	15,5	14,8	14,1
Food allergies	107,1	105,3	106,6	111,5	89,7	134,4	128,6
Skin allergies	106,3	105,9	97,3	101,2	98,6	101,8	99,6

Fig. 9. Epidemiology of individual diseases among children and adolescents from Katowice in 2017-2023

The incidence of diseases among children and adolescents living in Poznań showed a downward trend. The incidence of asthma in Poznań was the highest among all the analyzed cities. The decrease in asthma incidence in 2023 compared to 2017 was 28.1%. The highest incidence of hypertension was observed in 2019 (23.7 per 10,000) (Fig. 10). However, in 2023, a decrease in incidence of 11.7% was noted compared to 2017. For both food and skin allergies, a cyclical decline in incidence was also observed.



	2017	2018	2019	2020	2021	2022	2023
Bronchial asthma	518,6	391,7	485,2	451,8	402,3	394,4	372,8
Hypertension	21,4	19,4	23,7	21,7	20,3	19,6	18,9
Food allergies	126,2	102,1	97,1	92,3	91,8	88,6	87,1
Skin allergies	86,8	81,3	74,3	54,5	33,8	38,8	31,3

Fig. 10. Epidemiology of individual diseases among children and adolescents from Poznań in 2017-2023

3.3. Analysis of the relationship between disease frequency and air pollution levels

As shown in Figure 11, Katowice has the highest average concentration of suspended particulate matter PM10, exceeding 40 μg/m^3. In other cities, the concentration is significantly lower, ranging between 25-30 μg/m^3. Katowice also shows the highest concentration of suspended particulate matter PM2.5 over 25 μg/m^3. Poznań and Gdańsk have similar average values around 20 μg/m^3, while the lowest average value was observed in Lublin (around 15 μg/m^3). Katowice also recorded the highest concentration of nitrogen dioxide (averaging over 50 μg/m^3). In the other studied cities, NO_2 concentrations were at the level of 20-24 μg/m^3. The concentration of benzo(a)pyrene ranges from 2 to 5 μg/m^3 in all analyzed cities. The highest values are slightly higher in Katowice and Poznań, but the differences are not as significant as with other pollutants.

Katowice is the city with the highest pollution levels for all measured parameters, which may be due to industrial activity and higher traffic intensity. Poznań and Gdańsk show moderate pollution levels, while Lublin generally has the lowest pollution levels (Fig. 11). This trend is directly related to the degree of industrialization.

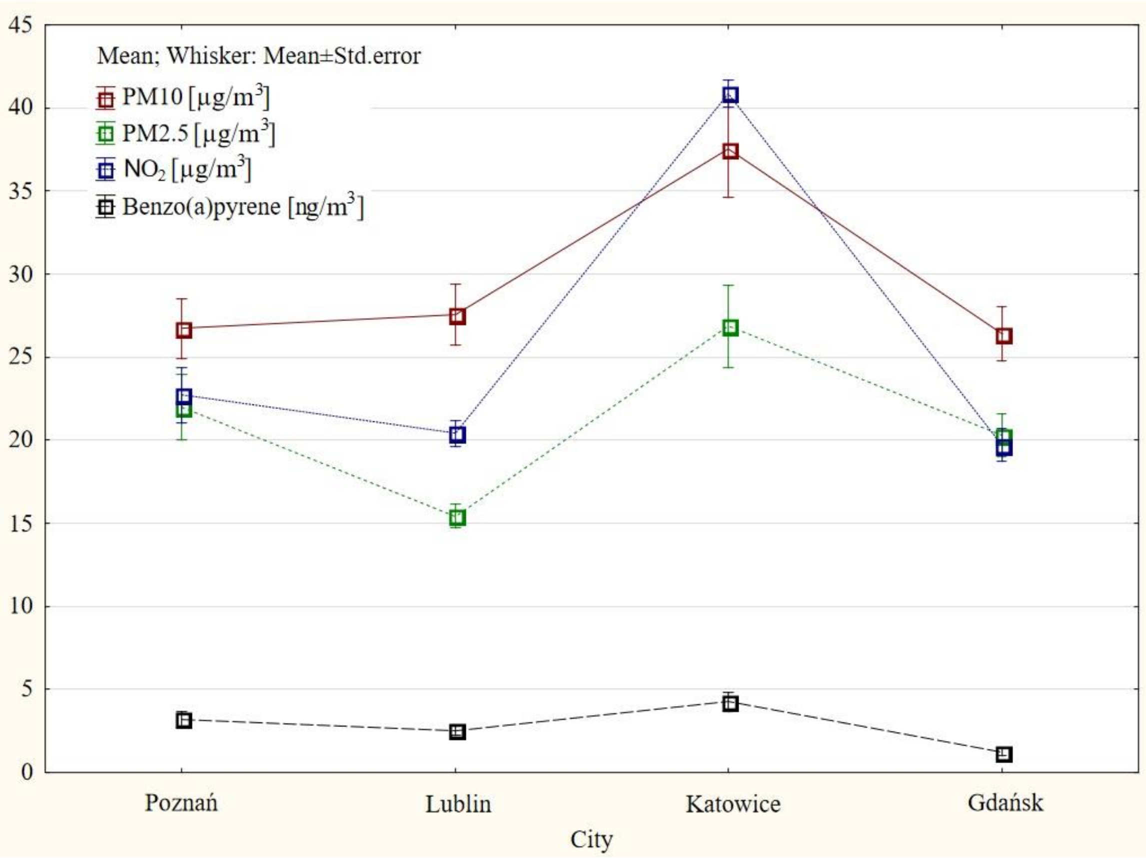


Fig. 11. Standard error for individual pollutant concentration

For the data on the frequency of diseases and air pollution concentrations from various cities, the Shapiro-Wilk Test was conducted to check the normality of the distribution of the studied relationships, which served as the basis for further analyses.

