Analysis of concentrations trends and origins of PM_{10} in selected European cities

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Abstract. Particulate matter is generated in many natural and anthropogenic processes and, therefore, taking part in chemical reactions and physical processes in the atmosphere could affect human health, climate, and natural environment. The dust, after emission to the atmosphere, remains there in a floating state to form an atmospheric aerosol with different properties – depending on the morphology, the fraction, shape, surface, and chemical composition of the particles. The chemical composition of particulate matter is heterogeneous and depends on the type of emission sources and the time of residence in the atmosphere. The contribution of individual types of sources in the total dust emission is different in European countries. The aim of the study was to analyze the concentrations of PM_{10} at urban background and traffic stations in the chosen 17 European cities. For this purpose, the data from the database of the European Environment Agency and Chief Inspectorate of Environmental Protection was used. The annual average concentrations of PM_{10} and daily average concentrations of PM_{10} in 2014 will be presented to confirm that in the European cities there is a problem about high PM_{10} concentrations, especially in Poland and other eastern countries. In the case of daily average PM_{10} concentration, the highest concentrations of pollutants in the winter season suggests that for the low air quality in these cities the phenomenon of so- called low-stack-emissions from the municipal sector is responsible.

1. Introduction

Nowadays the air pollution is a huge problem, especially in the cities. Both, politicians and social organizations try to fight with the air pollution in many different ways (for example legal norms, an environmental education etc.). Air pollution is any substance which changes normal composition of the air. The air pollution can have a different origin (natural or anthropogenic), a different physical state (gas, solid or aerosols), a different chemical compositions, a various residence time in the air and even a different ability to

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long-term transport. Also, some of air pollutants can react with other substances in the air to a new form, sometimes to more dangerous pollution [7]. Particulate matter, also known as dust or aerosols affect human health, environment and climate causing large economic losses [2, 5–7, 11, 13, 14, 16, 19, 20].

Some particulates occur naturally (primary PM), originating from volcanic eruptions, deserts, dust storms, trees, living vegetation, grassland or forest natural fires, and sea spray. Also particulate matter can be produced in the atmosphere through chemical reactions of gaseous precursors (secondary PM). There is a lot of sources of dust emission. The main anthropogenic sources, which are predominant in urban areas, are production processes and fossil fuels combustions (in vehicles, power plants and industrial processes). Metallurgical, energy, chemistry and mining industry are one of the biggest sources of their emission. Also, transport is the important to source of emission (tire and brake and road wear). Domestic heating for households plays the important role in air pollution in Poland [1, 7, 10, 12, 18].

Europe has a serious problem with the air pollution, especially a particulate matter pollution. Generally, the worst situation is in big cities. According to the data of the European air-quality database in 2014 PM_{10} concentrations continued to be above the UE Limit Value in the large part of Europe [4, 20]. Monitoring stations with measured concentrations of PM_{10} above daily limit value were situated in 21 EU Member States in 2014. About 94% of the cases were observed in urban or suburban areas [7]. Concentration above the PM_{10} annual limit value was monitored in 2014 in 4% of all the reporting to EEA stations. 93% of these stations were located in urban areas. According to the WHO guidelines, annual mean PM_{10} was exceeded at 55% of the total amount of the stations and in 31 countries. The decrease in concentrations of PM_{10} (about 0.6-0.9 $\mu g/m^3$ per year) were observed in 75% stations in Europe in 2000-2014 [7].

Trends of changes in particulate matter PM_{10} concentrations in selected European cities in 2010-2014 is presented in the paper. The aim of the study is to analyze the concentration and origin of PM_{10} measured at the urban traffic and background monitoring stations, in order to identify the main sources of particulate matter emissions in European cities.

2. Materials and methods

Data from the databases of the European Environment Agency and Chief Inspectorate of Environmental Protection was used for analysis. Poznan, Wroclaw, Warsaw, Cracow, Gdansk, Wien, Brussel, Praha, Berlin, Copenhagen, Barcelona, Helsinki, Paris, London, Budapest, Roma, and Stockholm are the chosen cities. The analysis of the concentration of particulate matter in these places should help to answer, what are the main sources of PM emission – traffic or so-called low-stack emissions (emissions from sources with a height lower than 40 m.

