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Analysis of selected air pollutants in 2015 in the city of Bielsko-Biała (Poland)

Abstract: The aim of the work is to analyze and assess the degree of air pollution in the city of Bielsko-Biała in 2015 and to indicate the potential negative impact of the elements and chemical compounds present in the air on the human body. The study uses data from the Provincial Inspectorate of Environmental Protection in Katowice, the Bielsko-Biała Office. The analysis covers the major air pollutants occurring in urbanized areas, which include: sulfur dioxide, benzene, benzo(a)pyrene, as well as particulate matter PM10 and particulate matter PM2.5. The analysis of air quality conducted for this study revealed that in 2015 in Bielsko-Biała particulate matter PM2.5 was exceeded by 1.25 μm and benzo(a)pyrene by 4.61 ng.

Keywords: air pollution, lead, sulfur dioxide, cadmium, benzo(a)pyrene, particulate matter PM10, particulate matter PM2.5.

1. Introduction

Atmospheric pollution is the cause of many diseases, including those afflicting the respiratory and circulatory systems. Children and the elderly, among others, due to the reduced immunity are most exposed to the negative impact of the above forms of pollution and the occurrence of related diseases (Krajowy Program..., 2015). It is estimated that in Poland every year 45,000 deaths are caused by air pollution. On the global scale, this number is seven million. A higher percentage of new cases also causes additional medical costs (Wojewódzki Fundusz..., 2015; Krajowy Program ..., 2015).

Sources of heavy metal emissions are mainly industrial plants, coal combustion in household furnaces, power plants, combined heat and power plants, as well as transport (Kalinowska et al., 2013).

In 2015, in the province of Śląskie there were 328 businesses considered particularly harmful to air purity (Stan środowiska ..., 2016). The main gas pollutant in Śląskie (including Bielsko-Biała), issued by particularly harmful factories, was carbon dioxide, which accounted for 98 percent of the total gas emissions in the area. Methane (63.8%), carbon monoxide (20.9%) and sulfur dioxide (8.2%) also had a significant share in the emission of gaseous pollutants.

In the city of Bielsko-Biała and the entire province of Śląskie, the main sources of air pollution are anthropogenic surface emissions, either from individual points, or linear ones (related to road transport).

2. Aim and methods

The aim of this study is to analyze and assess the level of air pollution in Bielsko-Biała in 2015. Two stations located in the city monitor atmospheric air quality. A manual and auto-

matic measurement station is situated in Kossak-Szczuckiej Street (south-western part of the city; station code: SlBielbBiel_kossa). This location is characterized by low intensity of traffic, near residential streets and single-family houses. There are no industrial areas here, but there is a busy beltway (Aleja Andersa). The second air monitoring station is located in Sternicza St. (station code: SlBielbBiel_stern), which has been conducting passive measurements for benzene since 2011 and manual measurements for particulate matter PM 2.5 since 2010 (www.gios.gov.pl).

The area of the city is 124.51 square kilometers. In 2014 its population was 173,013 inhabitants, and in 2015 it fell to 172,591 (www.katowice.stat.gov.pl). The city of Bielsko-Biała is located in the southern part of Śląskie, on the border of Śląsk Cieszyński and Małopolska. However, the greater part of Bielsko-Biała lies in Pogórze Śląskie, which is part of the macroregion of Pogórze Zachodniobeskidzkie. The climate of the city is diverse, because its area is located in two climatic regions – Podkarpackie (foothills) and Karpackie (mountains). This climate is characterized by highly irregular weather conditions and large fluctuations in temperature throughout the year (Barański, 2007).

Bielsko-Biała is the main city of Beskidzki Okręg Przemysłowy, one of Poland's eleven industrial districts. The main areas of industrial production developed in the district are machines, textiles, metallurgy, and food. Numerous industrial plants are located mainly in the districts of Wapienica and Komorowice. The largest industrial plants include Fiat Auto Poland, Fiat-GM Powertrain Poland, Nemak Poland, Eaton Automotive Systems, Alder Poland, Magneti Marelli, Techmex, Hutchinson Poland and Bielmar, a manufacturer of edible fats and oils (Haczek, 2014).

