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Influence of Changes in the Concentration of Selected Air Pollutants on the General Health of Children and Adolescents in Bielsko-Biala

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ABSTRACT

Air pollution results in smog, acid rain, ozone hole, global warming, as well as cardiovascular and respiratory diseases. It also contributes to cancer, which increasingly often occurs in children. Children and infants are particularly vulnerable to air pollution because their immune, respiratory and central nervous systems are not fully developed. Compared to adults, children often spend more time outdoors, and due to their lower lung capacity, they also breathe more frequently, which means that they inhale much more air than adults, in relation to their body weight. The article concerns the data on the meteorological conditions, air quality (annual average concentration of nitric oxides, benzo(a) pyrene, PM_{2.5} and PM₁₀ particulate matter) as well as morbidity and hospitalization due to the respiratory, circulation and cancer diseases in Bielsko-Biala in 2010–2018. The hypertension, cardiovascular malformations and cancer incidence among children and adolescents, has been systematically increasing since 2010, just like in the case of hospitalization due to bronchial asthma and congenital malformations. The basic cause of poor air quality in Bielsko-Biala is low emission and inversion phenomenon which are perfect conditions for smog development. Therefore, certain actions must be taken, which can include: liquidation of coal boilers and their replacement with environmentally friendly energy sources (e.g. subsidy of 100% return on investment costs), introducing communication solutions that will lead to a reduction in linear emissions, free communication and ecological education.

Keywords: air pollution, Bielsko-Biala, air monitoring, particulate matter, nitrogen oxides

INTRODUCTION

According to the currently binding Environmental Protection Law of 2001, the term air pollution is understood as an emission that may be harmful to the human health or the state of the environment, may cause damage to material goods, deteriorate the aesthetic value of the environment or interfere with other, justified methods of environment use (Wielgosinski, Zarzycki 2018).

Introduction of various types of pollutants constitutes the source of atmospheric contamination. The introduction of pollutants (contamination) into the environment is an emission, and the place (source) of introducing these pollutants is the emitter. The introduced pollutants are dispersed (spread) in the atmosphere, which takes place simultaneously as a result of:

- dispersion, the mechanism of which is based on the physical diffusion of pollutants (molecular migration of pollutants from the places where they occur in high concentrations to the places with lower concentrations),
- convection, i.e. the transfer of air masses due to temperature differences,
- advection, i.e. the transmission of pollutants by the wind (Juraszka, Dąbrowski 2011).

Pollution spreading in the atmosphere reaches individual elements of the environment (e.g. the Earth's surface, water surface, elements of nature, etc.). This process is known as immission. Pollutants can be introduced into the environment (air) through emitters releasing pollutants in an organized manner (e.g. with the use of a fan) and in an unorganized manner (e.g. gravity ventilation, surface and linear emitters, etc.).

Point emitters (which constitute the vast majority) are the emitters in which emissions are introduced into the air in an organized manner at one specific point. A point emission is an emission from identified large emitters (e.g. power plant, electrical heating and power station, boiler houses, etc.) and identified technological emitters of enterprises for which emission permits have been issued or emission notifications accepted.

Surface emitters are the emitters in the case of which the emission (most often unorganized) takes place from a flat surface (e.g. soil, water reservoir or a thin layer directly adjacent to it) with specific dimensions. Surface emission is the emission from overbuilt and overpopulated residential areas where individual heating systems dominate.

Linear emitters are a group similar to the surface emitters, where one of the horizontal geometric dimensions of the emitter is much smaller than the other, just as its height is significantly smaller than the horizontal geometric dimensions. Examples of linear emitters are roads and highways which are the source of car exhaust emissions, sewers emitting contamination or a row of point emitters located very close to each other. Linear emission are also generated from mobile sources (cars) traveling along communication routes (streets, roads, highways, etc.).

The most important pollutants emitted to the atmosphere as a result of economic activity (mainly production) are:

- sulfur dioxide: SO_2 ,
- nitrogen oxides: NO , N_2O , NO_2 ,
- particulate matter,
- volatile organic compounds,
- persistent organic pollutants,
- heavy metals,
- greenhouse gases,
- odors (Wielgosiński and Zarzycki, 2018).

Characterization of an examined area of Bielsko-Biala and location of measurement points

The city of Bielsko-Biala is located in the south of Poland, in the Silesian Foothills, at the foot of the Beskid Mountains. Its area is 125 km². It is spread over a dozen hills. The center itself is situated at an altitude of 310 meters above sea level. The lowest situated areas are Stawy Komorowickie – 262 meters above sea level, and the highest peak of Klimczok – 1117 meters above sea level. This landform causes a significant

deterioration of the atmospheric air during the days when the wind is still, especially in the lower center.

Urban development strongly influences the wind speed and direction. The critical value is 3–5 m/s, above which the wind speed slows down, and below it is accelerated due to e.g. the tunnel effect. Buildings, especially tall ones (e.g. Beskidzkie Estate in the southern part of the city and Lower Suburb in the city center) change the direction and the speed of the wind flow. Due to the convergence of the air flows, the windward side of the building is exposed to wind gusts and is therefore an area of high pressure. The leeward side of the building is in an aerodynamic shadow and is covered by a low pressure area. This situation creates the conditions for ventilation in the vicinity of the building, and the resulting pressure difference has a negative effect, especially on the people suffering from cardiovascular diseases (Prognosis of impact ... 2016).

In terms of ventilation, the city area can be broadly divided into two different types, i.e. into “well-ventilated” areas, for example with hills and “less ventilated” areas constituting valleys, where the percentage of the frequency of days with still wind and light breeze is much greater, thus reducing the possibility of exchanging and purifying air in the city.

The general air quality condition in Bielsko-Biala is influenced by many factors, making this phenomenon a complex multi-parameter system, difficult to model and forecast. However, the most important factors are those related to the formation, migration and local cumulation of pollutants at low elevations above ground level. What is more, the topography and the way of developing the city are also important. The geographical location of the city of Bielsko-Biala fosters the ventilation of the urban area, as the height of the land slopes from the south to the north and from the west to the east. On the other hand, there are local depressions of the land, and for this reason, appropriate landscape planning, especially of urbanized areas, is important. Clusters of buildings of different heights, different density and locations, multiply the roughness of the ground, and also clearly constitute an obstacle to the free flow of air masses, causing various types of turbulence. The increase of friction reduces the speed of the wind near the ground, while the turbulent mixing and gusts of wind increase. Another factor that directly causes the increased concentrations

of pollutants in the air are the climatic and meteorological conditions. Favorable 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 (about 2 meters above ground level) (Study ... 2012).

There are 3 stations in the city that monitor the air quality. On ul. Kossak-Szczucka (south-western part of the city) there is a station for manual and automatic measurement (station code: SIBielbBiel_kossa). The station is situated in a place with low traffic, close to community streets and detached houses. There are no industrial sites here, but there is a busy ring road (al. Andersa). The second air monitoring station is located at ul. Sternicza (station code: SIBielbBiel_stern), which passively measures benzene since 2011, and manually $PM_{2.5}$ since 2010. The third monitoring station is located on ul. Partyzantow (station code: SIBielPartyz). It performs automatic measurement for carbon monoxide, nitric oxide, nitrogen dioxide and $PM_{2.5}$ (Fig. 1).