The analysis of concentraction in relation to the limit values is based on the measurement at fixed sampling points. Sampling points chosen to analysis are located at two types of sites: urban background and traffic related locations. The AQD [4] sets the data quality objective as a minimum data capture of 90% (valid data out of all possible in a year) for official assesment purposes. For presented analysis the more relaxed coverage criterion of 50% has been used. It allows taking into account more stations without loss of representativeness. It should be noted that the vast majority of data series taken into consideration have completeness in excess of 75%. The analysis covers the period of 2010–2014.

In accordance with the provisions of the AQD and implementing legislation Member States shall report to the EEA provisional data continuously. This includes primarily the results of automatic measurements (so-called up-to-date UTD data), which are thus available to the public on the European Air Quality Portal. The annual series of verified and validated measurement data are delivered to the end of September in the year following the year of measurements performing. They are reported together with information about the assessment system and the results of annual air quality assessment: declarations of compliance with the air quality standards and descriptions of exceedance cases.

European standards for reference measurements of PM_{10} and $PM_{2.5}$ were concluded in PN-EN 12341: 2014 Ambient air - Standard gravimetric measurement method to determine the concentration of mass fractions PM_{10} or $PM_{2.5}$ particulate matter [15]. Basing on weight results the concentration of PM is specified [17].

3. Measurements results analysis and observations on PM_{10} concentrations trends through selected European cities

Annual indexes calculated for each selected cities are used in the presented analysis. These indexes have been calculated separately for urban background and traffic stations, as arithmetic averages of the annual mean values from measuring stations of the specific type in subsequent years. Referring the calculated index to the standards set by the European Commission for the annual PM_{10} concentration it can be indicated that the limit values has been exceeded nineteen times in 3 of 18 selected cities. All cases of exceedances were observed in Polish cities: 10 times in Cracow (5 times at the traffic station and 5 background stations), 3 times in Warsaw for a traffic station and 3 times in Wroclaw (once at the background stations and 2 times for the traffic station) (Tab. 1). PM_{10} concentrations approaching the specified standards were observed in Paris and Budapest at traffic stations and in other analyzed Polish cities. The highest and the lowest index value was observed in 2010 at the traffic station in Cracow and in 2012 at background station in Helsinki, respectively. These cities differ in terms of climate and culture that influence the quality of the air. In all of the analyzed cities, the higher concentrations of PM_{10} were observed for traffic stations, which are generally located in a close vicinity of the streets with high traffic level. It can indicate the dominant influence of transport emissions on air quality in the central parts of the cities, where the traffic stations are often situated. Referring to the average daily value recommended by the WHO (20 $\mu g/m^3$) it should be noted, that the population of most European cities are exposed to air pollution by PM_{10} levels dangerous to health. In 2010-2014, the value of 20 $\mu g/m^3$ was not exceeded only 17 times in 6 cities (Helsinki, Stockholm, Gdansk, London, Copenhagen, Paris).

The Institute of Environmental Protection – National Research Institute (IEP-NRI) study shows the general decrease in PM_{10} averaged concentrations in Poland since 2010, both of average annual and daily PM_{10} concentrations (Fig. 1) [9]. Since 2007, the calculated index of average annual concentration of PM_{10} for Polish does not exceed 40 $\mu g/m^3$. The situation in Polish cities is much worse than the PM_{10} pollution expressed as a population weighted index calculated for the whole country using the methodology described in [8]. Concentrations in Cracow and Warsaw is about 20 $\mu g/m^3$ higher than the average concentration calculated for the whole country. Although the annual average concentrations in the area of Poland remain several years of below standard values, every year the number of permitted days per year with a value greater than 50 $\mu g/m^3$ is exceeded. In Poland, air pollution with PM_{10} is generally a seasonal problem – exceedances occur mainly in autumn-winter period, hence the annual average value does not exceed the standard. On the other hand, a large number of days with high concentrations of PM_{10} in winter badly affects the quality of life. According to the IEP-NRI study in 2012 standard value of the 24-hour concentration was exceeded on at least one station in 21 of the 28 European Union countries. In 2012 the exceedance of the normative value determined on the basis of percentile values of S90,4 from the daily PM_{10} concentrations (above 50 $\mu g/m^3$)

was observed at 21.4% of measuring stations in EU countries (including Poland). In Poland, the exceedance was concerned for 71.6% of the stations. In a case of the limit value established for the annual average concentrations of PM_{10}, the exceedances occurred at 5.1% in the EU and 24.2% in Polish stations, respectively [3].