Bielsko-Biała is one of the most polluted cities in Poland, and in Europe. The biggest pollutants come from local central heating used in households and small and medium-sized enterprises (SMEs) burning coal for heating and technological purposes. Other major sources of air pollution include automotive transport and the energy industry, mainly low-stack emissions from local heating systems. The current organization of vehicle traffic in Bielsko-Biała is unfavorable, as it promotes the formation of photochemical smog. Also of importance are emissions originating from the energy industry of Górnośląski Obszar Przemysłowy, Rybnicki Okręg Węglowy and Zagłębie Ostrawsko-Karwińskie.

The Bielsko-Biała Office of the Provincial Inspectorate for Environmental Protection in Katowice monitors the quality of air in Bielsko-Biała. Measurements are taken manually, which involves the use of suction devices into which air is aspirated. Obtaining the results in this way takes approximately three weeks (www.gios.gov.pl). The automatic method, in turn, allows current assessment of the state of air pollution.

Based on the obtained data, concentrations of the following pollutants were analyzed: sulfur dioxide, lead, cadmium, benzo(a)pyrene, as well as particulate matter – PM10 and PM2.5. Concentrations of these pollutants were referred to the national standards. Their impact on human health was also determined.

Average annual concentrations were obtained on the basis of the number of measurements taken, whereupon the percentage of valid data was calculated. The results were as follows:

- benzo(a)pyrene: number of valid measurements – 327; percentage (%) of valid data – 98,
- sulfur dioxide; number of valid measurements – 8562; percentage (%) of valid data – 98,
- PM10: number of valid measurements – 332; percentage (%) of valid data – 91,
- PM2.5: number of valid measurements – 356 percentage (%) of the valid data – 98,
- cadmium contained in particulate matter PM10: number of valid measurements – 327; percentage (%) of valid data – 90,
- lead contained in particulate matter PM10; number of valid measurements – 327; percentage (%) of valid data – 90 (www.katowice.pios.gov.pl).

The manual measurements of benzo(a) pyrene, particulate matter PM2.5, particulate matter PM10, cadmium and lead are taken using a TECORA device. Automatic measurements of sulfur dioxide, in turn, is taken with the use of an Environment AF22M device.

3. Results and analysis

The average annual admissible concentration of lead, in accordance with the Regulation of the Minister of the Environment of 24 August 2012 on levels of certain substances in the air (Rozporządzenie Ministra Środowiska z dnia 24 sierpnia 2012 roku, item 1031), – for reasons of protection of human health – should not exceed 0.5 μg·m^{-3}. In Bielsko-Biała, in the period under study, it amounted to 0.023 μg·m^{-3} (Fig.1). The highest concentration was recorded in February (0.085 μg·m^{-3}) and in May and October (0.05 μg·m^{-3}). The concentration of lead in Bielsko-Biała in 2015, was lower by 45% compared to the level in 2010.