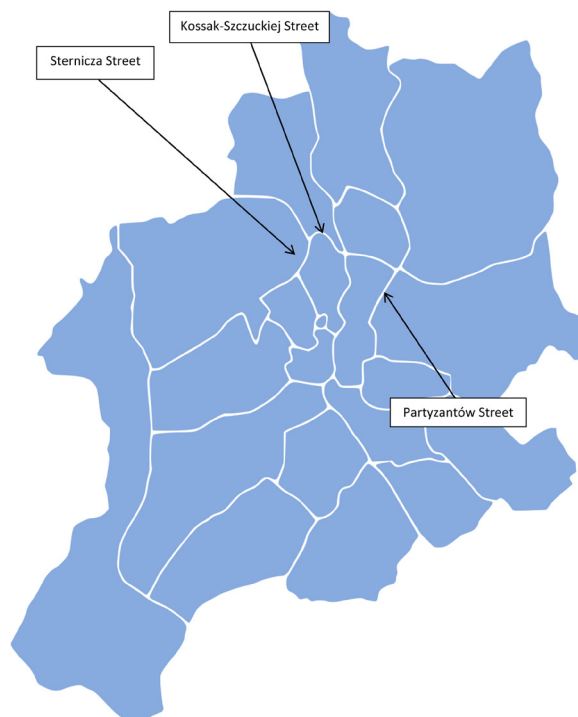


Fig. 1. Location of the air monitoring station in Bielsko-Biala (measuring points)

The influence of polluted air on the human body

Inhaling polluted air leads to the development of diseases of the respiratory system (mainly bronchial asthma), cardiovascular system, cancer as well as food and skin allergies.

Asthma is the most common chronic respiratory disease that affects children and adolescents. Its prevalence in the global population of children ranges from 2–30%. In Poland, the prevalence of asthma in school-age children is about 8%, and this number is slightly increasing (Umławska 2011). In the group of 6–8 year olds, the disease is very often unrecognized. It is estimated that in each class here is at least one asthmatic. In Poland, over a million children suffer from asthma (Trojanowska et al. 2013). It is currently an incurable disease, and the increased content of airborne particulate matter and pollutants in the environment adversely affects its course (Ścibor et al. 2015). Asthma, as a chronic disease, is the most common cause of hospitalization of children aged 3–16 and a frequent reason for using additional medical care due to its severe exacerbation. It is also the most common cause of school absences (Trojanowska et al. 2013).

About 20% of the children population in Poland suffers from allergic diseases. The Polish

Society of Allergology states that across the country, among the population of children between 3 and 16 years of age, atopic dermatitis occurs in 4.7% of children (Piskorz-Ogórek, 2012). Food allergy in Poland occurs in about 13% of children aged 6–7 years and 11% of children aged 13–14 years. Atopic dermatitis and other skin allergies are found in approximately 10% of children in both age groups, allergic rhinitis in 24% of children aged 6–7 years and 30% of children aged 13–14 years. It is mainly environmental pollution that contributes to the development of allergies (Bułoczko 2016).

Arterial hypertension (HT) is the main risk factor for cardiovascular disease in Poland. In children, this disease is much less common than in adults and affects 1–5% of the population up to 18 years of age. In Poland, 7.1% of children over 7 years of age with normal body weight and 22% of obese children have arterial hypertension (Jobs and Jung 2011).

Neoplastic diseases in children constitute a small percentage of cancers in the entire population, only about 1.5–3%. However, despite the enormous progress in medicine, it is still one of the leading causes of death among the patients under the age of 16, accounting for approximately 16% of all causes of death in this age group. The

incidence of neoplastic diseases in this group is estimated at about 130–140 cases per 1 million children; in Poland this amounts to about 1–1.2 thousand of new cancer cases annually. About 6 million children up to 14 years of age (15% of the total population) live in Poland, while the number of people under the age of 18 is estimated at nearly 7 million (18% of the population) (Kapała et al. 2016).

The subject of the study is the impact of changes in the concentration of selected air pollutants (PM_{10} and $PM_{2.5}$, benzo (a) pyrene and nitrogen oxides) in Bielsko-Biala in 2010–2018 on the general health of children and adolescents in connection with the meteorological conditions.

MATERIALS AND METHODS

In order to show the impact of air pollution (annual average particulate matter and gases) on the general health of children and adolescents, the data from the Provincial Inspectorate for Environmental Protection in Katowice-Branch Office (WIOŚ) in Bielsko-Biała were prepared, which concerned:

- the state of air quality in Bielsko-Biala for the period from 2010–2018, taking into account the average annual concentration of nitrogen oxides, benzo (a) pyrene, suspended $PM_{2.5}$ and PM_{10} ,
- the meteorological conditions in Bielsko-Biala for the period from 2010 to 2018,

In addition, the data from the Department of Health of the Silesian Voivodeship Office in Katowice on morbidity and hospitalization for diseases of the respiratory system, blood circulation as well as cancer and congenital defects of children and adolescents aged 0 to 19 in Bielsko-Biala were taken into account. These data concern the inhabitants of Bielsko-Biala and hospitalized in the area of the city.

The annual average permissible concentration of $PM_{2.5}$ according to the Regulation of the Minister of the Environment of 24th August 2012 on the levels of certain substances in the air due to the protection of human health should not exceed $25 \mu\text{g}/\text{m}^3$. The highest average monthly concentration of $PM_{2.5}$ in 2010 was recorded in January ($123 \mu\text{g}/\text{m}^3$), in December ($74 \mu\text{g}/\text{m}^3$) and in February ($67 \mu\text{g}/\text{m}^3$). In 2011, it was February ($79 \mu\text{g}/\text{m}^3$) and January ($65 \mu\text{g}/\text{m}^3$). The highest monthly averages in 2012 were recorded in February ($82 \mu\text{g}/\text{m}^3$) and November ($59 \mu\text{g}/\text{m}^3$). In 2013, the

highest monthly averages were recorded in January and February ($62 \mu\text{g}/\text{m}^3$), March ($53 \mu\text{g}/\text{m}^3$) and December ($48 \mu\text{g}/\text{m}^3$). In 2014 it was December ($50 \mu\text{g}/\text{m}^3$), January ($44 \mu\text{g}/\text{m}^3$) and February ($42 \mu\text{g}/\text{m}^3$). In 2015, the highest monthly averages were recorded in February ($49 \mu\text{g}/\text{m}^3$), October ($46 \mu\text{g}/\text{m}^3$) and November ($39 \mu\text{g}/\text{m}^3$). In 2016, the highest monthly averages of $PM_{2.5}$ were recorded in January ($71 \mu\text{g}/\text{m}^3$) and December ($50 \mu\text{g}/\text{m}^3$). The highest average monthly concentrations in 2017 were recorded in January ($90 \mu\text{g}/\text{m}^3$) and February ($77 \mu\text{g}/\text{m}^3$), while in 2018 it was February ($66 \mu\text{g}/\text{m}^3$) and March ($47 \mu\text{g}/\text{m}^3$). In the analyzed period (from 2010–2018), the annual average permissible concentration of $PM_{2.5}$ was exceeded each year. The highest average annual concentration of $PM_{2.5}$ was recorded in 2010 ($42 \mu\text{g}/\text{m}^3$) and the lowest in 2013 ($26 \mu\text{g}/\text{m}^3$). The highest monthly averages of benzene occur in the autumn and winter period (Fig. 2)

The annual average permissible concentration of PM_{10} according to the Regulation of the Minister of the Environment of 24 August 2012 on the levels of certain substances in the air, due to the protection of human health, should not exceed $25 \mu\text{g}/\text{m}^3$. The permissible 24-hour frequency of exceeding the permissible level of PM_{10} in a calendar year is 35 times. In 2010, the number of such days was 96, in 2011 – 82, in 2012 – 70, in 2013 – 83, in 2014 – 81, in 2015 – 69, in 2016 – 50, in 2017 – 57 and in 2018 – 59.

