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ANALYSIS AND ASSESSMENT OF AIR QUALITY IN THE CITY OF BIALYSTOK IN 2012-2017

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ABSTRACT: The aim of the research was to assess the state of air pollution with mentioned pollution for the area of the city of Bialystok. The analysis was carried out using data from 2 air monitoring stations. The stations are owned by the Provincial Inspectorate for Environmental Protection in Bialystok. The work also compared the air quality in Bialystok with the air quality in the main voivodship cities with a similar population: Olsztyn, Lublin, Bydgoszcz and two of the largest urban agglomerations in the country: Warsaw and Wroclaw. It was found that the quality of air in the city of Bialystok compared to the analyzed cities is the best. In addition, it was observed that increased concentrations of PM10 and PM2.5 suspended dust occur in Bialystok in the months of X-III, due to the low emission from combustion of fuels.

KEY WORDS: air quality, air monitoring, NOx, PM2.5, PM10

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Introduction

Air pollution is a local, pan-European and hemisphere problem. Air pollution is the most harmful and dangerous of all pollution, because it is mobile and can contaminate virtually all environmental components in large areas. The sources of air pollution are mainly anthropogenic emissions from the municipal and housing sector, transport and industry (Cembrzyńska et al., 2012; Pasela et al., 2017). We mainly deal with a large concentration of the above sources in urban-industrial agglomerations. Therefore, urban areas are particularly vulnerable to air pollution with dust and gases such as sulphur oxides, nitrogen oxides and car-bon monoxide.

The air quality in Poland is monitored as part of State Environ-mental Monitoring (SEM) and the responsibility for its maintenance lies with the Inspectorate for Environmental Protection. The city of Bialystok constitutes one zone from 46 SEM zones, where the air quality is assessed – Bialystok Agglomeration. The city has exceptional land-scape and environmental values, it is located in the functional area "Green Lungs of Poland". Over 32% of the city area is occupied by green areas. Due to the above-mentioned exceptional location of the city, it was decided to assess the air quality and to determine the trends of changes in individual gaseous pollutants in the last six years in the city of Bialystok. The aim of the study was to analyze and evaluate the results of gaseous pollutants measurements: NO_x, NO_2, SO_2, CO and suspended dust PM10 and PM2.5 obtained from urban background measurement stations in the city of Bialystok in 2012–2017. The work also compares the air quality in Bialystok with the air quality in the main provincial cities with similar population: Olsztyn, Lublin, Bydgoszcz and in two of the largest urban agglomerations in the country: Warsaw and Wroclaw.

Material and Methods

In the assessment of air quality, the analysis was limited to the results of measurements of total nitrogen oxides (NO_x), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon monoxide (CO) concentration as well as particulate matter PM10 and PM2.5. The results of measurements of gas air pollutants concentrations averaged over the year and the frequency of exceeding the 1- and 24-hour admissible levels specified in the Regulation of the Minister of Environment (Journal of Laws, pos. 1031) in 2012-2017, were obtained from the information service of the Main Inspectorate of Environmental Protection. The Provincial Inspector for Environmental Protection in Bialystok is responsible for monitoring and assessment of air quality in the Bialystok agglomeration (over 250 000 inhabitants). The air quality monitoring system in Bialystok consists of 3 stationary measurement stations. Two of them are characterized by the measurement of urban background: at Waszyngton Street 16 (1) and at Warszawska Street 75A (2). Data regarding the analyzed background stations are presented in table 1.

Table 1. Basic information about urban background measurement stations in Bialystok

	Name	National station code	Station classification	Location		Type of measurements	Measured parameters
				coordinates	address		
1	Bialystok – Miejska	PdBialWaszyn	background	Φ 53,126689 λ 23,155869	Waszyngton Street 16	A, M*	NO_x, SO_2, CO, PM2.5, PM10
2	Bialystok – Warszawska	PdBialWarsza	background	Φ53,129306 λ 23,181744	Warszawska Street 75A	A, M*	PM2.5, PM10

* A – automatic measurement, M – manual measurement
Source: www.powietrze.gios.gov.pl [20-01-2018].