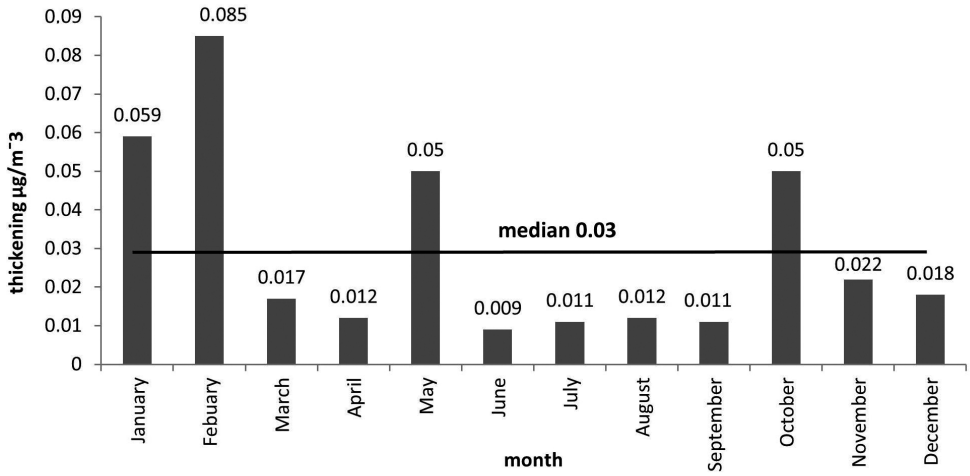

Figure 1. Lead concentration in individual months of 2015 in the city of Bielsko-Biała (the author's own study, based the data provided in www.gios.gov.pl)

Chronic lead poisoning has long been a very serious health problem (Strugała-Stawik et al., 2010). Lead is one of the most dangerous poisons in Poland (Dobrakowski et al., 2013). Exposure of a child to lead early in life has an impact on the child's learning ability, social behavior and behavioral disorders, contributing among others to the development of attention deficit hyperactivity disorder (ADHD) (Bellinger, 2011). The affected child tends to be aggressive, has learning, reading and writing difficulties, and shows emotional instability (Krzywy et al., 2010; Dobrakowski et al., 2013). It is assumed that long-term exposure to lead and other heavy metals may cause an increase in blood pressure (Poręba et al., 2010; Skoczyńska, 2008), especially in middle-aged and elderly people (Seńczuk-Przybyłowska et al., 2011). Lead and other heavy metals are not biodegradable, which causes them to accumulate in the food chains of various ecosystems (Pietrzak-Fiećko et al., 2013).

Lead and other heavy metals have a tendency to accumulate in the human body, in particular in the kidneys, which are very sensitive to their effects (Winiarska-Mieczana et al., 2011; Wilk et al., 2013). Lead is found in all organs and tissues of the body and, consequently, pass through the blood-brain barrier and the placenta. Passing through the placenta into fetal circulation, this metal accumulates in organs and tissues (Krzywy et al., 2010). A child exposed to lead may later develop anemia, brain damage, abdominal pain, and muscle weakness (Seńczuk-Przybyłowska et al., 2011). Children are more exposed to lead poisoning than adults (Seńczuk-Przybyłowska et al., 2011; Kapka et al., 2009; Szkup-Jabłońska, 2011). Lead infections may occur during intrauterine periods when the metal is present in the mother's body. Newborns, and then infants, ingest it with their mother's milk or other foods, water, inhaled air, and even with contaminated sand on a playground or may put objects covered with lead into their mouth (Szkup-Jabłońska, 2011). Anthropogenic sources of lead include mainly the mining industry, processing of non-ferrous metals, the automotive industry, combustion in the municipal sector, as well as road transport.

The average annual admissible concentration of cadmium under the Regulation of the Minister of the Environment of 24 August 2012 on the levels of certain substances in the air (Rozporządzenie Ministra Środowiska z dnia 24 sierpnia 2012 roku, item 1031) – for reasons related to protection of human health – should not exceed to 5 μg·m^{-3}. In Bielsko-Biała, the average annual concentration in 2015 was 0.55 μg·m^{-3} (Fig. 2). The highest concentration was recorded in February (2.03 μg·m^{-3}). The main routes of exposure to cadmium are contaminated food, inhaled air and cigarette smoke (Wilk et al., 2013). It is estimated that after burning one cigarette, which contains about 1-2 μg of carcinogenic cadmium, 0.1-0.2 μg of cadmium gets into the lungs. When a person smokes for about 20 years, almost 15 mg of this element are ingested (Wilk et al., 2013). This metal accumulates in the body, especially in the bones and kidneys (Seńczuk-Przybyłowska et al., 2011, Winiarska-Mieczana et al., 2011). Considering food contamination, the largest amount of cadmium is found in leafy vegetables and cereal grains grown in industrialized areas (Wilk et al., 2013). Cadmium poisoning leads to respiratory failure, impaired renal function and cancer. In the chromosomes of mammalian cells, it causes various types of changes in the genetic material. Ingestion of small amounts of this metal may also cause adverse effects in the function of the liver, testes and the immune system. Cadmium can also cause emphysema. It has the ability to penetrate the blood-brain barrier, which is why it is believed to be the cause of neurological disorders in the form of hyperactivity and learning difficulties in children. In addition, it is said to have nephrotoxic effects, damaging the renal tubules. Industrial plants producing metal alloys, zinc metallurgy, steel galvanization, welding and battery production pose the greatest threat. Cadmium, as a heavy metal, is characterized by a long biological half-life – 10 to 30 years. It is toxic even in small amounts. Cadmium pollution may also come from agricultural sources (Seńczuk-Przybyłowska et al., 2011).