The highest average monthly concentrations of PM_{10} in 2010 were recorded in January ($120 \mu\text{g}/\text{m}^3$), February ($90 \mu\text{g}/\text{m}^3$) and December ($72 \mu\text{g}/\text{m}^3$). In 2011, it was February ($98 \mu\text{g}/\text{m}^3$) and November ($92 \mu\text{g}/\text{m}^3$). The highest monthly averages in 2012 were recorded in February ($111 \mu\text{g}/\text{m}^3$) and November ($78 \mu\text{g}/\text{m}^3$). In 2013, the highest monthly averages were recorded in January ($73 \mu\text{g}/\text{m}^3$) and February ($68 \mu\text{g}/\text{m}^3$). In 2014, it was December ($62 \mu\text{g}/\text{m}^3$) and January ($55 \mu\text{g}/\text{m}^3$). In 2015, the highest monthly averages were recorded in February ($64 \mu\text{g}/\text{m}^3$) and October ($50 \mu\text{g}/\text{m}^3$). In 2016, the highest monthly averages of PM_{10} were recorded in January ($79 \mu\text{g}/\text{m}^3$) and in December ($58 \mu\text{g}/\text{m}^3$). The highest average monthly concentrations in 2017 were recorded in January ($101 \mu\text{g}/\text{m}^3$) and February ($88 \mu\text{g}/\text{m}^3$), while in 2018 it was February ($75 \mu\text{g}/\text{m}^3$) and January ($45 \mu\text{g}/\text{m}^3$). In the analyzed period (2010–2018), the annual average permissible concentration of PM_{10} was exceeded. The highest annual average concentration of PM_{10} was recorded in 2011 ($46 \mu\text{g}/\text{m}^3$) and the

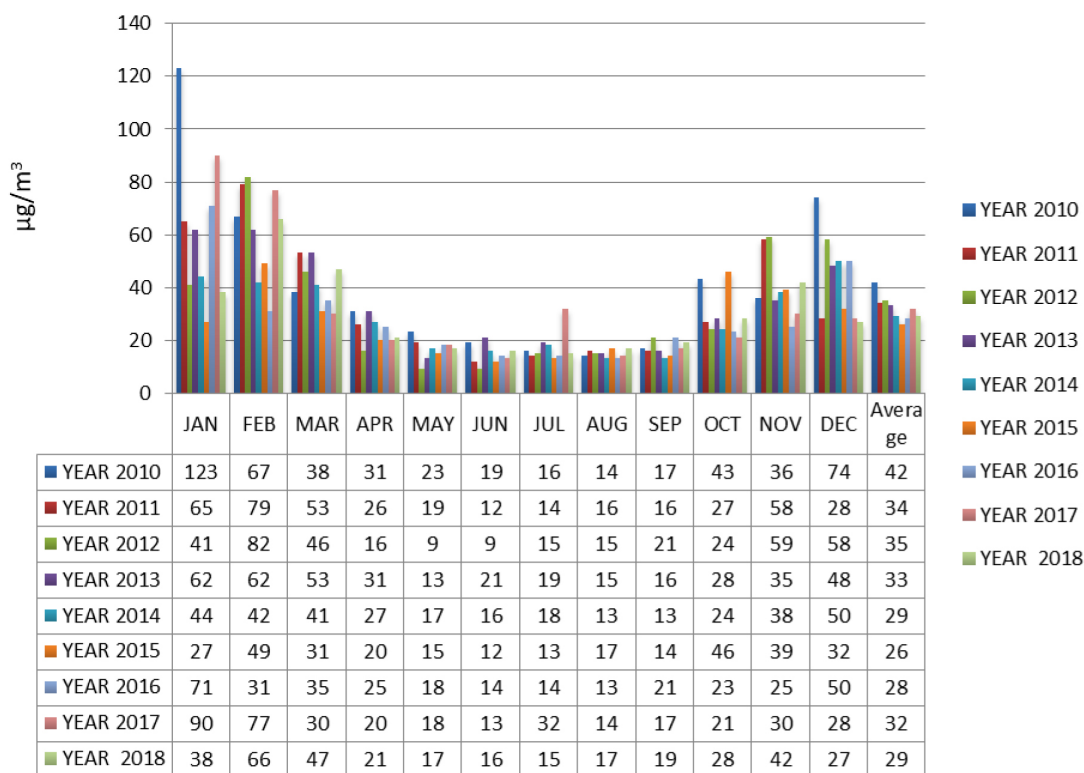


Fig. 2. Average annual concentrations of PM_{2.5} in the years 2010–2018 in Bielsko-Biala

[Based on the data from the Provincial Inspectorate of Environmental Protection in Katowice - Branch Office in Bielsko-Biala]

