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Review of air purification methods in urban open spaces

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Abstract

Cities, but also villages around the world, are struggling with air pollution that can lead to illness and even death of citizens. This phenomenon causes that many local governments are going to build an air purification installations in public spaces. The article presents an analysis of air quality in the center of Polish cietes like Warsaw, Krakow and Zakopane for PM10 and PM2.5 dusts in December 2018. There are proposed ways to improve the air quality in open urban spaces.

Keywords: air pollution, air purification, air purification in public space

1 Introduction

The quality of air in winter season in Central Europe, especially in Poland, is quite low. Its quality is largely influenced by the mutual interaction of two factors: pollutant emissions and meteorological conditions [6]. There is a relationship between atmospheric air quality and meteorological conditions. Weather conditions determine the transport of substances in the atmospheric air, while the presence of pollutants in the atmosphere affects the weather and climate. Emission is a decisive factor in the occurrence of pollution, however, its concentration in a unit of air volume depends primarily on meteorological conditions. It is estimated that the amount of air pollution in 70% is determined by meteorological conditions [6]. Meteorological conditions in the ground boundary layer of the atmosphere depend on the intensity of turbulence in the boundary layer of the atmosphere. The vertical stratification of the atmosphere is characterized by the atmosphere stability class, while the turbulence range describes the size defined as the height of the mixing layer.The meteorological factors such as wind speed and direction are most important. Wind speed determines the rate of pollution spread, while the wind direction is responsible for the transport route. Days with insolation-radiation weather (sunny during the day and large night heat radiation from the ground, weak wind) are conducive to the concentration of pollutants related to the emission of combustion products, such as suspended dust or sulfur dioxide, especially in the cool half of the year and at night, as well as and increased ground-level ozone during the summer day.

1.1 Pollution sources

Air pollutants affecting air quality are most often the result of combustion processes, although they can also come from other sources, such as the use of artificial fertilizers in agriculture, cattle breeding, or dust extraction from mining heaps [7]. Some of them are not related to human activity, but come from natural processes such as volcanic eruptions, weathering of rocks, biological processes. Some of them are not formed as a result of direct release into the air, but as a result of chemical reactions [9].

Burning fossil fuels is the most common way of energy production in industry, energy, households and communication. The harmfulness of combustion processes in the power industry and other branches of industry can be reduced through the use of appropriate technologies for removing pollutants from the flue gases (denitrification, desulphurization) or filtration processes. It is much more difficult to reduce the adverse impact on human health of emissions from household combustion and communication processes [3]. Unfortunately, pollution from such sources is emitted

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at a relatively low altitude, and the emission is the greater, the greater the concentration of people is. In a moderate climate zone, with a lack of alternative energy sources, such as nuclear, hydro or wind energy, and adequate heating infrastructure, a significant part of household emissions comes from heating individual buildings during the winter [14]. In Poland, this mainly concerns coal combustion in home boilers. The result of such situation is a poor air quality in large clusters of people in winter. Similar difficulties are caused by transport emissions, especially in the area of the centers of large cities [2, 11, 16].

1.2 Air pollution in Poland

In Poland, in the case of PM10 dust, the permissible level of average annual concentration is 40 $\mu g/m^3$, the permissible level of 24-hour average concentration is 50 $\mu g/m^3$ (exceeding this level is allowed 35 times per year) [12].