Characteristics of air pollution were elaborated by calculating averages: annual pollutant concentrations for both years and the entire analyzed period (2012-2017). The number of exceedances of normalized mean hour values in the analyzed period at each station was also calculated. In addition, from the set of PM10 and PM2.5 suspended particulates concentrations at the analyzed Bialystok-Miejska and Bialystok-Warszawska stations, in the period 2012-2017, monthly averages for the whole period were calculated to extract months with an increased concentration of particulate matter. Concentrations of gaseous and dust pollutants in the city of Bialystok were compared with those in cities: Lublin, Olsztyn, Bydgoszcz, Wroclaw and Warsaw in the same research period of 2012-2017.

Results and discussion

Tables 2 and 3 summarize the values of annual average concentrations (C_{year}), average annual minimum values (Min_{year}), average annual maximum values (Max_{year}) for the sum of nitrogen oxides (NO_x), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) (for CO, also the average annual maximum 8-hour concentration) and particulate suspended matter PM10 and PM2.5, exceedances of the allowable levels of 1-hour NO_2 (AL_{h1}) and 24-hour PM10 and sulfur dioxide (AL_{h24}) and 50% percentile of total NO_x, NO_2, CO, PM2.5 at 2 air quality monitoring stations in 2012-2017 in Bialystok.

Table 2. List of statistical parameters for NO_x, NO_2, SO_2, CO concentrations at the Bialystok-Miejska measurement station

Station	Parameter	2012	2013	2014	2015	2016	2017	Average 2012-2017
NO_x concentration [μg/m^3]								
Bialystok -Miejska	C_{year}	19.4	18.2	18.8	20.2	18.1	16.6	18.6
	Min_{year}	0.0	0.0	0.9	0.9	0.0	0.7	-
	Max_{rok}	469.4	470.5	327.0	530.3	353.5	675.0	-
	$S50_{PERC}$	13.4	13.3	12.8	13.7	12.8	12.2	-
NO_2 concentration [μg/m^3]								-
Bialystok -Miejska	S_{year}	14.5	14.4	13.7	14.9	13.4	13.1	14.0
	Min_{year}	0.0	0.0	0.9	1.0	0.5	0.7	-
	Max_{year}	153.3	107.4	94.3	111.9	96.9	93.6	-
	$S50_{PERC}$	11.6	11.6	10.7	11.7	10.7	10.4	-
	AL_{h1}	0	0	0	0	0	0	-
SO_2 concentration [μg/m^3]								-
Bialystok -Miejska	S_{year}	3.3	10.9	4.3	4.1	3.2	3.5	4.9
	S_{winer}	4.1	5.5	7.4	5.2	3.7	3.8	-
	Min_{year}	0.0	1.8	0.0	0.0	0.0	0	-
	Max_{year}	89.1	103.6	83.6	30.3	26.4	37.9	-
	ALD_{h24}	0	0	0	0	0	0	-
CO concentration [μg/m^3]								-
Bialystok -Miejska	S_{year}	0.3	0.3	0.3	0.4	0.4	0.3	0.3
	Min_{year}	0.0	0.0	0.1	0.2	0.1	0.1	-
	Max_{year}	4.0	5.1	2.9	4.1	2.4	2.1	-
	Max_{h8}	2.9	2.6	2.0	2.8	1.9	1.6	-
	$S50_{PERC}$	0.3	0.3	0.3	0.4	0.3	0.3	-

Source: www.powietrze.gios.gov.pl [20-01-2018].

The analyzes show that the average annual values of the concentration of total nitrogen oxides NO_x in 2012-2017 at the Bialystok-Miejska station range from 16.6 μg/m^3 in 2017 to 20.2 μg/m^3 in 2015. Minimum concentrations in the examined period oscillate between 0.0 and 0.9 μg/m^3, while the maximum concentration in the analyzed period was recorded in 2017 and amounted to 675.0 μg/m^3.