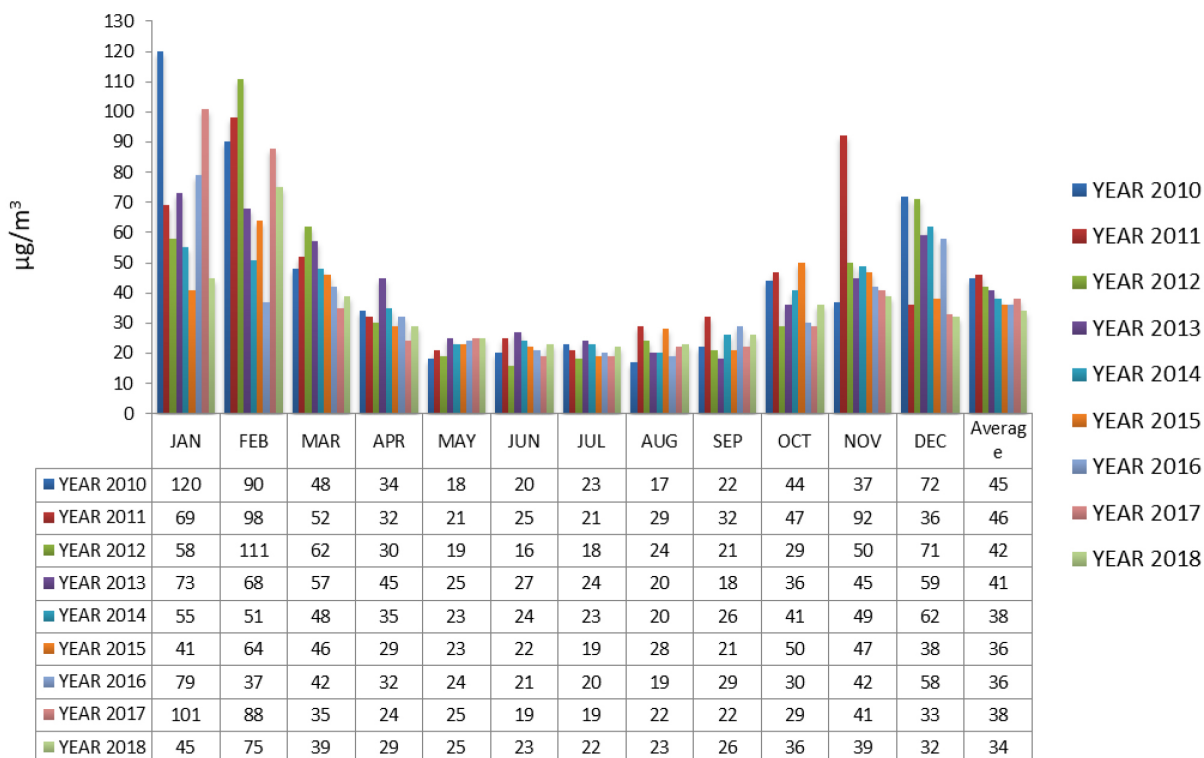


Fig. 3. Average annual concentrations of PM₁₀ in 2010–2018 in Bielsko-Biala

[Based on the data from the Provincial Inspectorate of Environmental Protection in Katowice - Branch Office in Bielsko-Biala]

lowest in 2018 (34 $\mu\text{g}/\text{m}^3$). The highest average monthly concentrations of PM_{10} occur in the autumn and winter period (Fig. 3).

The average annual concentration of benzo (a) pyrene according to the Regulation of the Minister of the Environment of August 24, 2012 on the levels of certain substances in the air should not exceed 1 ng/m^3 in order to protect human health. The highest average monthly concentration of benzo (a) pyrene in 2010 was recorded in January (24.1 ng/m^3), in December (15.6 ng/m^3) and in February (13.6 ng/m^3). In 2011, it was February (18.7 ng/m^3), January (16.6 ng/m^3) and December (12.3 ng/m^3). The highest monthly averages in 2012 were recorded in February (29.2 ng/m^3), January (15.2 ng/m^3) and November (13.1 ng/m^3). In 2013, the highest monthly averages were recorded in December (12.4 ng/m^3), January (12 ng/m^3) and November (8.11 ng/m^3). In 2014, it was December (14.2 ng/m^3), November (12.7 ng/m^3) and January (12.4 ng/m^3). In 2015, the highest monthly averages were recorded in February

(16.8 ng/m^3), March (9.87 ng/m^3) and December (9.67 ng/m^3). In 2016, the highest monthly averages of benzo (a) pyrene were recorded in January (19.51 ng/m^3) and in December (16.55 ng/m^3). The highest average monthly concentration of benzo (a) pyrene in 2017 was recorded in January (35.9 ng/m^3) and in February (19.74 ng/m^3), while in 2018 it was February (15.13 ng/m^3) and January (10.39 ng/m^3). In the analyzed time period (from 2010-2018), the annual average allowable concentration of benzo (a) pyrene was exceeded each year, and its highest concentration was recorded in 2012 (7.7 ng/m^3). Between 2010 and 2018, the average annual concentration of benzo (a) pyrene was between 7.7 ng/m^3 in 2012 and 4.47 ng/m^3 in 2018. The highest monthly averages of benzo (a) pyrene occur in the autumn-winter period (Fig. 4)

The annual average permissible concentration of nitrogen oxides according to the Regulation of the Minister of the Environment of 24th August 2012 on the levels of certain substances

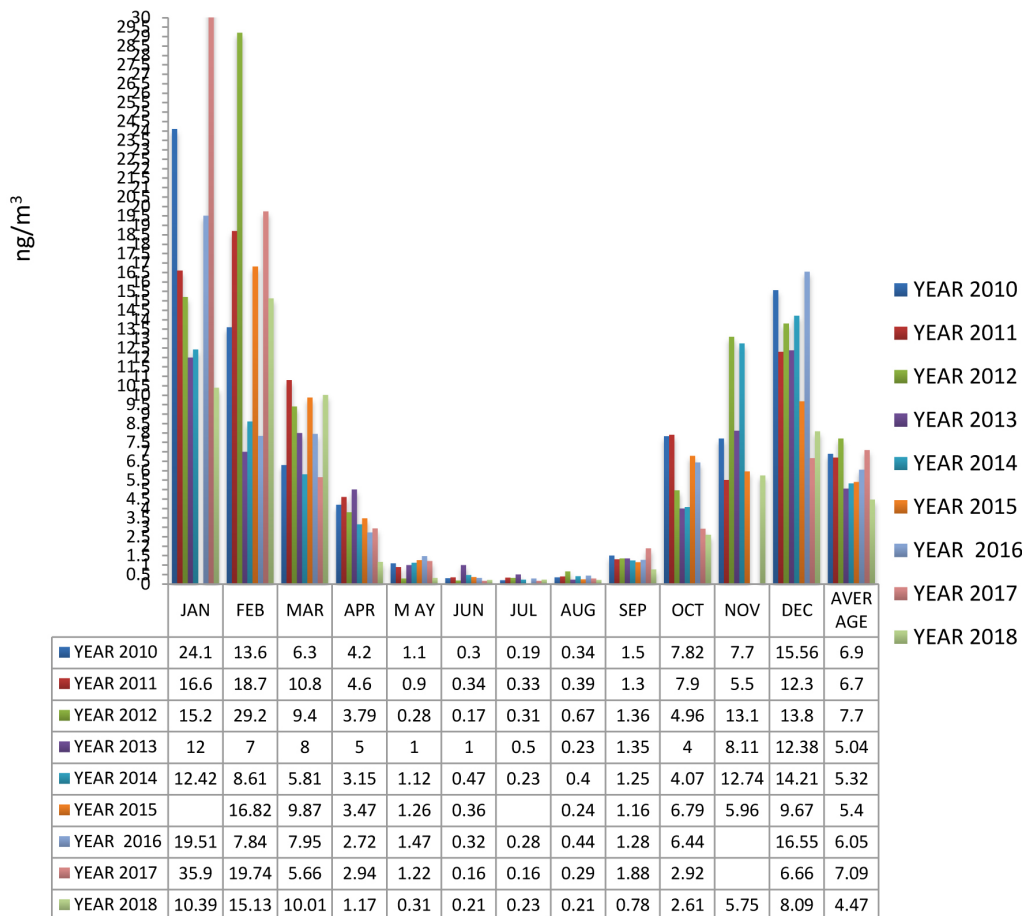


Fig. 4. Average annual concentration of benzo (a) pyrene in 2010–2018 in Bielsko-Biala [Based on the data from the Provincial Inspectorate of Environmental Protection in Katowice - Branch Office in Bielsko-Biala]