The average annual concentration of sulfur dioxide, under the Regulation of the Minister of the Environment of 24 August 2012 on levels of certain substances in the air (Rozporządzenie Ministra Środowiska z dnia 24 sierpnia 2012 roku, item 1031) – for reasons related to protection of plants – should not exceed 20 μg·m^{-3}. Its average annual concentration in Bielsko-Biała in the period in question was 9.8 μg·m^{-3}; the highest concentration was recorded in February – 21.1 μg·m^{-3} (Fig. 3).

Sulfur dioxide is a colorless water-soluble gas with a stifling odor. It enters the body through the respiratory system and through the skin. It is used as a disinfectant and fungicide, in the textile and refrigeration industry and as a preservative. The reason for its occurrence in the environment, in addition to natural causes,

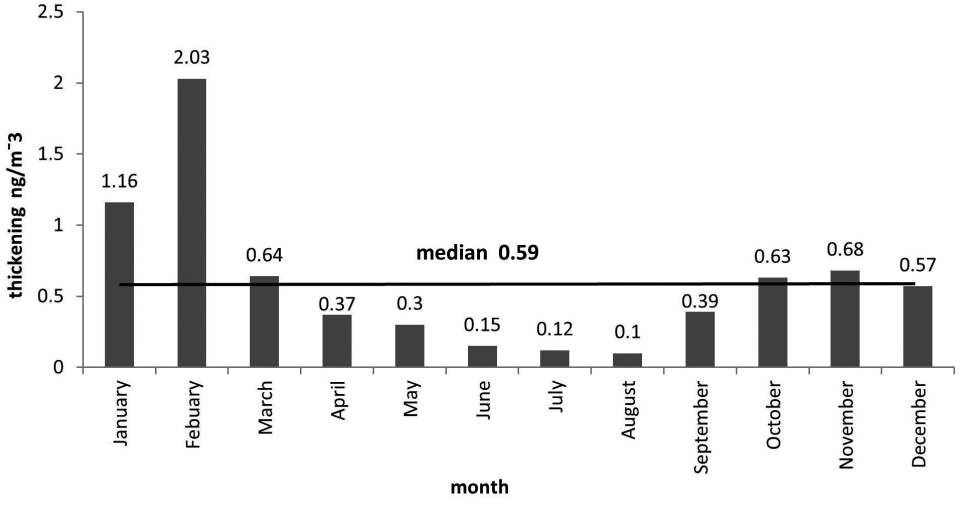

Figure 2. Concentration of cadmium in individual months of 2015 in the city of Bielsko-Biała (Source: the author's own study, based on VIEP data)