In the case of nitrogen dioxide NO_2, it was found that the average annual concentration values in the analyzed years 2012-2017 did not exceed the admissible annual value of 40 μg/m^3 (Journal of Laws on 2012, pos. 1031) and fluctuated from 13.1 to 14.9 μg/m^3 (table 2). In period 2012-2017, there were also no days exceeding the permissible 1-hour NO_2 limits. The minimum NO_2 concentrations in the analyzed time interval ranged from 0.0 to 1.0 μg/m^3, while the maximum observed concentrations ranged from 153.3 μg/m^3 in 2012 to 93.6 μg/m^3 in 2017. In period 2012-2017, a significant downward trend was observed in the case of maximum NO_2 concentrations. Nitrogen dioxide (NO_2) is commonly found in the work environment and in the municipal environment, resulting from the combustion of organic substances containing nitrogen, detonation of explosives, electrochemical treatment of metals and operation of diesel engines (Kostrz, Satora, 2017).

Analysis of annual average SO_2 concentrations in 2012-2017 indicates that in 6 years the SO_2 concentration remains at a similar level, and only in 2013, there was much higher annual average concentration compared to the remaining years from the analysis period. The average annual concentration of SO_2 in 2013 was 10.9 μg/m^3. In Bialystok, there are no exceedances of permissible concentration of sulfur dioxide (SO_2). Concentration of sulfur dioxide (SO_2) are dependent on the season of the year and associated emission factor, which are local individual heating sources, therefore the average concentration in the year from the winter period were separately calculated. It was observed that the winter average value in most years is slightly higher than average for the entire calendar year. Sulfur dioxide enters atmospheric air as a result of the process of burning the hard coal, when organic and inorganic sulfur compounds decompose and pass into the exhaust gases (Kostrz, Satora, 2017).

Concentration of carbon monoxide (CO) observed in the years 2012-2017 remained at the same level of 0.3-0.4 μg/m^3. The maximum 8-hour concentration of carbon monoxide in the period under study did not exceed the applicable standards.

Table 3. List of statistical parameters regarding suspended PM10 and PM2.5 concentrations at the Bialystok-Miejska and Bialystok-Warszawska measuring stations

Station	Parameter	2012	2013	2014	2015	2016	2017	Average 2012-2017
PM10 concentration [μg/m³]								
Bialystok -Miejska	Cyear	27.8	22.9	24.9	24.9	19.8	21.0	23.6
	Min_{year}	6.6	3.8	5.9	6.1	3.3	2.7	-
	Max_{year}	142.6	75.2	69.7	91.0	65.2	129.7	-
	AL_{h24}	26	8	10	26	2	8	-
Bialystok-Warszawska	S_{year}	30.9	26.9	30.0	29.2	23.9	23.3	27.4
	Min_{year}	0.0	0.0	0.0	0,0	0.0	0.0	-
	Max_{year}	485.0	385.6	402.6	362.6	294.1	309.2	-
	LD_{S24}	38	20	37	46	15	13	-
PM2.5 concentration [μg/m³]								
Bialystok -Miejska	S_{year}	24.7	20.5	19.6	19.3	19.0	16.9	20.0
	Min_{year}	0.0	0.0	0.0	0.0	0.0	0.0	-
	Max_{year}	430.0	456.0	246.0	261.0	185.0	200.6	-
	$S50_{PERC}$	18.0	17.0	15.1	14.,0	15.0	11.9	-
Bialystok -Warszawska	C_{year}	22.3	19.3	21.9	21.2	17.5	17.6	19.9
	Min_{year}	4.6	2.5	4.5	3.4	1.7	1.2	-
	Max_{year}	139.2	88.2	88.3	106.5	71.1	134.2	-

Source: www.powietrze.gios.gov.pl [20-01-2018].