in the air should not exceed 30 $\mu\text{g}/\text{m}^3$. The highest average monthly concentrations of nitrogen oxides in 2010 were recorded in January (73 $\mu\text{g}/\text{m}^3$), in December (68 $\mu\text{g}/\text{m}^3$) and in February (43 $\mu\text{g}/\text{m}^3$). In 2011, it was November (51 $\mu\text{g}/\text{m}^3$), January and February (50 $\mu\text{g}/\text{m}^3$). The highest monthly averages in 2012 were recorded in February (53 $\mu\text{g}/\text{m}^3$) and November (50 $\mu\text{g}/\text{m}^3$). In 2013, the highest monthly averages were recorded in January (52 $\mu\text{g}/\text{m}^3$), February (46 $\mu\text{g}/\text{m}^3$) and November (39 $\mu\text{g}/\text{m}^3$). In 2014, it was December (43 $\mu\text{g}/\text{m}^3$), February and October (40 $\mu\text{g}/\text{m}^3$) and January (39 $\mu\text{g}/\text{m}^3$). In 2015, the highest monthly averages were recorded in February (46 $\mu\text{g}/\text{m}^3$), November (42 $\mu\text{g}/\text{m}^3$) and October (41 $\mu\text{g}/\text{m}^3$). The highest annual average was recorded in 2011 (46 $\mu\text{g}/\text{m}^3$) and the lowest in 2015 (35.6 $\mu\text{g}/\text{m}^3$). In 2016, the highest monthly averages were recorded in December (50 $\mu\text{g}/\text{m}^3$) and January (48 $\mu\text{g}/\text{m}^3$). The highest average monthly concentrations of nitrogen oxides in 2017 were recorded in January (64 $\mu\text{g}/\text{m}^3$) and February (5 $\mu\text{g}/\text{m}^3$), while in 2018 it was November (91 $\mu\text{g}/\text{m}^3$) and March (84 $\mu\text{g}/\text{m}^3$). In the analyzed period (from 2010-2018), the average annual permissible

concentration of nitrogen oxides was exceeded many times: in 2010 (34 $\mu\text{g}/\text{m}^3$), in 2011 (32 $\mu\text{g}/\text{m}^3$) and in 2018, (62 $\mu\text{g}/\text{m}^3$). Between 2010 and 2018, the average annual concentration of nitrogen oxides was between 62 $\mu\text{g}/\text{m}^3$ in 2018 and 28 $\mu\text{g}/\text{m}^3$ in 2014-2016. The highest monthly mean of nitrogen oxides occur in the autumn and winter period (Fig. 5).

Weather conditions in Bielsko-Biala between year 2010–2018

The year 2010 was characterized by a high variability of the weather in the Silesian Voivodeship, which was reflected in the course of individual meteorological elements. Significant positive deviations were noted in the case of the total amount of precipitation. The highest annual was recorded in Bielsko-Biala (1482 mm). However, in terms of temperature, it was a cooler year than the long-term norm. The average annual air temperature in Bielsko-Biala was 7.9 degrees Celsius (Table 1), while in May in Bielsko-Biala the highest amount of monthly precipitation was recorded in relation to the norm in the country (above 500%

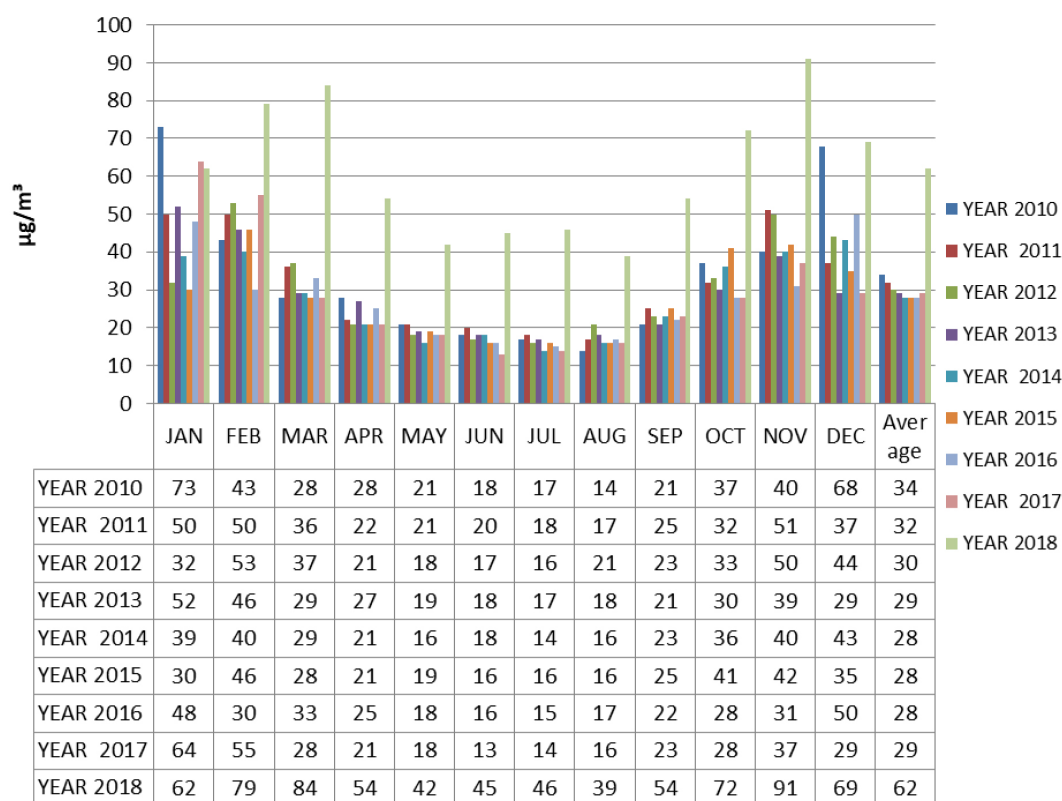


Fig. 5. Average annual concentrations of nitrogen oxides in 2010–2018 in Bielsko-Biala.

[Based on the data from the Provincial Inspectorate of Environmental Protection in Katowice - Branch Office in Bielsko-Biala]

of the norm). The sum of monthly precipitation in May 2010 for Bielsko-Biala exceeded by 265.2 mm the extreme value from the multi-annual period 1951–2009 and it was the highest excess of the extreme for the selected several dozen stations in Poland included in the analysis. The dominant wind direction in Bielsko-Biala was SW wind (21.3%) (State of the environment ... 2011).

In 2011, in Bielsko-Biala, the average annual air temperature was 9.1 degrees Celsius (Table 1). In terms of thermal conditions, 2011 was warmer than the average, and the average annual temperatures were higher than the climatic norm in the entire Silesian Voivodeship (from 0.5 to 2.0 degrees Celsius). The highest positive deviation from the average monthly temperature in January was recorded in Bielsko-Biala (3.1 degrees Celsius). The recorded absolute maximum air temperature of 33.9 degrees Celsius at the station in Bielsko-Biala (August 26, 2011) was the second value in Poland after Torun (34.30 degrees Celsius, August 27, 2011). In the period from October 26 to November 24, 2011, in the Silesian Voivodeship, including Bielsko-Biala, there was a situation with high concentrations of particulate matter pollutants. The PM_{10} concentrations were above the acceptable daily average value of 50 $\mu\text{g}/\text{m}^3$. The minimum air temperature slightly dropped below 0 degrees Celsius, but light breeze, mist formation, inhibitory layers (inversion, isotherm) and lack of precipitation caused that the above-standard concentrations of particulate matter in this region classified this episode as the longest particulate matter episode in the Silesian Voivodeship since 2005 (State of the environment ... 2012). The year 2010 was characterized by a high variability of the weather in the Silesian Voivodeship, which was reflected in the course of individual meteorological elements. Significant positive deviations were noted in the case of the total amount of precipitation. The highest annual rainfall was recorded in Bielsko-Biala (1482 mm). However, in terms of temperature, it was a cooler year than the long-term norm. The average annual air temperature in Bielsko-Biala was 7.9 degrees Celsius (Table 1), while in May in Bielsko-Biala the highest amount of monthly precipitation was recorded in relation to the norm in the country (above 500% of the norm). The sum of monthly precipitation in May 2010 for Bielsko-Biala exceeded by 265.2 mm the extreme value from the multi-annual period 1951–2009 and it was the highest excess of the extreme for the

selected several dozen stations in Poland included in the analysis. The dominant wind direction in Bielsko-Biala was SW wind (21.3%) (State of the environment ... 2011).