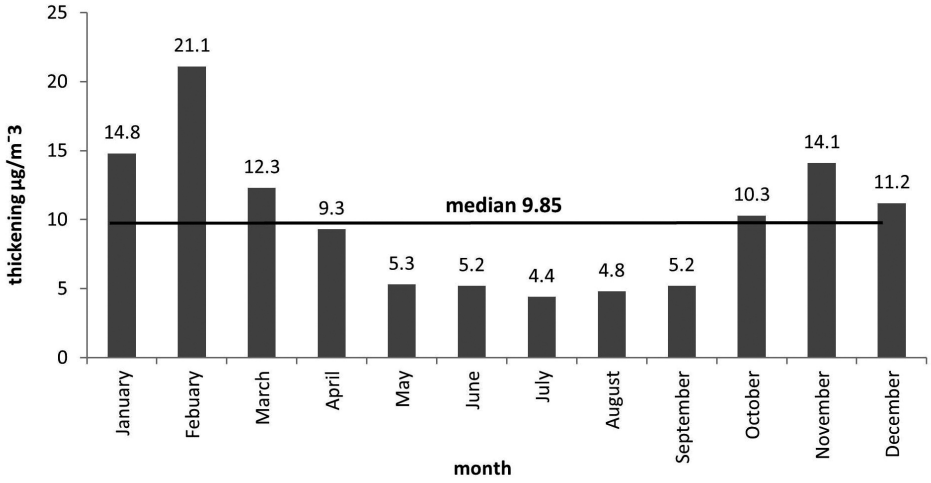

Figure 3. Concentration of sulfur dioxide in individual months of 2015 in the city of Bielsko-Biała (the author's own study, based the data provided in www.gios.gov.pl)

is combustion of coal, vulcanization, and smelting of cast iron. In humans, sulfur dioxide contributes to bronchial asthma and hypertension, and it irritates the mucous membranes of the eyes (Kroczyńska-Bednarek, 2008).

The average annual concentration of particular matter PM10, under the Regulation of the Minister of the Environment of 24 August 2012 on the levels of certain substances in the air – for reasons of protecting human health and plants – should exceed 40 $\mu g \cdot m^{-3}$. In 2015, in Bielsko-Biała, its average annual concentration was 35µg (Fig. 4) and in comparison to 2014 it decreased by 6 percent. In 2015, in 62 cases, the level of 24-hour particular matter PM10 was exceeded. The highest concentrations were recorded, among others, on November 3 and 5 (146 $\mu g \cdot m^{-3}$), December 31 (145 $\mu g \cdot m^{-3}$), December 8 (127 $\mu g \cdot m^{-3}$), October 31 and November 6 ($\mu g \cdot m^{-3}$) and February 14 (124 $\mu g \cdot m^{-3}$).

The average annual admissible concentration of particular matter PM2.5, under the Regulation of the Minister of the Environment of 24 August 2012 on the levels of certain substances in the air (Rozporządzenie Ministra Środowiska z dnia 24 sierpnia 2012 roku, item 1031) – for reasons related to protection of human health – should not exceed 25 $\mu g \cdot m^{-3}$. In 2015, in Bielsko-Biała, its average annual con-

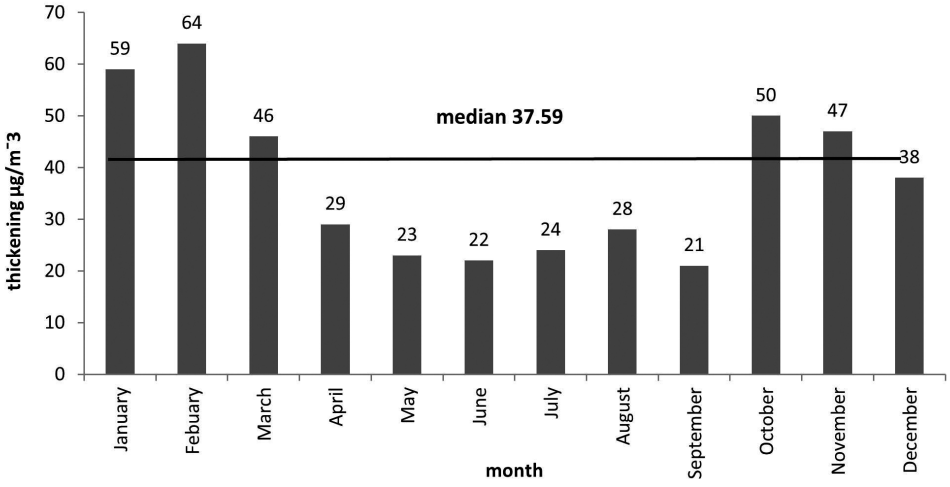

Figure 4. Concentration of particular matter PM10 in individual months of 2015 in the city of Bielsko-Biała (the author's own study, based the data provided in www.gios.gov.pl)