Table 3 presents results for suspended particulate matter PM10 and PM2.5. The tests showed that values of 24-hour concentrations of suspended dust PM10 above the LD_{24} standard = 50 μg/m³ were above the frequency of exceeding the permissible level in the calendar year for 24-hour concentrations of particulate matter PM10 determined at 35 times. This took place in 2012, 2014, 2015 at the Bialystok-Warszawska station. The overruns in the above-mentioned years were respectively: 2012 – 38 times, 2014 – 37 times and 2015 – 46 times. At the Bialystok-Miejska measurement station, in 2012-2017, the exceedance of the permissible frequency of exceeding the level from the Regulation was not noted. Comparing the annual mean concentrations of PM10 with the levels recommended by the World Health Organization, to which the EU adheres, it was found that in all years from the period 2012-2017, the average annual concentration of PM10 was close to or exceeded the recommended level of 20 μg/m³ at both stations. The mean concentrations from the 6-year analysis period were respectively 23.6 µg/m^3 at the Bialystok-Miejska station and 27.4 µg/m^3 at the Bialystok-Warszawska station. At the Bialystok-Warszawska station, slightly higher average annual concentrations of PM10 and maximum annual concentrations were observed than at the Bialystok-Miejska station. Specific meteorological conditions contribute to the occurrence of high maximum concentrations of PM10, which, along with the unfavorable ventilation conditions characteristic of compact urban buildings, cause frequent, especially during winter inversion, occurrence of extremely high concentrations of particulate matter called *"smog episodes"* (Cembrzyńska et al., 2012). In Bialystok, the highest maximum concentration of PM10 in 2012-2017 was recorded at the Bialystok-Warszawska station in 2012 and it amounted to 485 µg/m^3. In Wroclaw, in the winter season of 2009-2012, the average concentration of PM2.5 in the air was exceeded by an average of 25% from the established national standard (Sówka et al., 2015).

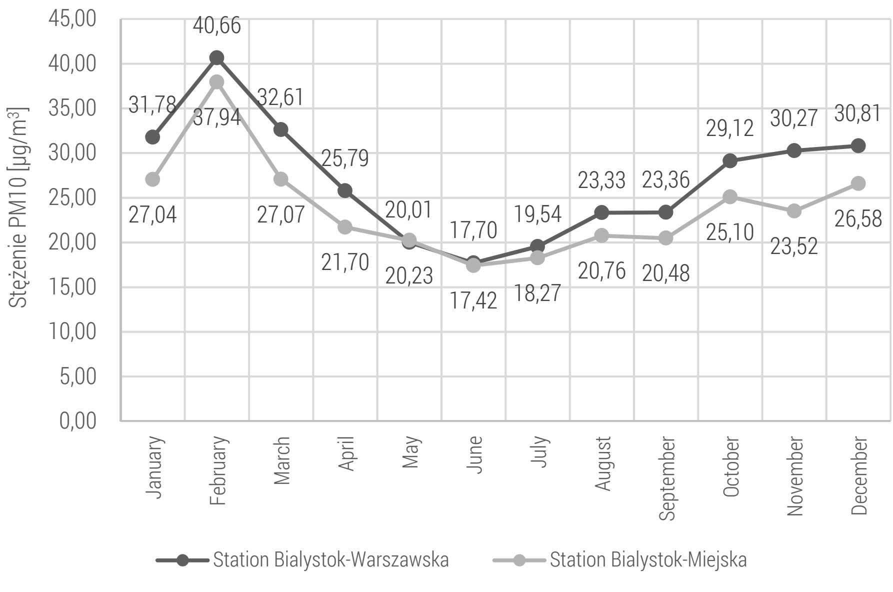


Figure 1. The annual course of the average monthly PM10 [µg/m^3] in Bialystok in 2012-2017

Source: author's own work based on www.powietrze.gios.gov.pl [20-01-2018].

Figure 1 shows the annual course of the average monthly PM10 concentration in Bialystok in 2012-2017, based on which it was observed that the monthly values in the annual course, similar as in the case of PM2.5 (figure 3), are the lowest between April and September, while the largest ones fall between October and March. Such dependence results, among others, from the start of the heating season due to the lowering of air temperatures in the winter months. Slightly lower concentrations were observed at the Bialystok-Miejska station. The average PM10 for the heating season (X-III) was 30.23 µg/m³ at the Bialystok-Warszawska station, and at the Bialystok-Miejska station – 27.87 µg/m³. In the case of summer season, i.e. non-heating period (IV-IX), the average PM10 at the Bialystok-Warszawska station was equal to 23.16 µg/m³, while at the Bialystok-Miejska station, 19.81 µg/m³. At both stations in winter season, the PM10 concentration was higher by around 20% as compared to the summer season.