In 2012, the average annual air temperature in Bielsko-Biala was 9.2 degrees Celsius (Table 1) and exceeded the average for the multiannual period from 1981–2010. The average annual wind speed and the share of no still wind conditions were close to the long-term average value. The anemological conditions in the course of the month showed seasonal variation, the highest values were recorded in the winter season, and the lowest in the summer season. The highest gust wind speed in the Silesian Voivodeship equal to 22 m/s was recorded (3.07) at the station in Bielsko-Biala. Most days with fog were recorded during the autumn. Episodes of high particulate matter concentrations ($PM > 150 \mu\text{g}/\text{m}^3$) occurred mostly (over 10 days a month) in February, November and December, and were of a regional nature related to the anticyclonal weather (State of the environment ... 2013).

The weather conditions observed in 2013 in the area of the Silesian Voivodeship were the result of natural climate-forming processes typical for this part of Europe, modified with anthropogenic factors. The average annual air temperature in Bielsko-Biala was 8.9 degrees Celsius (Table 1). The absolute maximum of the daily air temperature was recorded on 8th August in Bielsko-Biala, Katowice, Czestochova and Raciborz (36 °C). The highest positive deviation of the average monthly temperature was recorded in Bielsko-Biala in December (3.1 °C). The annual sum of atmospheric precipitation constituted from 90% to 110% of the long-term average value. In the scale of the voivodship, it was very dry, i.e. the monthly sum below 50% of the precipitation norm, mainly in December in Bielsko-Biala. The maximum daily precipitation was 49 mm in Bielsko-Biala (12/06). In January 2013, there were the most days with precipitation, while the fewest in August. The average annual wind speed and the share of no wind conditions were similar to the long-term average value. The highest wind speed in Bielsko-Biala with gusts equal to 25 m/s was recorded in December 25, and the prevailing wind direction was SW wind (20.4%). The observed episodes of increasing PM_{10} were mostly regional in nature and resulted from the occurrence of anticyclonal weather, the occurrence of temperature inversion and isotherm, and periods

without precipitation. The most unfavorable day due to poor air quality was 24th January, 2013, when the daily concentration of $PM_{10} > 150 \mu\text{g}/\text{m}^3$ was exceeded at almost all monitoring stations of the Provincial Inspectorate of Environmental Protection in Katowice, and also daily permissible average concentration of sulfur dioxide was exceeded at the stations in Bielsko-Biala and Zywiec (State of the environment ... 2014).

The average annual air temperature in Bielsko-Biala in 2014 was 10.2 degrees Celsius, and the maximum daily air temperature was recorded on 10th June (31.3 degrees Celsius) (Table 1). Negative air temperature deviations appeared in the entire Silesian Voivodeship in May, June and August. The seasonal distribution of annual rainfall throughout the entire Silesia Province was highly diversified (very dry winter, very humid spring, humid summer, normal autumn). May was an extremely wet month in Silesian Foothill (Bielsko-Biala). The maximum daily precipitation occurred in Bielsko-Biala on 15th May (63.3 mm). The average annual wind speed at all stations in the Silesian Voivodeship was lower than the long-term value. The strongest wind gusts in Bielsko-Biala were recorded on 12th December (26 m/s). Quite mild meteorologically cool half of the year resulted in relatively good air quality compared to previous years. The most unfavorable period due to the persistently high concentrations of PM_{10} was the first decade of December (State of the environment ... 2015).

The year 2015 was characterized by high variability of the weather in the Silesian Voivodeship. The average annual temperature in Bielsko-Biala was 10.5 degrees Celsius, and the wind speed was 2.7 m/s. In terms of the rainfall conditions, 2015 was a dry year. The maximum daily precipitation occurred in Bielsko-Biala (30.9 mm) on May 26.

This year was characterized by high temperature, relatively good ventilation conditions, low rainfall totals and high insolation. Therefore, this resulted in few episodes of high particulate matter concentrations (State of the environment ... 2016).

2016 was another year in which the average annual air temperature was higher than the norm, and it was a cooler year than in the previous years in the Silesian Voivodeship. This area, despite the average annual air temperature exceeding the long-term value, was not characterized by extreme air temperature values. This resulted in a much better air quality conditions in terms of particulate matter than in recent years. The average annual wind speed in Bielsko-Biala was 2.5 m/s and the temperature was 9.9 degrees Celsius (Table 1). The maximum daily precipitation was recorded in Bielsko-Biala on 25th July (46.1 mm). As in 2015, in 2016, there were few episodes of high dust concentrations in the Silesian Voivodeship (State of the environment ... 2017).

The meteorological conditions of the Silesian Voivodeship in 2017 differed from the average long-term course. Long-term low air temperatures in January throughout the entire Silesian Voivodeship, and especially the cold wave from 4 to 17 January, caused a deterioration of the air quality, especially in terms of particulate matter (PM_{10} and $PM_{2.5}$). Although in the annual balance, the ventilation conditions in Bielsko-Biala were not the worst (5.6% of silence, which means that their share was lower by about 50% than in the long-term period), in the coldest month of the year – January – the share of silence was higher by 50% than in a multiannual time in the same period (State of the environment, 2018).

In 2018, the average annual air temperature in Bielsko-Biala was 10.2 degrees Celsius, and the wind speed was 2.9 m/s (Table 1). This year was

Table 1. Selected meteorological elements in Bielsko-Biala between 2010–2018

Meteorological elements	2010	2011	2012	2013	2014	2015	2016	2017	2018
Average annual temperature	7.9	9.1	9.2	8.9	10.2	10.5	9.9	9.3	10.2
Temperature max.	32.7	33.9	34.1	36.4	31.3	34.5	33.9	33.2	33.8
Temperature min.	- 21.1	- 13.1	- 23.2	- 13.8	- 14.6	- 11.6	-16.1	- 21.7	- 18.1
Average wind speed (m/s)	3.1	2.8	2.9	2.8	2.6	2.7	2.5	3.1	2.9
Share of silence (%)	3.7	3.8	3.7	3.9	2.5	2.7	2.9	2.6	2.7
Sum of atmospheric precipitation (mm)	1482	879	846	954	1069	768	1076	1116	907
Number of days with fog	80	43	39	55	56	34	56	49	39

Source: Based on the data from the Provincial Inspectorate of Environmental Protection in Katowice – Branch Office in Bielsko-Biala.

warmer than the last years (with the exception of February and March which were much cooler) and with less rainfall in the first quarter and summer season, as well as lower wind speed in the first quarter. This had an impact on the air quality, i.e. the occurrence of particulate matter episodes in the first quarter of the year, as well as a greater number of days with exceeded concentrations of monitored pollutants in the winter season and a greater number of days when the level of tropospheric ozone was exceeded in the summer season (State of the environment ... 2019).