Table 1. Annual concentration of PM_{10} in selected European cities in 2010–2014.

Country	City name	Type of measurement stations	Annual concentration of PM_{10} [µg/m^3]				
			2010	2011	2012	2013	2014
Austria	Wien	Background	27	27	23	23	21
Austria	Wien	Traffic	31	32	26	26	23
Belgium	Brussel	Background	26	27	25	24	23
Belgium	Brussel	Traffic	27	27	24	24	23
Czech Republic	Prague	Background	25	26	24	25	26
Czech Republic	Prague	Traffic	32	30	27	27	28
Germany	Berlin	Background	25	23	21	21	23
Germany	Berlin	Traffic	33	30	27	27	31
Denmark	Copenhagen	Background	12	nd	17	nd	19
Denmark	Copenhagen	Traffic	26	32	28	27	28
Spain	Barcelona	Background	27	28	27	21	22
Spain	Barcelona	Traffic	33	36	35	26	28
Finland	Helsinki	Background	14	13	11	12	15
Finland	Helsinki	Traffic	23	22	18	21	21
France	Paris	Background	26	24	27	26	18
France	Paris	Traffic	39	39	37	36	29
United Kingdom	London	Background	17	21	18	18	19
United Kingdom	London	Traffic	26	29	25	26	25
Hungary	Budapest	Background	32	33	29	28	29
Hungary	Budapest	Traffic	36	38	28	31	36
Italy	Roma	Background	28	31	28	26	27
Italy	Roma	Traffic	34	35	34	31	30
Poland	Gdansk	Background	27	25	22	20	26
Poland	Cracow	Background	48	54	53	44	46
Poland	Cracow	Traffic	79	76	66	60	64
Poland	Poznan	Background	38	39	33	27	32
Poland	Warsaw	Background	35	35	37	32	32
Poland	Warsaw	Traffic	52	49	39	40	42
Poland	Wroclaw	Background	48	39	39	36	35
Poland	Wroclaw	Traffic	62	53	nd	nd	nd
Sweden	Stockholm	Background	13	15	13	15	14
Sweden	Stockholm	Traffic	25	29	24	28	22

Institute of Meteorology and Water Management – National Research Institute (IMGW) data indicates that since 2010 in Poland as well in the summer seasons the higher temperatures, as in the autumn-winter season are registered (Fig. 2). Referring PM_{10} concentrations reported in Poland in the years 2010-2014 there is observed a clear converse relationship between the air temperature and the concentration of PM_{10} in the air (e.g. anomaly cold and very cold periods). This is another proof that the particulate matter in the air in Poland is affected by low-stack emission from the municipal sector. Low temperatures force Polish cities inhabitants to heat homes and fuel burning of poor quality coal (it is associated with their economic situation and the low environmental awareness) affects the deterioration of air quality in the urban areas. Moreover, in winter season often a low wind speed, a high atmospheric pressure and temperature inversion situations can favor the occurrence of smog situation.

For selected European cities average daily concentrations of PM_{10} in 2014 were analyzed in the way to demonstrate the dependence of PM_{10} concentrations on the season. The results are presented in the form of a mosaic in Figure 3. Each grid in the figure shows the daily average PM_{10} concentration. The value of the annual average PM_{10} concentrations and the number of days with a value of more than 50 µg/m^3 during the year was added to the graph. Presented data show that there is a strong seasonal concentrations change in the Polish cities – in autumn-winter season daily average concentrations and number of days with exceedance of 50 µg/m^3 reach the highest values. A city located in the north of Europe (Copenhagen, Helsinki, Stockholm, London) have concentrations of PM_{10} at a similar level throughout the year. Additionally, there are low PM_{10} concentrations levels - below the European standards. It shows that an influence of the climate of these cities and also the heating system of buildings is quite different than in cities of Central and Eastern Europe. In other analyzed cities (Vienna, Brussels, Prague, Paris, Berlin, Rome, Barcelona) variation in concentrations within a year was also not observed. It can be assumed that the main source of emissions of PM_{10} in those parts of Europe is transport. Similar conclusions can be drawn based on the analysis of hourly PM_{10} concentrations averaged for every the same hour within the calendar year (Fig. 4). The analysis of data from the selected background stations shows that in the Polish cities the highest daily PM_{10} concentrations are observed in the evening and late evening (18.00–23.00) and then again in the morning (6.00–9.00). It is correlated with the rhythm of home heating – residents (especially owners of old central heating) start heating homes after work (in the afternoon) and then repeat this step in the morning. Also, some influence of worse pollution dispersion situations which sometimes occur during the night hours should be taken into consideration. In other selected cities (Paris, Prague, Berlin, Vienna and Brussels) a slight increase in the concentrations of PM_{10} in the morning at the time when people are traveling to work was observed.