Normality tests for variables in the case of Gdańsk showed that all distributions are normal ($p > 0.05$) (Tab. 1), allowing for the use of Pearson correlation to assess the strength of the relationship between pollution and the frequency of diseases.

Table 1. Summary of normality test using Shapiro-Wilk test for the research variables for Gdańsk

Variable	Shapiro-Wilk test	p - value
Asthma	0.955720	0.781285
Hypertension	0.956758	0.790488
Food allergies	0.916804	0.444980
Skin allergies	0.908702	0.386957
Suspended dust PM10	0.938243	0.622950
Suspended dust PM2.5	0.919644	0.466630
Nitrogen dioxide	0.868157	0.178849
Benzo(a)pyrene	0.957006	0.792675

The Shapiro-Wilk normality test results for Poznań data indicated that most variables (except for food allergies) follow a normal distribution (Tab. 2), making it possible to apply Pearson correlation. However, for food allergies, the p-value is lower than the accepted significance level of 0.05 (p =

0.026896). Therefore, the null hypothesis of normality was rejected, and Spearman's rank correlation was used in further analysis.

Table 2. Summary of normality test using Shapiro-Wilk test for the research variables for Poznań

Variable	Shapiro-Wilk test	p - value
Asthma	0.893143	0.291460
Hypertension	0.925539	0.513628
Food allergies	0.781734	0.026896
Skin allergies	0.879557	0.224489
Suspended dust PM10	0.954000	0.765910
Suspended dust PM2.5	0.958241	0.803510
Nitrogen dioxide	0.990718	0.994469
Benzo(a)pyrene	0.956246	0.785954

The Shapiro-Wilk normality test results for most variables in Lublin (except for PM2.5) show that the distributions follow a normal distribution (Tab. 3), allowing the use of Pearson correlation in the analyses.

Table 3. Summary of normality test using Shapiro-Wilk test for the research variables for Lublin

Variable	Shapiro-Wilk test	p - value
Asthma	0.845021	0.110608
Hypertension	0.936250	0.605206
Food allergies	0.943642	0.671708
Skin allergies	0.898726	0.323338
Suspended dust PM10	0.948341	0.714573
Suspended dust PM2.5	0.799162	0.040190
Nitrogen dioxide	0.945173	0.685662
Benzo(a)pyrene	0.916188	0.440375

In the case of PM2.5 ($p = 0.040190$), the null hypothesis of normality was rejected, so Spearman's rank correlation was used for this variable. The Shapiro-Wilk normality test results for most variables from Katowice (except for benzo(a)pyrene) indicate that the distributions follow a normal distribution, allowing the use of Pearson correlation in the analyses (Tab. 4). For benzo(a)pyrene ($p = 0.038631$), at the 0.05 significance level, the null hypothesis of normality was rejected. Consequently, Spearman's rank correlation was used in further analysis for this variable.

Table 4. Summary of normality test using Shapiro-Wilk test for the research variables for Katowice

Variable	Shapiro-Wilk test	p - value
Asthma	0.941698	0.654061
Hypertension	0.981765	0.967660
Food allergies	0.923421	0.496439
Skin allergies	0.915146	0.432648
Suspended dust PM10	0.914720	0.429520
Suspended dust PM2.5	0.945116	0.685141
Nitrogen dioxide	0.840446	0.100313
Benzo(a)pyrene	0.797430	0.038631

Gdańsk. To investigate the relationship between the occurrence of the studied diseases (asthma, hypertension, and food and skin allergies) in children and adolescents and the level of air pollution in Gdańsk, Pearson correlation coefficients were calculated, and the statistical significance of these correlations was assessed (Tab. 5). There is a very strong positive correlation between the concentration of suspended particulate matter PM10 in Gdańsk and the occurrence of asthma (r = 0.9621, p = 0.001). This indicates that higher concentrations of PM10 are associated with a higher frequency of asthma. Similarly strong, statistically significant positive correlations were found for PM2.5, nitrogen dioxide, and benzo(a)pyrene (Tab. 5).

Table 5. Pearson correlations between air pollutants and diseases in Gdańsk

Variable	Suspended dust PM10	Suspended dust PM2.5	Nitrogen dioxide	Benzo(a)pyrene
Asthma	0.9621 p=0.001	0.9288 p=0.003	0.9126 p=0.004	0.9712 p=0.000
Hypertension	0.9539 p=0.001	0.9279 p=0.003	0.8351 p=0.019	0.9568 p=0.001
Food allergies	0.9938 p=0.000	0.9618 p=0.001	0.8855 p=0.008	0.9613 p=0.001
Skin allergies	0.8699 p=0.011	0.8348 p=0.019	0.8443 p=0.017	0.8995 p=0.006

The marked correlation coefficients are significant with $p < 0.05$

In the case of hypertension, very strong positive correlations were found with the concentrations of suspended particulate matter PM10, PM2.5, and benzo(a)pyrene. All these correlations are statistically significant. The correlation between hypertension and nitrogen dioxide concentration is also positive and significant, although slightly weaker compared to PM10, PM2.5, and benzo(a)pyrene. The correlations between air pollution and food allergies are also very strong and positive. High concentrations of PM10, PM2.5, and benzo(a)pyrene are associated with a higher frequency of food allergies. The correlation with nitrogen dioxide is also high and statistically significant.

For skin allergies, as with the other diseases, the correlations with the analyzed air pollutants are positive and statistically significant (Tab. 5). These correlations clearly indicate a relationship between increased air pollution and a higher risk of the studied diseases among children and adolescents living in Gdańsk.

Poznań. The results presented in Table 6 show strong positive correlations between bronchial asthma in children and adolescents living in Poznań and the suspended particulate matter PM10, PM2.5, nitrogen dioxide, and benzo(a)pyrene. However, only the correlation with nitrogen dioxide is statistically significant (r = 0.7615, p = 0.047), suggesting that higher nitrogen dioxide concentrations are associated with a higher frequency of bronchial asthma. The other correlations are close but do not reach the standard significance level (0.05). These results may be a consequence of the small sample size.