The occurrence of selected diseases and hospitalizations among children and adolescents in Bielsko-Biala between 2010–2018

Over the period of time studied, the incidence rate of bronchial asthma in Bielsko Biala was between 32.4/10,000 in 2013 and 91/10,000 in 2014. The highest incidence rate of food allergies was 34.6/10,000 in 2010 and the lowest 17.2/10,000 in 2011. The incidence rate of skin allergies was variable. From 2010 (31.7/10,000) to 2012 to 2013 – (20.4/10,000), it exhibited a

downward tendency. From 2014 (16.6/10,000) to 2018 (38.2/10,000), the incidence of food allergies was increasing. The incidence rate of hypertensive disease among children and adolescents in Bielsko Biala was increasing from 2010 (3.6/10,000) to 2018 (6.6/10,000). In Bielsko-Biala, from 2010 (2.1/10,000) to 2018 (7.2/10,000), the incidence rate of cardiovascular development defects is increasing. Over the studied period, the cancer incidence rate in Bielsko Biala is also increasing and amounts to 3.1/10,000 in 2010 and 8.4/10,000 in 2018 (Fig. 6).

Over the studied period, the cancer incidence rate in Bielsko Biala was between 20.1/10,000 in 2017 and 35.9/10,000 in 2013. In Bielsko-Biala, starting from 2010 (17.6/10,000) till 2014 (20.4/10,000), the hospitalization rate was increasing. Over the analyzed period, the rate of hospitalization due to respiratory diseases (without taking into account bronchial asthma) in Bielsko Biala was increasing from 2010 to 2014 and amounted to 213.4/10,000 and 291.8/10,000. The lowest (189.6/10,000) hospitalization rate (without bronchial asthma) was recorded in 2017. From 2010 (1.4/10,000) to 2018 (7.8/10,000), the rate of hospitalization for bronchial asthma among children

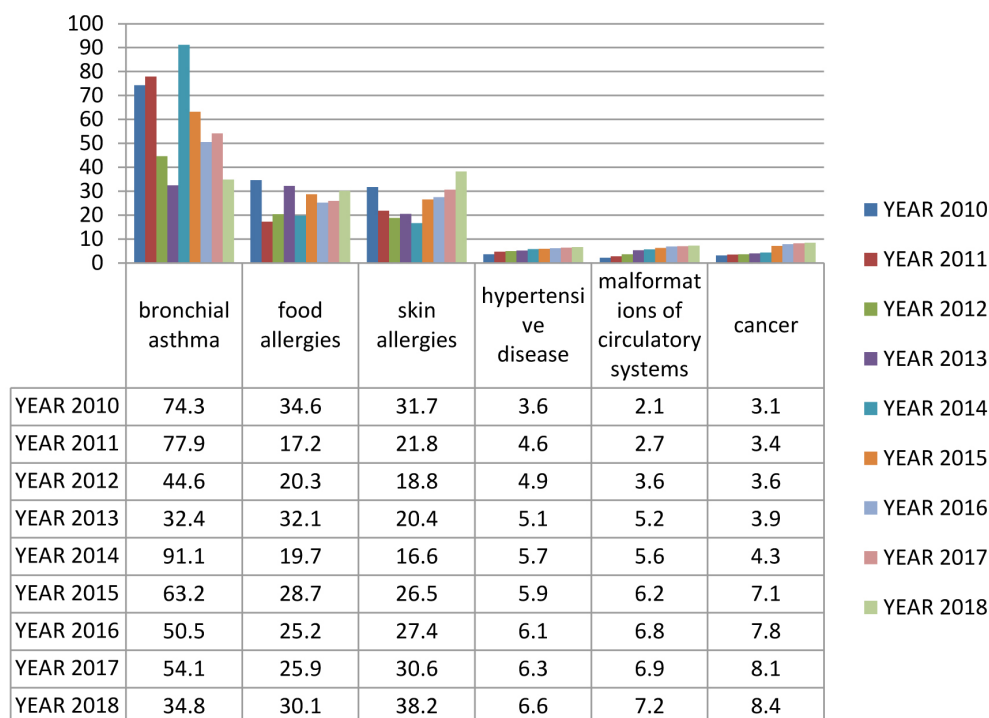


Fig. 6. Data on the status of bronchial asthma, food and skin allergies, hypertension, cardiovascular malformations and neoplastic disease in children and adolescents in Bielsko-Biala aged 0–19 under the care of GP between 2010–2018 – indicators per 10,000 thousand (people diagnosed with the disease for the first time in the reporting period)

[Based on the Health Department of the Silesian Voivodeship Office in Katowice]

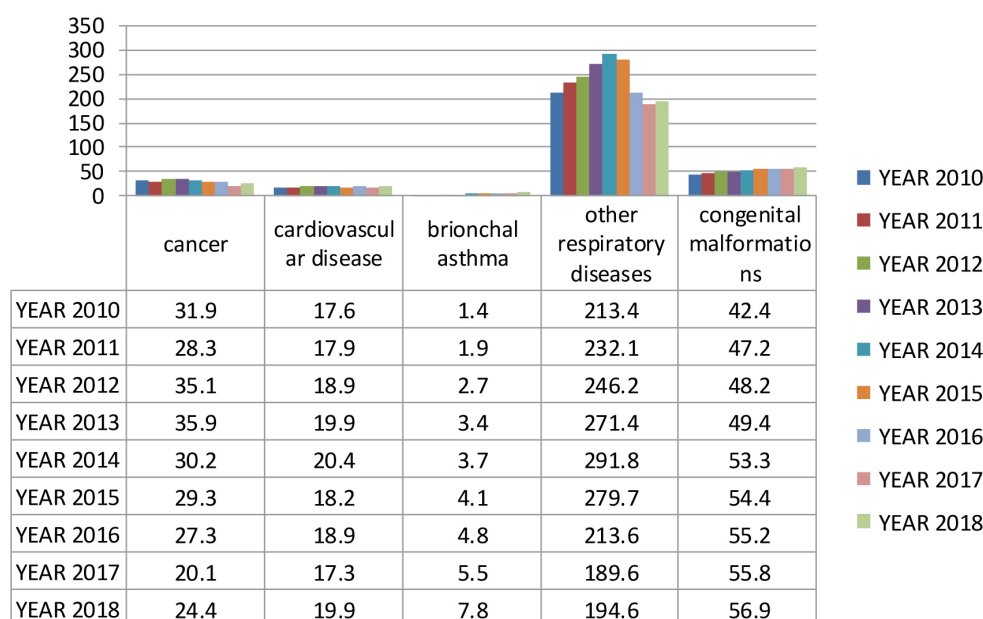


Fig. 7. Data on hospitalization of children and adolescents from 0–19 years of age in Bielsko-Biala due to the occurrence of neoplastic diseases, cardiovascular and respiratory diseases, bronchial asthma and congenital malformations between 2010–2018 – indicators per 10,000 thousand
[Based on the Health Department of the Silesian Voivodeship Office in Katowice]

and adolescents was increasing. Over the analyzed period, the rate of hospitalization due to congenital malformations in Bielsko Biala was increasing from 2010 to 2018 and amounted to 42.4/10,000 and 56.9/10,000, respectively (Fig. 7).