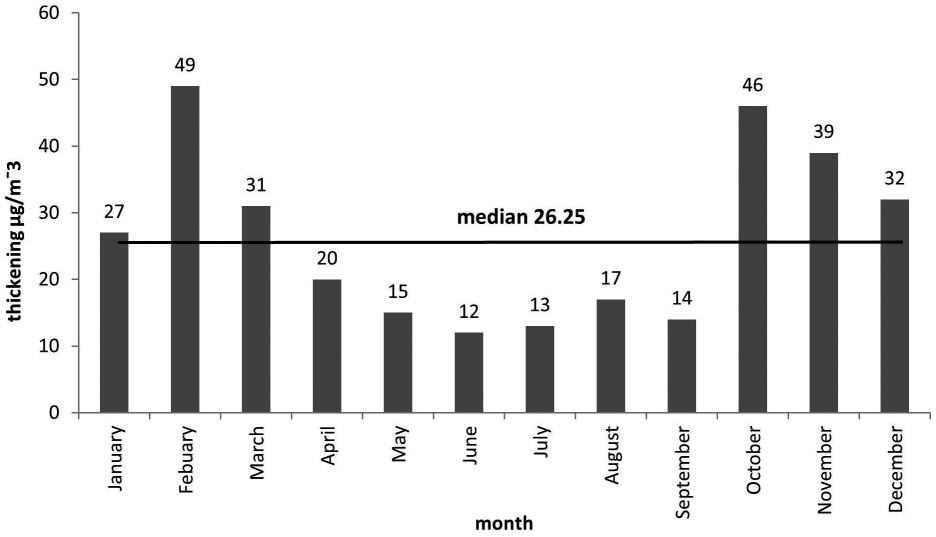

Figure 5. Concentration of particular matter PM2.5 in individual months of 2015 in the city of Bielsko-Biała (the author's own study, based the data provided in www.gios.gov.pl)

centration was 26 $\mu g \cdot m^{-3}$ (Fig. 5). The highest average was recorded in February (49 $\mu g \cdot m^{-3}$) and in October (46 $\mu g \cdot m^{-3}$).

Particular matter PM2.5 and PM10 are particles with a diameter of 2.5 and 10 µm. Their main sources are road transport, emissions from household furnaces, the heating industry and the use of fireplaces. They are among the most dangerous pollutants to human health and life. They constitute a mixture of solid and liquid phase particles, which may have different compositions and sizes (Moździerz et al., 2010). PM10 particles appear mainly as a result of vehicles moving on unpaved surfaces, which results in crushing and crumbling the surface, and as a result of the so-called secondary dusting. Particulate matter PM2.5 arises mainly during combustion of fuels in automobile engines, industrial plants, home furnaces and combined heat and power plants (Radziszewska et al., 2015). Automobile fumes cause up to 90 percent of dust pollutants in large cities (Ścibor et al., 2015). Particular matter is the cause of bronchial asthma (Pac et al., 2008; Ścibor et al., 2015), pneumonia, chronic obstructive pulmonary disease and heart attacks (Bakera and Gawrońska, 2015).

The average annual concentration of benzo(a)pyrene, under the Regulation of the Minister of the Environment of 24 August 2012 on levels of certain substances in the air (Rozporządzenie Ministra Środowiska z dnia 24 sierpnia 2012 roku, item 1031) – for reasons related to protection of human health – should remain below 1 $\mu g \cdot m^{-3}$. In 2015, its average annual concentration in Bielsko-Biała was 5 $\mu g \cdot m^{-3}$ (Fig. 6). The highest average concentration was recorded in February (166 $\mu g \cdot m^{-3}$) and in March (9.87 $\mu g \cdot m^{-3}$).