Table 6. Pearson correlations between air pollutants and diseases in Poznań

Variable	Suspended dust PM10	Suspended dust PM2.5	Nitrogen dioxide	Benzo(a)pyrene
Asthma	0.7382 p=0.058	0.7131 p=0.072	0.7615 p=0.047	0.7009 p=0.079
Hypertension	0.5235 p=0.228	0.4736 p=0.283	0.5119 p=0.240	0.5343 p=0.217
Food allergies	0.9550 p=0.001	0.9591 p=0.001	0.9553 p=0.001	0.9174 p=0.004

The marked correlation coefficients are significant with $p < 0.05$

The correlations between hypertension and the analyzed air pollutants are positive and moderate but not statistically significant. These results suggest that the impact of air pollution on hypertension in the studied sample is not clear-cut. On the other hand, all correlations between the analyzed air pollutants and skin allergies are very strong, positive, and statistically significant. For food allergies, Spearman's rank correlation coefficient was used in the analyses, as the distribution of the food allergy variable does not follow a normal distribution (Tab. 7). The obtained correlation coefficients with the analyzed air pollutants are positive and statistically significant. Higher concentrations of these pollutants are strongly associated with a higher frequency of food allergies, indicating a significant impact of air pollution on the occurrence of this type of allergy.

Table 7. Spearman's rank correlation coefficient (Poznań)

Pair of variables	R Spearman	t(N-2)	p
Food allergies & Suspended dust PM10	0.8199	4.819629	0.0024
Food allergies & Suspended dust PM2.5	0.9047	7.677566	0.0016
Food allergies & Nitrogen dioxide	0.9642	8.140806	0.0004
Food allergies & Benzo(a)pyrene	0.7740	2.171381	0.0410

The marked correlation coefficients are significant with $p < 0.05$

Lublin. The correlations between the occurrence of asthma in children and adolescents living in Lublin and air pollution concentrations PM10, nitrogen dioxide, and benzo(a)pyrene are low and not statistically significant (Tab. 8). Similarly, for PM2.5, where due to the lack of normality in the distribution, Spearman's rank correlation coefficient was calculated (Tab. 9). The analyses did not reveal a statistically significant impact of air pollution on the frequency of bronchial asthma among children and adolescents living in Lublin.

Table 8. Pearson correlations between air pollutants and diseases for Lublin

Variable	Suspended dust PM10	Nitrogen dioxide	Benzo(a)pyrene
Asthma	0.1557 p=0.739	0.1449 p=0.757	0.4922 p=0.262
Hypertension	0.7042 p=0.077	0.6318 p=0.128	0.7280 p=0.064
Food allergies	0.7052 p=0.077	0.5143 p=0.238	0.7637 p=0.046
Skin allergies	0.9516 p=0.001	0.8552 p=0.014	0.5865 p=0.166

The marked correlation coefficients are significant with $p < 0.05$

Table 9. Spearman's rank correlation coefficient (Lublin)

Pair of variables	R Spearman	t(N-2)	p
Astma & Suspended dust PM 2.5	0.205832	0.47033	0.657923
Hypertension & Suspended dust PM 2.5	0.594763	1.65435	0.158963
Food allergies & Suspended dust PM 2.5	0.449089	1.12390	0.312098
Skin allergies & Suspended dust PM 2.5	0.804617	3.02997	0.029082

The marked correlation coefficients are significant with $p < 0.05$

The correlations between hypertension and the concentrations of air pollutants PM10, nitrogen dioxide, and benzo(a)pyrene are positive but not statistically significant. When the significance level is increased to 0.01, the correlations with PM10 and benzo(a)pyrene become significant. The relationship between PM2.5 concentrations and hypertension also proved to be statistically insignificant. The impact of pollution on hypertension in the studied sample remains inconclusive.

For food allergies, the correlations with air pollution - PM10 and nitrogen dioxide, are positive, moderate, and statistically insignificant. The correlation for PM10 is close to the significance level but does not reach the standard 0.05 threshold. The correlation coefficient between food allergies and benzo(a)pyrene is statistically significant, indicating that higher concentrations of benzo(a)pyrene are strongly associated with a higher frequency of food allergies. The correlation coefficient is $r = 0.7637$ ($p = 0.046$) (Tab. 8). The Spearman rank correlation coefficient between food allergies and PM2.5 concentration was not statistically significant, with $r_s = 0.4491$ ($p = 0.3121$) (Tab. 9).

Most of the correlation coefficients between skin allergies and air pollution concentrations are strong. For PM10, the Pearson correlation coefficient is $r = 0.9516$ ($p = 0.001$), for nitrogen dioxide $r = 0.8552$ ($p = 0.014$), and for benzo(a)pyrene $r = 0.5865$ ($p = 0.166$) (Tab. 8). High concentrations of PM10 and nitrogen dioxide are strongly associated with a higher frequency of skin allergies. The correlation with benzo(a)pyrene, although high, is not statistically significant at $p < 0.05$. The correlation between skin allergies and PM2.5 concentrations is statistically significant. In this case, the Spearman rank correlation coefficient was calculated and amounted to $r_s = 0.8046$ with $p = 0.029$ (Tab. 9).

Katowice. The correlation analysis results show that the occurrence of asthma among children and adolescents living in Katowice is very strongly positively correlated with PM10, PM2.5, and nitrogen dioxide concentrations (Tab. 10).