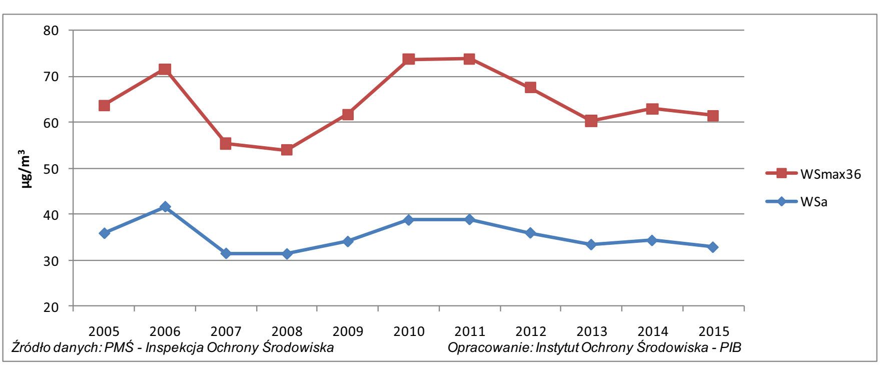

Fig. 1. Variability in annual and daily average concentrations of PM10 at urban and suburban background monitoring stations in Poland in the years 2005-2015 [9].

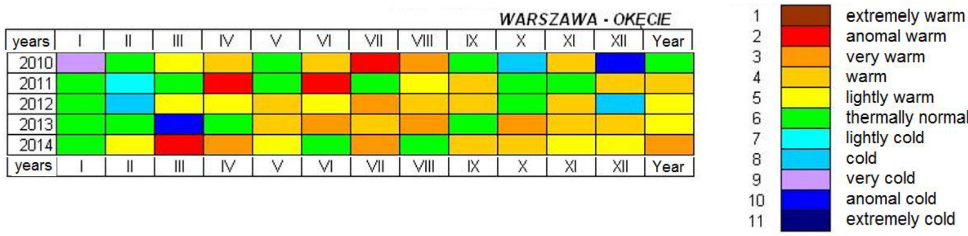

Fig. 2. Thermal classification of months and years (2010-2014) *[source: own compilation based on IMGW-PIB]*.

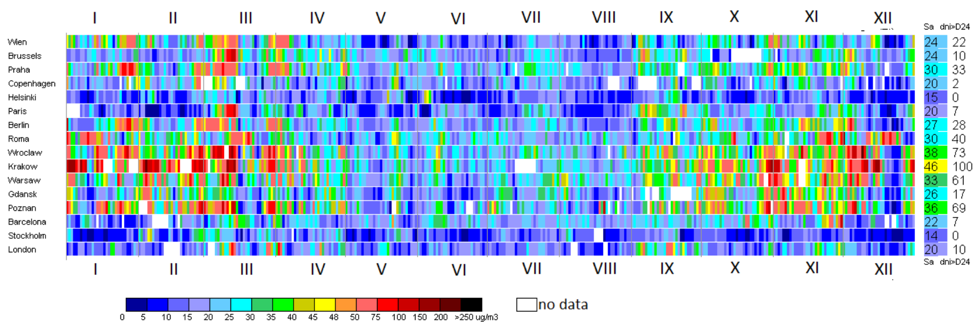

Fig. 3. The variability of PM10 daily mean concentrations measured at selected urban background stations in 2014 *[source: own elaboration based on data published by the EEA]*.