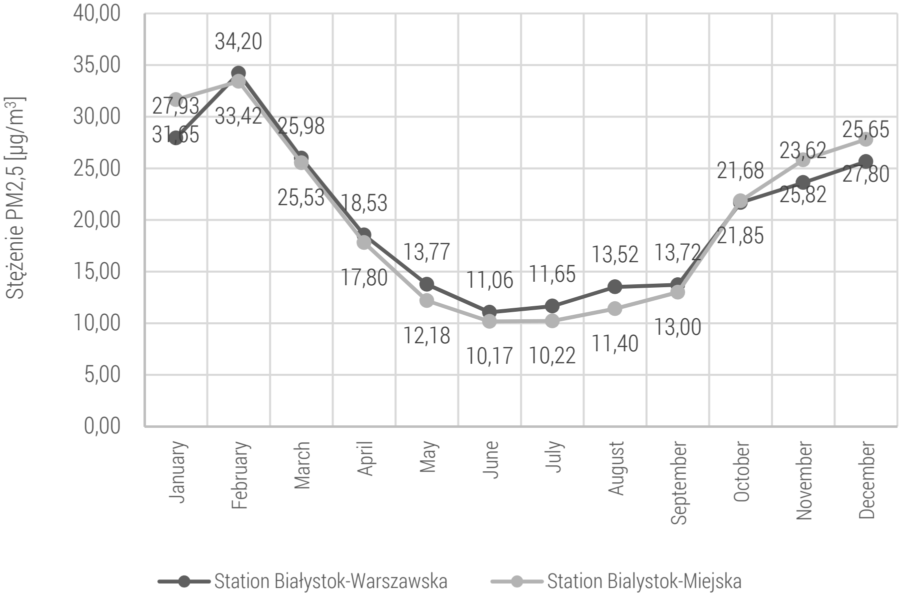
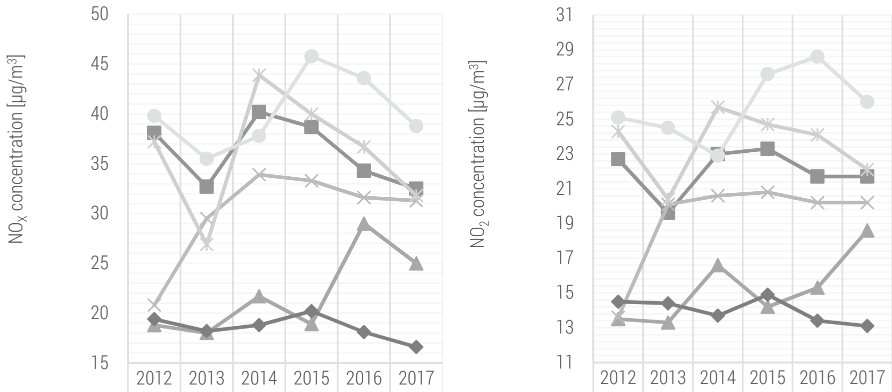


Figure 2. The annual course of the average monthly PM2.5 [µg/m³] in Bialystok in 2012-2017
Source: author's own work based on www.powietrze.gios.gov.pl [20-01-2018].

The analysis results of air pollution with suspended dust PM2.5, taking into account the annual course of the average monthly concentration at both city background measurement stations in Bialystok (figure 2), show identical trends as in the case of PM10. There is a significant decrease in the mean monthly PM2.5 in months IV-IX. The average PM2.5 in months X-III was 26.51 µg/m³ at the Bialystok-Warszawska station, while at the Bialystok-Miejska station, it was 27.68 µg/m³. In months IV-IX, the average PM2.5 at Bialystok-Warszawska station was equal to 13.71 µg/m³, whereas at Bialystok-Miejska station – 12.46 µg/m³. At both stations in winter season, the concentration of PM2.5 was higher by about 45-50% as compared to the summer season.