Table 10. Pearson correlations between suspended dust PM2.5 and PM10, nitrogen dioxide and asthma, hypertension, food and skin allergies for Katowice

Variable	Suspended dust PM10	Suspended dust PM2.5	Nitrogen dioxide
Asthma	0.9471 p=0.001	0.9795 p=0.000	0.9645 p=0.000
Hypertension	0.9621 p=0.001	0.9824 p=0.000	0.9016 p=0.006
Food allergies	-0.6406 p=0.121	-0.5755 p=0.176	-0.4599 p=0.299
Skin allergies	0.4442 p=0.318	0.5287 p=0.222	0.5841 p=0.168

The marked correlation coefficients are significant with p < 0.05

Higher concentrations of these pollutants are strongly associated with a higher frequency of asthma. The Spearman rank correlation coefficient between the frequency of asthma and benzo(a)pyrene concentrations in the air in Katowice was $r_s = 0.9285$ ($p = 0.025$), which is also statistically significant and a very strong correlation (Tab. 11)

Table 11. Spearman's rank correlation coefficient (Katowice)

Pair of variables	R Spearman	t(N-2)	p
Asthma & Benzo(a)pyren	0.9285	5.59431	0.0025
Hypertension & Benzo(a)pyrene	0.9285	5.59431	0.0025
Food allergies & Benzo(a)pyrene	-0.6785	-2.06571	0.0937
Skin allergies & Benzo(a)pyrene	0.3214	0.75901	0.4820

The marked correlation coefficients are significant with p < 0.05

For hypertension, the correlation coefficients with air pollutants are positive and statistically significant for PM10, PM2.5, and benzo(a)pyrene. The Pearson correlation coefficient for PM10 is $r = 0.9621$ ($p = 0.001$), and for PM2.5, it is $r = 0.9824$ ($p = 0.000$) (Tab. 10). The Spearman rank correlation coefficient for benzo(a)pyrene is $r_s = 0.8802$ ($p = 0.009$), and for nitrogen dioxide, it is $r_s = 0.9016$ ($p = 0.006$) (Tab. 11). High concentrations of particulates and benzo(a)pyrene are therefore strongly associated with a higher risk of hypertension.

The correlations between food allergies and air pollution concentrations PM10, PM2.5, nitrogen dioxide, and benzo(a)pyrene are negative but not statistically significant (Tab. 10). The Spearman rank correlation coefficient for the relationship between food allergies and benzo(a)pyrene concentration is also not statistically significant ($r_s = -0.6785$, $p = 0.0937$) (Tab. 11).

The correlations between skin allergies and air pollution are not statistically significant for any of the air pollution concentrations studied. The Pearson correlation coefficients are $r = 0.4442$ ($p = 0.318$) for PM10, $r = 0.5287$ ($p = 0.222$) for PM2.5, and $r = 0.5841$ ($p = 0.168$) for nitrogen dioxide (Tab. 10). The Spearman rank correlation coefficient for the relationship between skin allergies and benzo(a)pyrene concentration is also not statistically significant ($r_s = 0.4820$, $p = 0.4820$) (Tab. 11).

4. DISCUSSION

According to the World Health Organization, air pollution is a significant threat to children, causing the deaths of 543,000 children under 5 years old [21]. Nearly 300 million children worldwide are exposed to toxic air pollution, primarily due to fossil fuel burning, waste incineration, and industrial processes. About 93% of children and adolescents under 15 globally are exposed to air pollution levels exceeding WHO limits. The mortality rate related to air pollution is higher in children from low- and middle-income countries, with some regions experiencing death rates 40 times higher than wealthier areas [22].

In the last decade, epidemiological studies have shown a relationship between air pollution and an increased incidence of respiratory symptoms and infections, an increased number of hospitalizations due to respiratory and circulatory system diseases, skin and food allergies, as well as premature mortality [23,24].

Based on numerous studies, it has been proven that approximately 2 billion children live in areas polluted by car exhaust fumes, dust, waste incineration and the use of fossil fuels. The problem is most serious in South Asia and Africa, which have the highest number of children: 620 million and 520 million respectively, living in areas where pollution exceeds set limits. Air pollution is highest in low-income urban areas. The research also took into account the impact of internal pollution, which is typically caused by the use of coal and wood for cooking and heating, and showed that it primarily affects children living in low-income rural areas [25].

Poland is one of the most polluted countries in the European Union, although its quality has significantly improved over the last few years. The quality of atmospheric air in Silesia, which is a highly industrialized region of Poland, is among the worst in Europe. This densely populated area is responsible for the majority of coal mining in Poland, and has numerous coal-fired power plants, steelworks and mineral mines. Of the 50 most polluted cities in the European Union, as many as 36 are located in Poland, most of them in Silesia [6,16]. Due to the high level of pollution, Silesia is the region with the shortest life expectancy in the city and the highest incidence of premature births, genetic congenital defects and spontaneous miscarriages in Poland, as well as a higher incidence of respiratory and circulatory system diseases [26].

When analyzing the results regarding the incidence of selected diseases among the residents of the cities under study, attention should be paid to the economic and environmental conditions, which may have a significant impact on pollutant emissions and the frequency of certain diseases in the regions. The presence of polluting industries, specific environmental or topographic conditions that can lead to the prolonged presence of pollutants in a region may have a considerable influence on the frequency of diseases. High population density may also contribute to an increase in the number of cases of certain ailments.