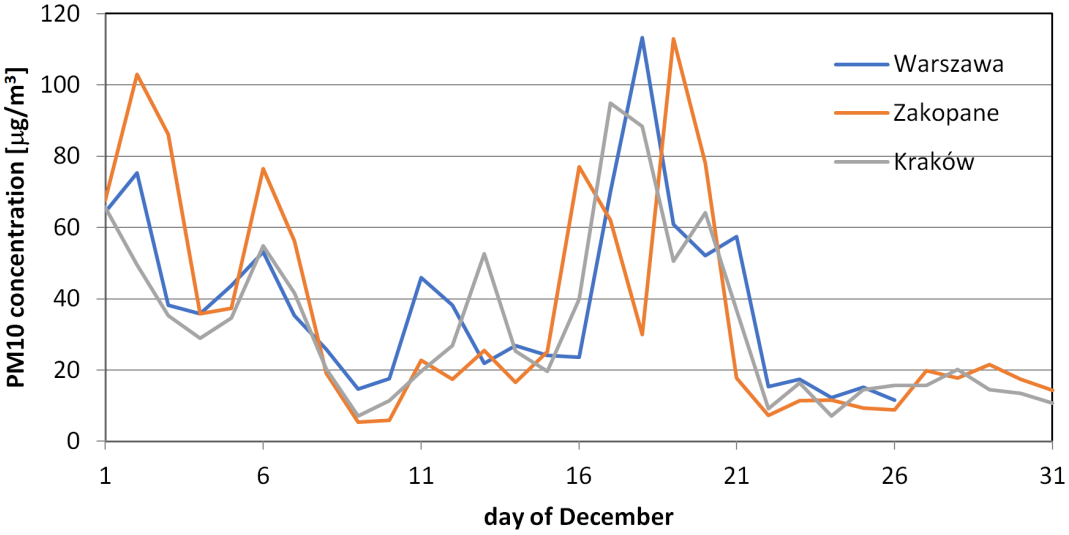

Figure 1. The average 24-hour PM10 concentration in Polish cities in December 2018

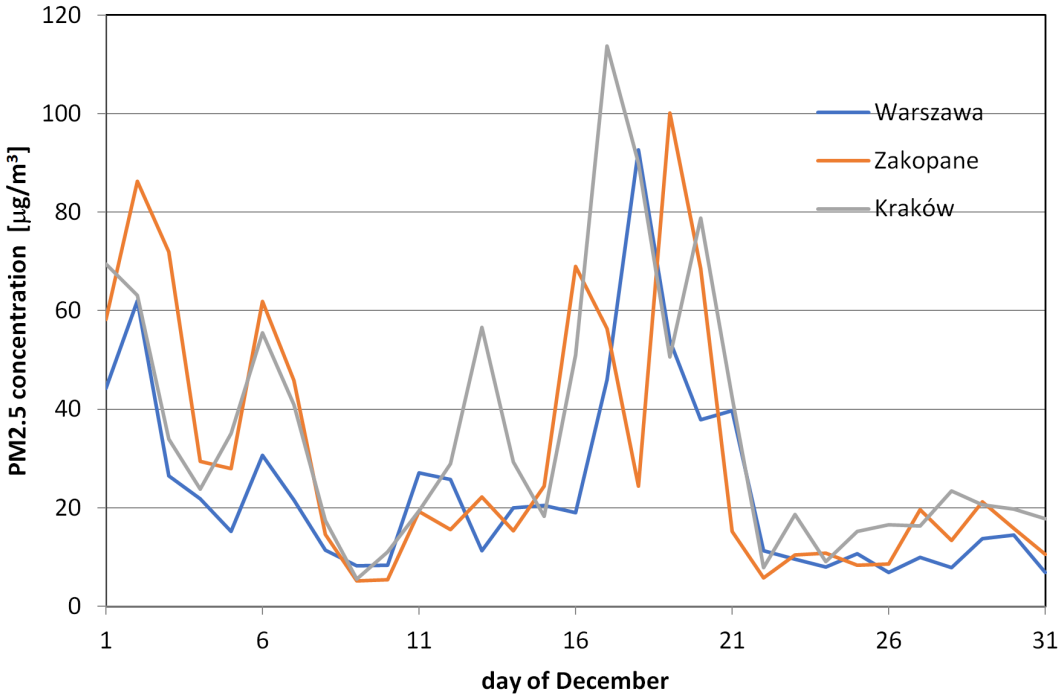

Figure 2. The average 24-hour PM2.5 concentration in Polish cieties in December 2018.

For PM2.5 dust, the allowable annual average concentration in 2020 is 20 $\mu g/m^3$. In October 2019, new alarm thresholds were introduced [13], the smog alarm is announced when the average daily value of 150 $\mu g/m^3$ for PM10 dust is exceeded (previous value was 300 $\mu g/m^3$), and the information level is equal to 100 $\mu g/m^3$.

Figures 1 and 2 present the concentration of PM10 and PM2.5 in Polish cities in December 2018. It can be seen that the level of pollution is far from satisfactory. It should also be noted that low levels of pollution result only from favorable weather conditions. There is rain or snow, or strong wind is blowing out pollution from cities. Cities under pressure of residents are starting to introduce solutions that are reducing the pollution.

Problems with air quality do not only concern Poland, much worse air purity is observed in large Asian agglomerations [10].

2 Air purification methods in open spaces

As a part of projects with a wider reach and air purification streams, anti-smog tower designs are emerging. Designer Daan Roosegaard creates with his team Smog Free Tower (shown in Fig. 3.) - a purifier several meters high, which is not standing at home, but in urban space. Powered by green energy, it can filter up to 30,000 cubic meters of air per hour. This proposal has met with the interest of numerous Chinese cities that wanted to try this solution [15].