The obtained high values of suspended particulate matter concentrations PM10 and PM2.5 in the winter season (figures 1 and 2) are mainly associated with low emissions from the municipal and housing sector. The use of hard coal in Poland for heating buildings contributes to the creation of dust, the share of which in the total amount of emitted dust is from about 55% to 85%. Dust that occurs in cities comes from the combustion of coal for energy purposes (generation of energy and heat for technological and municipal needs) (Widawski, 2015; Pasela et al., 2017). According to GUS data, the consumption of fuels in the Podlasie province in 2016 was classified as follows: hard coal – 1785 thousand tons, which accounted for approximately 64%, natural gas – 828 thousand TJ – 30%, liquid gas (without vehicles, stationary consumption) – 110,000 tons – 4%, light heating oil – 63 thousand tons – 2%, heavy fuel oil – 3 thousand tons – 0.1%. Summing up, the highest dust concentration values were observed in Bialystok in winter season, which indicates the main source of dust, which is low emissions from the municipal and living sector.

For the comprehensive comparison of air quality in the city of Bialystok (about 297 thousand inhabitants) with other urban agglomerations, three main provincial cities with a similar number of inhabitants were selected: Lublin (about 340,000 residents), Olsztyn (about 180,000 residents) and Bydgoszcz (around 355,000 inhabitants) and 2 cities from the largest urban agglomerations in Wroclaw (about 638,000 inhabitants) and Warsaw (about 1,758 thousand residents). Data for the comparison of concentrations of individual pollutants came from the GIOŚ Database. Urban background measurement stations were selected where measurements of the same pollutants as at the Bialystok-Miejska station were made. Measurement stations in individual cities were: Lublin Obywatelska Street 13, Olsztyn Puszkin Street 16, Bydgoszcz, Warszawska Street 10, Warsaw, Kondratowicz Street 8, Wroclaw, J. Conrad-Korzeniowski Street 18, Wroclaw, Na Grobli Street. Figures 3a and 3b present comparison of the average annual concentrations of the sum of nitrogen oxides and nitrogen dioxide in the city of Bialystok and selected cities. The city of Bialystok is characterized by the lowest average annual concentrations of the nitrogen oxides sum and nitrogen dioxide during the analysis period of 2012-2017. In all analyzed cities, since 2015, a downward trend in NO_x and NO_2 has been observed. The capital city of Warsaw was characterized by the highest average annual concentrations of analyzed pollutants.



	2012	2013	2014	2015	2016	2017
Lublin	38,1	32,7	40,2	38,7	34,3	32,5
Olsztyn	18,8	18	21,7	18,9	29	25
Bydgoszcz	20,8	29,5	33,9	33,3	31,6	31,3
Wroclaw	37,2	26,9	43,9	40	36,7	31,8
Warszaw	39,8	35,5	37,8	45,8	43,6	38,8
Bialystok	19,4	18,2	18,8	20,2	18,1	16,6

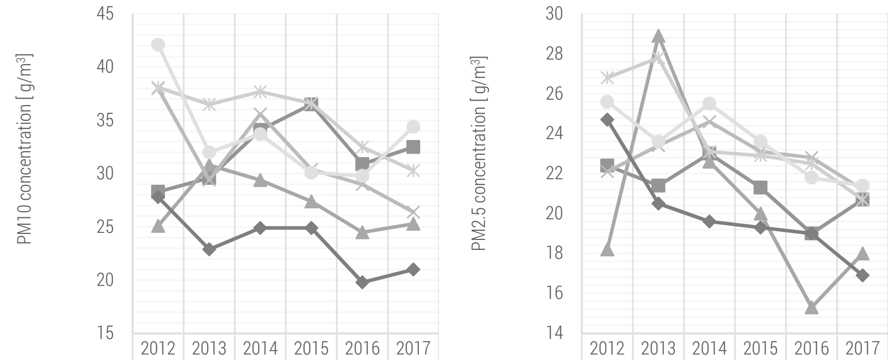
	2012	2013	2014	2015	2016	2017
Lublin	22,7	19,6	23	23,3	21,7	21,7
Olsztyn	13,5	13,3	16,6	14,2	15,3	18,6
Bydgoszcz	13,6	20,1	20,6	20,8	20,2	20,2
Wroclaw	24,3	20,4	25,7	24,7	24,1	22,1
Warszaw	25,1	24,5	22,9	27,6	28,6	26
Bialystok	14,5	14,4	13,7	14,9	13,4	13,1