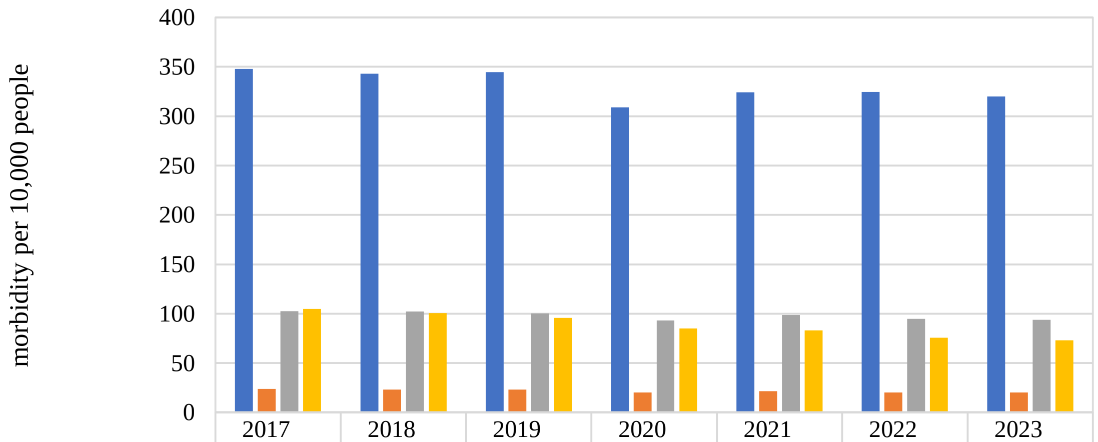
Gdańsk is a city located in the Pomeranian Voivodeship in northen Poland More than half of the regional GDP is generated in the Tri-City (Gdańsk, Gdynia, Sopot) in the service sector, where tourism, industry, construction, and trade play key roles. Gdańsk is the largest city and the capital of the voivodeship. The main industries include maritime industry, enabled by the rapidly developing ports in Gdynia and Gdańsk. Additionally, the wood and paper, petrochemical, and electromechanical industries are also developing here. Important sectors also include electronics, logistics, modern business services, ICT, biotechnology, light chemistry, and agri-food processing (including fish processing) [27].

Katowice is the capital of the Silesian Voivodeship, which is located in southern Poland, covering an area of 12,334 km², accounting for 3.9% of Poland's total area. It is home to more than 4.4 million people (ranking second in the country after the Mazovian Voivodeship). The region has the highest population density in the country—355 people per km², three times the national average. It is the most urbanized area in the country, with 76.5% of the population living in cities. The largest cities with county rights include Katowice, Częstochowa, and Sosnowiec. The Silesian Voivodeship, where Katowice is located, plays an important role in the economic development of the country, based on natural resources and industrial and service activities. In addition to mining and extractive industries, the region also produces and supplies electricity, gas, and steam. Industrial production is distinguished by the manufacturing of metals and the processing of coke and refined petroleum products. The Silesian Voivodeship, together with the Mazovian Voivodeship, has the highest contribution to Poland's Gross Domestic Product. Katowice is also heavily influenced by the Upper Silesian Industrial Region, which is the largest industrial hub of its kind in Poland. It comprises 14 large cities located in the central part of the Silesian Voivodeship (the Upper Silesian conurbation): Będzin, Bytom, Chorzów, Czeladź, Dąbrowa Górnicza, Gliwice, Katowice, Mysłowice, Ruda Śląska, Siemianowice Śląskie, Sosnowiec, Świętochłowice, Tychy, Zabrze, and the surrounding industrial areas. The area of this district is about 3.2 thousand km². This area is home to about 3.5 million people (over 1,000 people per km²), including about 2.8 million urban residents. The Upper Silesian Industrial Region (GOP) is one of the regions with the highest environmental risks in Poland. Dust and gas emissions account for about 21% of the air pollution emissions in the country. Additionally, 32% of the industrial and municipal wastewater generated in the GOP area is discharged into surface waters without treatment, particularly saline mining water [28].

Lublin, on the other hand, is a city located in the eastern part of the country, in a region rich in natural values with unique landscapes, including the Polesie, Roztocze, Solska Forest, and the Bug Valley. The Lublin Voivodeship is home to two national parks (Polesie National Park and Roztocze National Park) with a combined area of 182.43 km², 17 landscape parks with a total area of 2,850 km², 89 nature reserves (120.34 km²), and the Transboundary Biosphere Reserve "Western Polesie." The Lublin Voivodeship is predominantly an agricultural region with a low degree of industrialization and a low level of entrepreneurship. Due to its agricultural nature, the Lublin region is a significant producer of cereals, potatoes, sugar beets, vegetables, hops, and tobacco. The processing industry is dominated by dairy production and fruit and vegetable processing [29].

Poznań is located in the central-western part of Poland, in the Wielkopolska Voivodeship. The area of the voivodeship is 29,826 km², making it the second-largest voivodeship in Poland in terms of area and the third-largest in terms of population. In terms of biodiversity and landscape values, the Wielkopolska Voivodeship is one of the most attractive regions in Poland. This is evidenced by the number and area of legally protected areas and objects that encompass diverse natural elements. Currently, the voivodeship has two national parks (Wielkopolski and Drawieński), numerous nature reserves, landscape parks, nature monuments, protected landscape areas, and nature-landscape complexes. Poznań is the fifth-largest city in Poland by population (541,316 inhabitants in 2023) and the ninth-largest by area (261.9 km²) [30]. Poznań is an important center of the automotive, food, pharmaceutical, chemical, and machinery industries.

Based on data obtained from the National Institute of Public Health – National Hygiene Institute for Poland, there is a very slight downward trend in the frequency of diseases such as bronchial asthma, hypertension, and food allergies in the 0-18 age group. The decrease in morbidity in 2023 compared to 2017 for these diseases was respectively 8.0%, 15.9%, and 8.6% (Fig. 12). A greater decrease in morbidity was recorded for skin allergies – 30.4%. A similar downward trend in the incidence of the studied diseases was observed for Gdańsk and Poznań (Fig. 7 and 10). In contrast, in the case of Katowice, the downward trend applied to cases of bronchial asthma and hypertension (Fig. 9). The frequency of skin allergies showed slight fluctuations, while there was an increase in food allergies between 2017 and 2023. However, in Lublin, no clear consistent trends were noted during this period. From 2018 to 2021, an increase in morbidity for most of the diseases under study was observed, followed by a decline after this period. Ultimately, in 2023, there was a decrease in the incidence of all studied diseases compared to 2017 (Fig. 8).