RESULTS AND CONCLUSIONS

The analysis of the average annual concentrations of air pollutants in Bielsko-Biala in the years 2010-2018 in connection with meteorological conditions showed that the pollutants exhibit seasonal and annual variability. The average annual concentration of benzo (a) pyrene was between 7.7 ng/m³ in 2012 and 4.47 ng/m³ in 2018. In each analyzed year, the permissible average annual concentration of benzo (a) pyrene was exceeded (Fig. 4). Moreover, in the case of annual average concentrations of nitrogen oxides, the permissible norms were exceeded many times and they were between 28 µg/m³ in 2014-2016 and 62 µg/m³ in 2018 (Fig. 5). When analyzing the annual average concentrations of PM_{2.5}, it can be noticed that in the discussed period of time, their permissible value was exceeded in each year and it was between 26 µg/m³ in 2015 and 42 µg/m³ in 2010 (Fig. 2) and the average annual

concentration of PM₁₀ particulate matter was between 34 µg/m³ in 2018 and 46 µg/m³ in 2011 (Fig. 3).

It should be noted that in the winter and summer seasons, there is a negative correlation between NOx and particulate matter and the temperature, which means that as the temperature drops, the levels of the above-mentioned air pollutants increase, due to fuel combustion for heating purposes.

Atmospheric air and the pollutants are elements of the environment that have a direct and constant impact on the human body, including children, because their respiratory system is not yet fully developed and the number of breaths per minute is higher than in adults. By breathing more frequently, children take more toxic substances from the air into their respiratory system. Due to the undeveloped immune system, children are also more susceptible to the negative health effects from the pollutants entering the body, which results in disease and hospitalization due to the respiratory and blood system diseases, skin and food allergies, and cancer. The smaller the child, the more harmful effect the pollutants have on the body. Even during pregnancy, a woman inhaling contaminated air may expose the fetus to various types of birth defects (Biela-Mazur et al., 2017).

In the discussed period in Bielsko-Biala there was an increasing number of cases of hypertensive disease, developmental defects of the circulatory system and cancer among children and adolescents from 2010 to 2018, where the rate was 3.6/10,000, 2.6/10 000 and 3.1/10,000 in 2010 and 6.6/10,000, 7.2/10,000 and 8.4/10,000 in 2018. In the case of the incidence of bronchial asthma, skin and food allergies, this indicator has variable nature (Fig. 6).

Hospitalization of children and adolescents living in the city of Bielsko-Biala in 2010–2018 due to bronchial asthma and congenital malformations was increasing from 2010 to 2018 and amounted to 1.4/10,000 and 42.4/10,000 in 2010 and 7.8/10,000 and 56.9/10,000 in 2018. In the case of hospitalization for cardiovascular diseases, cancer and respiratory diseases (except for bronchial asthma), this indicator is variable (Fig. 7).

It is confirmed by a numerous international studies that by breathing polluted air in which there are elevated concentrations of particulate matter and gases, the human body is exposed to the incidence of mainly respiratory diseases and to more frequent hospitalizations. The observation of a group of 146 397 small children from the state of Utah combined with the results of air monitoring (where the average annual concentration of benzo (a) pyrene and $PM_{2.5}$ and PM_{10} were exceeded multiple times) in the years 1999–2016, showed that just a week after the increase in $PM_{2.5}$ concentration by $10 \mu\text{g}/\text{m}^3$ the reporting rate increased due to acute respiratory infections, which increased up to three weeks and lasted up to 28 days after the increase in concentration. The increase in reporting due to the incidence of respiratory diseases was 32% for children between 2 and 18 years of age (Horne et al. 2018).

An analysis of hospitalizations for respiratory diseases (both infectious and allergic) in children and adolescents up to 18 years of age in Busan (Korea) showed that the adverse effect of exposure to particulate matter on the number of hospitalizations was intensified in the presence of low air humidity. The analysis of the number of hospitalizations for respiratory reasons (preceded by an increase in air pollutant concentrations) in the years 2007–2015 showed their increase in periods of increased pollutant concentrations and temperature rise, as well as of reduced relative air humidity. $PM_{2.5}$ had a greater impact than PM_{10} , with the greatest consequences reported in the extreme age groups. In the group of children up to 15 years of

age, the risk of hospitalization due to asthma exacerbation was 7.69 times higher than in the group aged 16–64 (Ierodiakonou et al. 2016).

Many studies performed in various parts of the world confirm that the children suffering from asthma are exposed to particulate matter up to $10 \mu\text{m}$ in diameter (PM_{10}) and a more dynamic increase in the frequency and intensity of respiratory symptoms (coughing, wheezing, dyspnoea) and exacerbations of the disease is observed than in healthy children. The children with asthma are diagnosed with exacerbation of symptoms and an increased response to the allergen during the days with increased pollutant concentrations. As a result of exposure to dust, the use of drugs is increasing and also the use of medical assistance - including hospitalization for respiratory reasons. The greater risk appears when the exposure is additive with the viral infection period or is related to physical effort (deposition-promoting hyperventilation). Patients with insufficiently controlled asthma and persistent bronchial hyperresponsiveness are threatened by exacerbation of symptoms (Bowatte et al. 2017).

The main cause of poor air quality in Polish cities is the so-called low emission, i.e. emission from domestic heating systems fired with solid fuels and car traffic, in particular old vehicles without catalytic converters. In addition, in Poland, relatively frequent inversion phenomena occurs in winter (e.g. after the period of frosts and eastern circulation, the influx of warmer Polar Sea masses from the west, periods of high-pressure weather, lack of cloud cover and weak wind). All of this creates perfect conditions for smog, which occurs during the high-pressure weather and negative air temperatures. During the winter months, it is often associated with cloudless weather, which results in significant night temperature drops and the formation of inversion. What is more, at low temperatures, the demand for heat increases, which causes greater emissions of pollutants from individual heating systems. As a result, the concentration of particulate matter and gases in the ground-level part of the atmosphere heavily exceeds the permissible levels, which directly affects the human health (Wielgosinski and Zarzycki 2018).

Therefore, the problem of polluted air can be considered as one of the most important problems of our civilization. The air quality condition in our country is poor and, therefore, broadly understood corrective actions are necessary, which may include:

- liquidation of coal boilers and their replacement with environmentally friendly energy sources (e.g. subsidy of 100% return on investment costs),
- introducing communication solutions that will lead to a reduction in linear emissions,
- free public transport,
- restriction of entry to city center for the cars over 3.5 tons,
- reduction of emissions from individual home heating systems,
- elimination of old boilers (individual coal-fired boilers) and replacing them with connection to heating networks (where possible), gas, oil or electric heating or the use of alternative methods of obtaining energy in the form of heat pumps or solar collectors, which are complementary sources of thermal energy,
- ecological education,
- development of the municipal heating network, modernization of the central heating plant and liquidation of community and local coal-fired boiler houses,
- thermal insulation of facilities, replacement of windows, external doors and lighting with energy-saving ones,
- promoting road transport based on the vehicles powered by LPG,
- reconstruction of ventilation and air conditioning systems with the use of weather automation, stabilizing the temperature inside the building regardless of external conditions and building management systems,
- limiting car traffic in city centers through the use of appropriate solutions, such as: construction of lines for urban rail transport, construction of lanes intended only for buses, construction of fast battery charging stations for electric vehicles, reserving some parking spaces for hybrid vehicles, improvement of the effective use of the existing infrastructure by introducing solutions to improve the traffic light system, improving road infrastructure by building ring roads or extending bicycle paths.

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