Benzo(a)pyrene is the main representative of aromatic hydrocarbons (PAHs), which are classified among the so-called persistent organic compounds. This group of compounds also includes anthracene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(ah)anthracene, benzo(ghi)perylene and indeno(123)pyrene (Brzeźnicki et al., 2009). Benzo(a)pyrene is a component of tobacco smoke and contributes to the development of cancer (Brzeźnicki et al., 2009; Starek and Podolak, 2009; Moździerz et al., 2010; Radziszewska et al., 2015), damages the fetus (Pac et al., 2008), is cytotoxic, teratogenic, immunotoxic and genotoxic (Moździerz et al., 2010; Moździerz et al., 2011; Moździerz and Świetlik, 2013). It diminishes the count and worsens the quality of human sperm cells and their ability to fertilize an egg. Female reproductive cells, in turn, are exposed to chromosomal diploidy. This compound is stored in the kidneys, liver, adipose tissue and lungs. It also impairs the function of bone marrow, the spleen, thymus and lymph nodes. Moreover, it contributes to a decrease in the number of lymphocytes and eosinophils. Polycyclic organic compounds originate from combustion of fossil fuel and organic materials. They come from

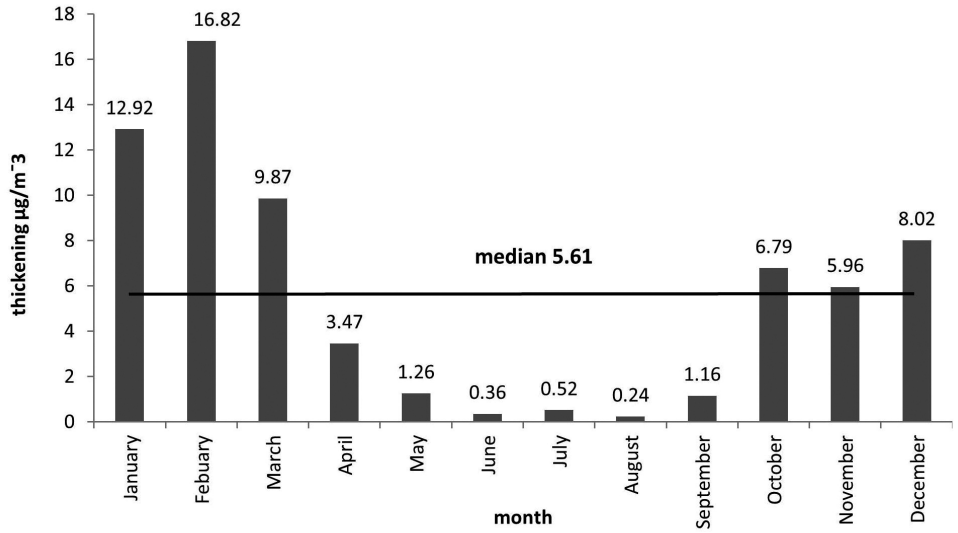

Figure 6. Concentration of benzo(a)pyrene in individual months of 2015 in the city of Bielsko-Biała (the author's own study, based the data provided in www.gios.gov.pl)

home furnaces, motor transport, forest fires and volcanic eruptions. High concentrations of benzo(a)pyrene are found mainly in heavily urbanized and industrialized areas (Możdzierz et al., 2011).

Since the beginning of air quality assessments, Poland has had the biggest problem with exceeded levels of particulate matter PM10 concentrations, mainly in urban areas. In numerous zones, permissible concentrations of benzo(a)pyrene are exceeded. In comparison with the other 28 countries of the European Union, Poland is in the penultimate position in terms of exceeding the permissible concentrations of particulate matter PM10 (with Bulgaria behind and Slovakia ahead of us) and in the last position (behind Bulgaria and Czechia) in the concentration of benzo(a)pyrene (Wielgosiński and Zarzycki, 2018).