	2017	2018	2019	2020	2021	2022	2023
Bronchial asthma	347,9	342,9	344,6	309,1	324,2	324,4	319,9
Hypertension	23,9	23,3	23,1	20,4	21,6	20,3	20,1
Food allergies	102,7	102,1	100,2	93,3	98,5	94,8	93,9
Skin allergies	104,8	100,7	95,8	84,9	83,1	75,6	72,9

Bronchial asthma Hypertension Food allergies Skin allergies

Fig. 12. Epidemiology of individual diseases among children and adolescents from Poland in 2017-2023

Based on Eurostat data, it can be inferred that in 2019, 22% of people in the EU aged 15 and older reported high blood pressure. The highest percentage of individuals over the age of 15 suffering from hypertension was recorded in Croatia (37%), followed by Latvia and Hungary (32% each). The lowest rate was noted in Ireland (12%). According to Eurostat data, the percentage of women reporting high blood pressure in 2019 was higher than that of men (23% vs. 21%) [31].

Studies conducted on a group of children aged 3-15 in northeastern Hungary indicate that the prevalence of hypertension in the entire studied population of children was 4%. Hypertension was more frequently observed in boys (4.7%) compared to girls (3.2%). Among boys, an increasing prevalence of this condition was found in successive age groups within the studied population, while among girls, the highest morbidity rates were recorded in the 12-15 age group [32].

According to the European Commission, allergies are among the most common chronic non-communicable diseases in Europe. Today, about 150 million people in Europe live with an allergic condition, such as allergic rhinitis, asthma, atopic eczema, or a food allergy [33]. According to some authors, food allergies are increasingly being reported in Europe. However, the latest estimates regarding its prevalence are based on studies published several years ago [34,35]. Spolidoro et al. [36] conducted meta-analyses of 110 available publications on the development of food allergies in Europe from 2000-2021. The results indicate an increasing number of reports on food allergy issues, especially among children and adolescents up to the age of 17. However, the number of diagnosed cases of such diseases depends on methodological approaches and proper diagnosis. It is also known that there is a link between food allergies and asthma. Forty-eight percent of people with asthma have a food allergy [37], and about half of children with food allergies experience allergic reactions with respiratory symptoms [38].

Numerous studies confirm that polluted air affects lung function in children. Research conducted by Dąbrowiecki et al. showed that children between 9 and 15 years of age living in Zabrze (region of Silesia) had impaired lung function due to their lower FVC (increased vital capacity, i.e. the amount of air exhaled, starting from the deepest inhalation to the maximum exhalation), unlike children living in the northern areas of the country. In addition, children in Zabrze suffered from seasonal colds, a higher incidence of asthma, food and skin allergies, circulatory system diseases (including hypertension), and cough more often than in children in the north of the country. Daily exposure to PM10, SO_2 and NO_2 dust was higher in Zabrze than in Gdynia, which consequently slows down lung development in children, as evidenced by reduced FVC with an increase in their concentration in atmospheric air [39, 40]. This research for Katowice (Silesian region) confirmed these trends.

In their study among children aged 6–8 (residents of large and industrialized cities in Germany, Sweden, the Netherlands and Great Britain), Gehring et al. found that FVC decreased with increasing concentrations of PM2.5, NO_2 and NO_x in ambient air [41]. Similarly, Asgari et al. observed reduced FVC among children between 9 and 13 years of age living in highly urbanized and industrialized areas of Iran with a negative correlation between FVC and the concentrations of PM, SO_2 and NO_2 in the ambient air [42].

As reported by an international team of researchers, reducing air pollution from particulate matter, benzo(a)pyrene, sulfur dioxide and nitrogen oxides in almost 1,000 European cities to the World Health Organization's target levels could save approximately 50,000 lives. human lives per year. Using 2018 data on air pollution and deaths in these cities, researchers estimated the health impacts of reducing levels of PM2.5, nitrogen oxides and nitrogen sulfur dioxide according to WHO air quality guidelines. These guidelines recommend an annual average of no higher than 10 μg/m3 for PM2.5 and 40 $\mu g/m^3$ for NO_2. The authors found that meeting WHO targets would prevent an estimated 51,213 premature deaths from PM2.5 exposure and 900 premature deaths from NO_2 exposure each year. Achieving even lower levels of 3.7 $\mu g/m^3$ for PM2.5 and 3.5 $\mu g/m^3$ for NO_2 would prevent an estimated 124,729 premature deaths from NO_2 exposure annually. Health effects related to air pollution varied significantly it from city to city. Three northern European cities - Tromsø in Norway, Umeå in Sweden and Oulu in Finland - had the lowest premature mortality related to exposure to PM2.5 and NO_2. Cities in northern Italy, southern Poland and eastern Czech Republic had the highest PM2.5-related mortality, while large cities and capitals in western and southern Europe had the most premature deaths attributed to NO_2 [43].

Polish cities that struggle with the problem of air pollution are taking a number of actions to improve air quality. A complex air protection system requires the cooperation of many institutions at various administrative levels. Only close cooperation aimed at improving air quality can make cities places that ensure an adequate standard of living and protect their inhabitants against diseases and premature death.

5. CONCLUSIONS

- In all the cities discussed (Katowice, Poznań, Gdańsk, and Lublin), permissible annual average concentrations of air pollutants were exceeded during the analyzed periods. This includes suspended particulate matter PM10 (2017-2019), PM2.5 and nitrogen dioxide (2017-2020), and benzo(a)pyrene (for the entire period). Specifically, in Katowice, all pollutants exceeded limits. In Poznań, PM2.5 exceeded limits in 2017-2018 and benzo(a)pyrene exceeded limits from 2017 to 2023. In Gdańsk and Lublin, like Katowice and Poznań, benzo(a)pyrene exceeded limits for the entire period analyzed.
- Analyses of the frequency of asthma, hypertension, and skin and food allergies in children and adolescents living in Gdańsk indicate strong correlations of all diseases with the concentrations of PM10 and PM2.5 particles. Benzo(a)pyrene and nitrogen dioxide also had a significant impact on the occurrence of these diseases, although to a lesser extent than particulate matter.
- All the examined pollutants in Poznań, significantly affect the frequency of skin and food allergies in children and adolescents. The results indicate that the severity of bronchial asthma is dependent on nitrogen dioxide concentrations. For other diseases, the correlations with pollutants are positive but not statistically significant, which may result from the smaller sample size studied.
- No clear relationship was found between the concentrations of the analyzed air pollutants and the occurrence of bronchial asthma and hypertension in the 0-18 age group residing in Lublin. The frequency of food allergies was influenced by benzo(a)pyrene. All the examined air pollutants had a strong impact on the occurrence of skin allergies in children and adolescents in Lublin.
- The results of the analyses of the impact of air pollution concentrations on selected diseases in children and adolescents in Katowice indicate strong correlations between particulate matter (PM10, PM2.5), nitrogen dioxide, and benzo(a)pyrene concentrations, and the frequency of bronchial asthma. Similar trends are observed for hypertension. No significant associations were found between skin and food allergies and the analyzed air pollutants for Katowice.
- Studies have shown significant correlations between the concentrations of selected pollutants and the frequency of diseases such as bronchial asthma, hypertension, and food and skin allergies. However, this impact varies across cities, which may depend on pollutant concentration levels, population density, environmental and climatic conditions, or additional pressure factors.