Figure 3. Comparison of changes in average annual concentration a) sum of nitrogen oxides NO_x, b) NO_2 nitrogen dioxide in 2012-2017 in selected cities

Source: author's own work based on www.powietrze.gios.gov.pl [20-01-2018].

Analysis of average annual suspended particulate PM10 and PM2.5 (figure 4a and 4b) concentrations values indicates that, within six years, a downward trend in airborne dust concentrations in all analyzed cities was observed as compared to 2012. The city of Bialystok, in terms of the PM10 and PM2.5 analysis, was classified as a city with the lowest pollution in the analyzed period.

In conclusion, it can be stated that the air quality in the city of Bialystok is at a good level. The city is characterized by lower average annual concentrations of gaseous pollutants and suspended particulate matter as compared to the cities of similar size and function (provincial cities): Lublin, Olsztyn and Bydgoszcz. Also, in comparison to one of the largest urban agglomerations such as Wroclaw and Warsaw, the average annual concentrations of gaseous and particulate pollutants in the city of Bialystok are significantly lower. However, levels of suspended particulates PM10 and PM2.5 recommended by the WHO are exceeded in Bialystok.



	2012	2013	2014	2015	2016	2017
Lublin	28,3	29,6	34,1	36,5	30,9	32,5
Olsztyn	25,1	30,8	29,4	27,4	24,5	25,3
Bydgoszcz	38	29,4	35,6	30,4	29	26,4
Wroclaw	38,1	36,5	37,7	36,6	32,5	30,3
Warszaw	42,1	32	33,7	30,1	29,8	34,4
Bialystok	27,8	22,9	24,9	24,9	19,8	21

	2012	2013	2014	2015	2016	2017
Lublin	22,4	21,4	23	21,3	19	20,7
Olsztyn	18,2	28,9	22,6	20	15,3	18
Bydgoszcz	22,1	23,4	24,6	23,1	22,8	21,2
Wroclaw	26,8	27,8	23,1	22,9	22,5	20,7
Warszaw	25,6	23,6	25,5	23,6	21,8	21,4
Bialystok	24,7	20,5	19,6	19,3	19	16,9

Figure 4. Comparison of changes in average annual concentration of a) PM10, b) PM2.5 in 2012-2017 in selected cities

Source: author's own work based on http://powietrze.gios.gov.pl/pjp/archives [20-01-2018].

Conclusions

1. In the analyzed period of 2012-2017, average annual values of NO_2 and SO_2 concentrations on the analyzed Bialystok-Miejska station were not exceeded.
2. The average annual value of particulate matter concentration at the analyzed urban background measurement stations in Bialystok in 2012-2017 was respectively for PM10 23.6 μg/m^3 at the Bialystok-Miejska station, while at Bialystok-Warszawska station 27.4 μg/m^3 and analogously 20,0 and 19.9 μg/m^3 for PM2.5.
3. Increased PM10 and PM2.5 concentrations above the average for the period 2012-2017 were observed in the winter season (October-March) on both measuring stations, which indicates that the main source of dust is low emissions from the municipal and housing sector.
4. The air quality in the city of Bialystok is slightly lower compared to other cities with similar population and function. During the period 2012-2017, a slight decrease in the majority of gaseous and particulate pollutants in the city of Bialystok was observed.

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The contribution of the authors

Iwona Skoczko – 50%
Ewa Szatyłowicz – 50%

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