Analyzing the average annual concentrations of benzo(a)pyrene in Bielsko-Biała between 2010-2015, it can be noted that the highest annual concentration was recorded in 2012 (7.7 $\mu g \cdot m^{-3}$) and the lowest in 2013 (5.0 $\mu g \cdot m^{-3}$). In 2010, compared to 2011, its average annual concentration decreased by 0.2 $\mu g \cdot m^{-3}$. Starting from 2013 (5.0 $\mu g \cdot m^{-3}$) the average annual concentration rises (Fig. 7).

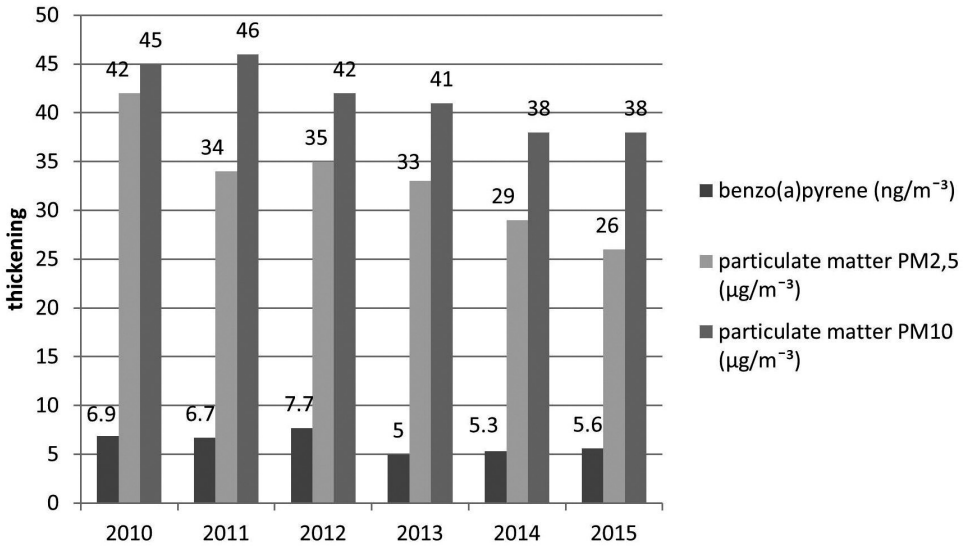

Figure 7. Annual concentrations of benzo(a)pyrene, particular matter PM2.5 and particular matter PM10 in 2010-2015 in the city of Bielsko-Biała (the author's own study, based the data provided in www.gios.gov.pl)

In contrast, average annual concentrations of particular matter PM10 starting from 2011 (46 μg·m^{-3}) show a decreasing tendency. In 2014 and 2015 it was 38 μg·m^{-3}. In 2010, compared to 2011, its average annual concentration increased by 1 μg·m^{-3} (Fig. 7).

In 2010, in relation to 2011, the average annual concentration of particular matter PM2.5 decreased by 8 μg·m^{-3}. Starting from 2012, this concentration (35 μg·m^{-3}) decreased, to reach 26 μg·m^{-3} in 2015 (Fig. 7).

4. Conclusions

The primary objective of the air quality assessment is to identify instances of exceeding the acceptable levels of substances in the air, the target levels, and the levels of the long-term goal. The analysis of air quality showed that the level of particulate matter PM2.5 was exceeded by 1.25 μm and benzo(a)pyrene by 4.61 ng. In addition, there was a noticeable decrease in the levels of particulate matter PM2.5 and PM10 emissions from 2011 to 2015.

To improve the quality of atmospheric air, the program of air protection introduces obligatory guidelines. The biggest challenge (not only) in Polish cities are surface emissions and emission lines. The most important goals aimed at reducing the negative effects of low-stack emissions in Bielsko Biała include reduction of toxic dusts and gases from low-stack emitters, which primarily comprise chimneys, e.g. in single-family houses or tenement buildings. The relatively large number of low-stack emitters introducing into the atmosphere pollutants that are very harmful to human health, leading to the development of cardiovascular and respiratory diseases as well as cancer.

In addition, to limit low-stack emissions, thermo-modernization of buildings with replacement of heat sources can be proposed, along with development of the heating infrastructure and improvements in transport.

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