REFERENCES

1. Uwak, I et al. 2021. Application of the systematic navigation guide review methodology to assess prenatal exposure to air pollution by particulate matter and infant birth weight. *Environmental International*, **148**, 106378. https://doi.org/10.1016/j.envint.2021.106378

2. WHO, 2021. *Global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*; https://apps.who.int/iris/handle/10665/345329 License: CC BY-NC-SA 3.0 IGO.
3. Landrigan, P et al. 2019. Pollution and children's health. *Science of The Total Environmental*, **650(2)**, 2389-2394. https://doi.org/10.1016/j.scitotenv.2018.09.375.
4. Ahn, TG et al. 2024. Association between individual air pollution (PM10, PM2.5) exposure and adverse pregnancy outcomes in Korea: A multicenter prospective cohort, air pollution on pregnancy outcome (APPO) study. *Journal of Korean Medical Science*, **39(13)**, 131. https://doi.org/ : 10.3346/jkms.2024.39.e131
5. Czubaj-Kowal, M, Kurzawa, R, Nowicki, G 2022. Impact of air pollution on the concentration of nitric oxide inthe exhaled air (FeNO) in children - a review of the literature on the subject. *Journal of Education, Health and Sport*, **12(1)**, 92-105. https://doi.org/10.12775/JEHS.2022.12.01.007
6. WHO, 2019. *Global perspectives on assistive technology Ambient Air Quality Database Geneva*, Switzerland. https://iris.who.int/bitstream/handle/10665/330372/9789240000261-eng.pdf
7. Oleniacz, R and Gorzelniak, T 2021. Assessment of the Variability of Air Pollutant Concentrations at Industrial, Traffic and Urban Background Stations in Krakow (Poland) Using Statistical Methods, *Sustainability*, **13(10)**, 5623. https://doi.org/10.3390/su13105623
8. Krynicka, J and Drzeniecka-Osiadacz, A. 2013. Analysis of Variability in PM10 Concentration in the Wrocław Agglomeration. *Polish Journal of Environmental Studies*, **22(4)**, 1091-1099.
9. Sówka, I, Chlebowska-Styś, A, Pachurka, Ł, Rogula-Kozłowska, W, Mathews, B 2019. Analysis of Particulate Matter Concentration Variability and Origin in Selected Urban Areas in Poland. *Sustainability*, **11(20)**, 5735, https://doi.org/10.3390/su11205735.
10. Amato-Lourenço, LF, Dos Santos Galvão, L, de Weger, LA, Hiemstra, PS, Vijver, MG, Mauad, G 2020. An emerging class of air pollutants: Potential effects of microplastics to respiratory human health? *The Science of the Total Environmental*, **749,**141676. https://doi.org 10.1016/j.scitotenv.2020.141676.
11. Pope, CA 3rd, Coleman, N, Pond, ZA, Burnett, RT 2020. Fine particulate air pollution and human mortality: 25+ years of cohort studies. *Environmental Research*, **183**, 108924. https://doi.org/10.1016/j.envres.2019.108924.
12. Khomenko, S et al. 2021. Premature mortality due to air pollution in European cities: a health impact assessment. *Lancet Planet Health*, **5(3)**, 121-134. https://org/10.1016/S2542-5196(20)30272-2.
13. Shetty, SS et al. 2023. Environmental pollutants and their effects on human health. *Heliyon*, **9(9)**, 19496. https://org/10.1016/j.heliyon.2023.e19496.
14. Zhang, Z, Zhang, G, Li, L 2023. The spatial impact of atmospheric environmental policy on public health based on the mediation effect of air pollution in China. *Environmental Science and Pollution Research*, **30(55)**, 116584-116600. https://org 10.1007/s11356-022-21501-6.
15. Bălă, GP, Râjnoveanu, RM, Tudorache, E, Motișan, R, Oancea, C 2021. Air pollution exposure-the (in)visible risk factor for respiratory diseases. *Environmental Science and Pollution Research*, **28(16)**, 19615-19628. https://org 10.1007/s11356-021-13208-x.
16. Domański, B 2011. Foreign capital and the development of Polish regions. *Czasopismo Geograficzne* [*Geographical Journal*], **82(1–2)**, 173–187.
17. Główny Inspektorat Ochrony Środowiska. Wykonawczy Program Państwowego Monitoringu Środowiska na rok 2024. Warszawa, 2024 [Chief Inspectorate for Environmental Protection. Executive Program of the State Environmental Monitoring for 2024. Warsaw, 2024]

file:///C:/Users/dell/Downloads/Program%20wykonawczy%20na%202024_wersja_fin%20(1).pdf