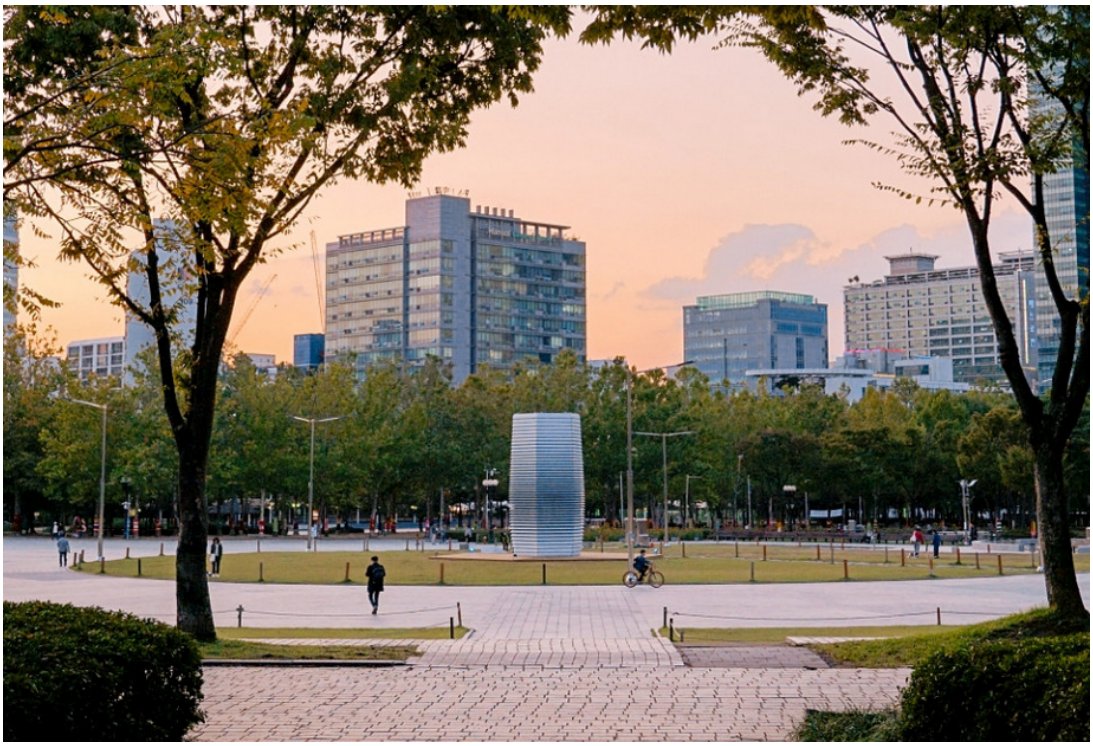

Figure 3. Smog Free Tower [15]

At the same time, a pilot installation was launched in China in Xian, with a tower over 100 meters high (Fig. 4). The tower cleans the 10 million cubic meters of air per day. An improvement in air quality was observed in the area of 10 square kilometers, the tower was able to reduce smog to an acceptable level [4].

On similar solutions are working engineers in India [5]. The air in New Dheli, which is the capital of the country and one of the most densely populated urban centers, exceeds the norms almost 25 times every day. This makes life in a city that is permanently covered with a tight layer of smog which is very dangerous to life and health [1]. But, this may by very soon changed thanks to the filter towers called Aura. Aura is to be a tower system (Fig. 5), which according to its shapes and the technology used can efficiently and on a large scale clean the air in the city. New Dheli would be surrounded by a ring of 60 meters high filter towers. The interior of the rings thus formed is to be covered with a mesh of smaller filter towers, which will be just 18 meters high. Larger objects are going to be built at the city borders. Their task will be to purify the air that comes from the suburbs of New Dheli. The 60-meter towers will purify the air within a 900-meter radius, and each area will clear about 2.5 square kilometers. The smaller ones,

Figure 4. Air purifying tower in Xian, China [4]

which will stand, among others, in parks, on busy streets in the city center or on roundabouts will have a range of about 1 square kilometer.

Figure 5. The concept of the Aura air purification tower system in New Dheli [5]

Another way to clean air in public spaces is to use plants. An example of such a solution is presented in Figure 6 [8].

Figure 6. A CityTree in Brussels, Belgium [8]

3 Conclusions

The best way to make the air cleaner is not to pollute it. However, this is impossible at the current economic, political and technical level. Because of this, solutions are being developed around the world that will purify the air in an open space. Problems of polluted air in cities apply to all continents. In Poland, significant areas of the Małopolskie and Śląskie voivodeships are included in the list of areas exceeding the air pollution standards in WHO reports. Hence the need to look for solutions to improve air quality in open public spaces.

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