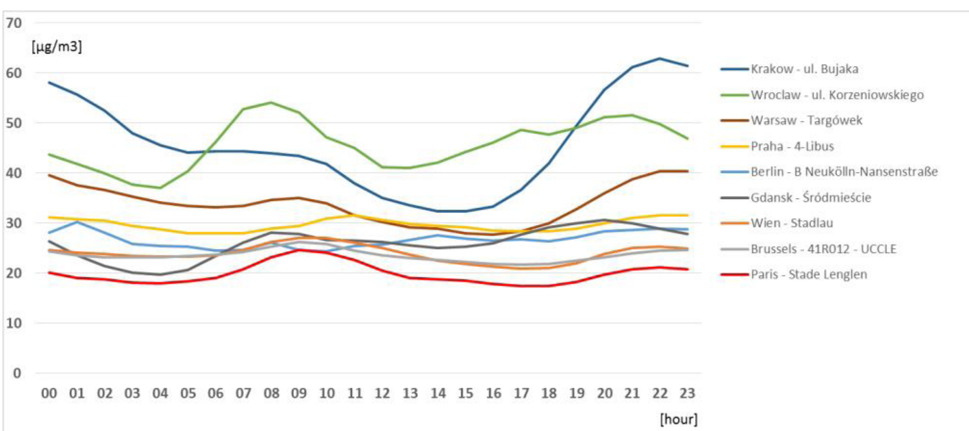

Fig. 4. Averaged diurnal variability of 1-hour PM10 concentrations at selected urban background monitoring stations in 2014 *[source: own elaboration based on data published by the EEA]*.

In 2014 the maximum daily PM_{10} concentration in Cracow and Wroclaw was above 200 $\mu g/m^3$ (Fig. 5). In Poland, the appropriate services have the obligation to inform the public about the occurrence of health hazards due to high concentrations of PM_{10} in a situation of daily mean value above 200 $\mu g/m^3$. The high PM_{10} concentrations episodes (above 100 $\mu g/m^3$) were also observed in Paris, Poznan, Brussels, Rome, Berlin, and Poznan. The intensity of smog situations (height of concentrations) in Poland is often much greater than in other analyzed countries. Even short-term exposure to such high concentrations of PM_{10} could pose a serious threat to human health, especially vulnerable groups (children, the elderly, pregnant women and people suffering from lung diseases) [2].

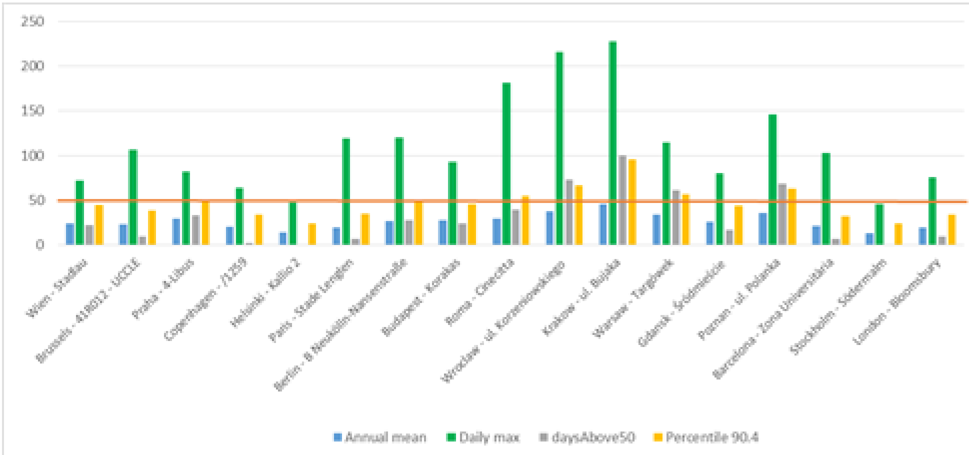

Fig. 5. The values of the selected statistical parameters for the PM10 concentration data series at urban background stations in 2014 *[source: own elaboration based on data published by the EEA]*.

5. Summary

The analysis of the data shows that European cities face the problem of air pollution by particulate matter (PM). Every year, millions of inhabitants are exposed to oversize PM concentrations, in the case of PM_{10} annually states exceedance of the maximum PM concentrations levels established for the protection of human health. Practically, in each of the analyzed cities the average concentration recommended in the WHO Guidelines (20 $\mu g/m^3$) was exceeded, and there were only a few cities with background pollution below that level. Definitely, the worse situation is observed in central and east-central Europe, where dominates the culture of apartments heated using the coal, often of poor quality. It can also be seen that location, climate, and terrain of the cities have a huge impact on their air quality. EEA data shows that the highest concentration of PM10 in Europe in Poland, Italy, Bulgaria and Slovakia is registered [3]. While the location of the city in the mountain sites affects the deterioration of air quality (Cracow), cities located in well-ventilated terrain, on the shores of seas and boasting a large area of green spaces in their borders have good air quality (Helsinki, Gdansk).

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