18. Gronba- Chyła, A et al. 2024. Municipal waste utilization as a substitute for natural aggregate in the light of the circular economy. *Journal of Cleaner Production,* **440**, 140907. https://doi.org/10.1016/j.jclepro.2024.140907
19. Gronba-Chyła, A and Generowicz, A. 2020. Frakcja odpadów komunalnych poniżej 10 mm i możliwość jej wykorzystania w ceramicznych materiałach budowlanych. *Przemysł Chemiczny Chemical Industry, 99* , 1318–1321.
20. Rozporządzenie Ministra Środowiska z dnia 24 sierpnia 2012 r. w sprawie poziomów niektórych substancji w powietrzu (Dz. U. z 2012 r., poz. 1031). [Regulation of the Minister of the Environment of August 24, 2012 on the levels of certain substances in the air (Journal of Laws of 2012, item 1031].
21. Friedrich, MJ 2018. Air pollution is the biggest environmental threat to health. *Jama*, **320(23)**, 2412. https://org : 10.1001/jama.2018.2366
22. Friedrich, MJ 2018. The relationship between air pollution and infant deaths. *Jama*, **320(7)**, 633.https://org 10.1001/jama.2018.11673
23. Brumberg, HL and Karr, CJ 2021. Ambient Air Pollution: Health Hazards to Children. *Pediatric*, **147(6)**, 2021051484. https://org 10.1542/peds.2021-051484
24. Ratajczak, A, Badyda, AJ, Czechowski, P, Czarnecki, A, Dubrawski, M, Feleszko, W 2021. Air pollution increases the incidence of upper respiratory tract symptoms among Polish children. *Journal of Clinical Medicine*, **10(10)**, 2150. https://org 10.3390/jcm10102150
25. WHO, 2022. Ambient air quality database, 2022 update Status report; https://iris.who.int/bitstream/handle/10665/368432/9789240047693-eng.pdf?sequence=1
26. Parascandola, M 2018. Ambient air pollution and lung cancer in Poland: research findings and gaps. *Journal of Health Ineqalitis*, **4(1)**, 3-8. https://doi.org/10.5114/jhi.2018.77639
27. GIOŚ, 2022. Główny Inspektorat Ochrony Środowiska. *Roczna ocena jakości powietrza w województwie pomorskim. Raport wojewódzki za 2022 rok*. Gdańsk.
28. GIOŚ, 2022. Główny Inspektorat Ochrony Środowiska. *Roczna ocena jakości powietrza w województwie śląskim. Raport wojewódzki za 2022 rok.* Katowice.
29. GIOŚ, 2022. Główny Inspektorat Ochrony Środowiska. *Roczna ocena jakości powietrza w województwie lubelskim. Raport wojewódzki za 2022 rok*. Lublin.
30. GIOŚ, 2022. Główny Inspektorat Ochrony Środowiska. *Roczna ocena jakości powietrza w województwie wielkopolskim. Raport wojewódzki za 2022 rok*. Poznań.
31. Eurostat. Health in the European Union – facts and figures. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Health_in_the_European_Union_–_facts_and_figures. (access. 8.10.2024).
32. Kovács, B, et al. 2023. Determining the prevalence of childhood hypertension and its concomitant metabolic abnormalities using data mining methods in the Northeastern region of Hungary. Front Cardiovasc Med., 9:1081986. doi: 10.3389/fcvm.2022.1081986.
33. European Commision. 2022. Question for written answer E-002242/2022 to the Commission, Rule 138, Sirpa Pietikäinen (PPE), Juozas Olekas (S&D), Manuel Pizarro (S&D), Tilly Metz (Verts/ALE), Subject: *Allergy prevention, support and research policies in the EU*. https://www.europarl.europa.eu/doceo/document/E-9-2022-002242_EN.pdf
34. Sampson, HA, et al. 2012. Standardizing double-blind, placebo-controlled oral food challenges: American Academy of Allergy, Asthma & Immunology-European Academy of Allergy and Clinical Immunology PRACTALL consensus report. *Journal of Allergy and Clinical Immunology*, **130(6)**, 1260-1274. https://doi: 10.1016/j.jaci.2012.10.017
35. Nwaru, BI, et al. 2014. The epidemiology of food allergy in Europe: a systematic review and meta-analysis. *Allergy*, **69(1)**, 62-75. https://doi: 10.1111/all.12305.

36. Spolidoro, GCI, et al. 2023. Frequency of food allergy in Europe: An updated systematic review and meta-analysis. *Allergy*, **78(2)**, 351-368. https://doi: 10.1111/all.15560
37. Roberts, G and Lack, G.2003. Food allergy and asthma-what is the link? Paediatric Respiratory Reviews, **4**, 205–212. https://doi:10.1016/s1526-0542(03)00058-7
38. James, JM, 2003. Respiratory manifestations of food allergy. *Pediatrics*, *111*, 1625–1630. https://doi.org/10.1542/peds.111.S3.1625
39. Dąbrowiecki, P et al. 2021: Impact of Air Pollution on Lung Function among Preadolescent Children in Two Cities in Poland. *Journal Clinical Medicine,* **10(11)**, 2375. https://doi.org/10.3390/jcm10112375
40. Badyda, AJ, Grellier, J, Dąbrowiecki, P 2016. Ambient PM2.5 Exposure and Mortality Due to Lung Cancer and Cardiopulmonary Diseases in Polish Cities. *Respiratory Treatment and Prevention,* **27**, 9–17. https://doi.org 10.1007/5584_2016_55
41. Gehring, U et al. 2013. Air pollution exposure and lung function in children: the ESCAPE project. *Environmental Health Perspectives*, **121(11–12)**,1357–1364. https://doi.org/ 10.1289/ehp.1306770
42. Asgari, MM, Dubois, A, Asgari, M, Gent, J, Beckett, WS 1998. Association of Ambient Air Quality with Children's Lung Function in Urban and Rural Iran. *Archives Environmental Health International Journal*, **53**, 222–230. https://doi.org/ 10.1080/00039899809605699
43. Bridget, M and Kuehn, MS 2021. Saving tens of thousands of lives by reducing air pollution. *JAMA*, **325(11)**, 1031.https://doi.org/ 10.1001/jama.2021.2292