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STRUCTURE OF ATMOSPHERIC AEROSOL IN UPPER SILESIA (POLAND) – CONTRIBUTION OF PM2.5 TO PM10 IN ZABRZE, KATOWICE AND CZĘSTOCHOWA IN 2005–2007

KRZYSZTOF KLEJNOWSKI*, WIOLETTA ROGULA-KOZŁOWSKA, ANDRZEJ KRASA

Institute of Environmental Engineering of the Polish Academy of Sciences
ul. M. Skłodowskiej-Curie 34, 41-819, Zabrze, Poland
*Corresponding author e-mail: kklejnowski@ipis.zabrze.pl

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Abstract: The PM2.5/PM10 ratio expresses the anthropogenic share in atmospheric dust. Very high values of this ratio, i.e. high contribution of PM2.5 to PM10, have occurred recently in atmospheric air within European industrialized areas. The paper compiles results of three year pair wise measuring of concentrations of PM2.5 and PM2.5–10 and compares shares of PM2.5 in PM10 at three urban background sites in Upper Silesia Poland (towns of Zabrze, Katowice and Częstochowa). At all the three locations, the PM2.5/PM10 ratio of daily concentrations of dust only occasionally differed considerably from the PM2.5/PM10 ratios for the seasonal and yearly concentrations that, in turn, did not differ from the PM2.5/PM10 ratios at urban sites in Europe.

INTRODUCTION

The size of ambient particles depends on their origin. Almost all their properties, their impact on the environment or health – on their size. The smaller they are the farther from their source they float [8] and more deeply penetrate lungs.

Therefore, most often the ambient dust is classified by size of its particles. The ambient air contains particles of aerodynamic diameters from 0.002 to 100 μm [21], but in most cases, due to their influence on the chemistry of atmosphere, their physical properties and significance to human health, it is necessary and sufficient to consider the two main fractions:

- fine dust, PM2.5 – particles of aerodynamic diameter not exceeding 2.5 μm, most often related to combustion, may be of primary (from a source) or secondary (from chemical reactions in the atmosphere) origin [4, 6];

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- coarse dust, PM2.5–10 – particles of aerodynamic diameter between 2.5 and 10 μm, mainly from mechanic processes, includes also pollens and spores;
- and their sum, PM10, i.e. particles of aerodynamic diameter not exceeding 10 μm.

According to the data published by the European Commission [4], the concentration of PM2.5 plays the key role in assessment of the health hazard from air pollutants. For some last few years, PM2.5 in Europe has been investigated quite thoroughly [2, 18, 22]. Many studies yield close or identical PM10 and PM2.5 concentrations [1, 7] i.e. negligible PM2.5–10 mass. Therefore, replacement of the PM10 limit values with standards for PM2.5 and intensified researches on PM2.5–10 to recognize relations between both fractions seem to be necessary. They may help to limit emission of the dominating fraction in areas threatened by violation of the PM standards.

In the presented work, results from three years of simultaneous measurements of PM2.5 and PM2.5–10 are exploited to compare shares of PM2.5 in PM10 at three different urban background sites (Zabrze, Katowice, Częstochowa). The specific conditions, different from conditions in other parts of Europe or Poland, affecting emission of PM were the reason for choosing the investigation areas. While emission of PM (both primary and secondary) in most European countries comes from traffic [3, 9, 24, 25], in Poland, especially in urban areas, municipal and industrial emission dominates [5, 16, 17, 19, 20].

SAMPLING SITES

The measurements were carried out during 2005–2007 period in three towns:

1. Zabrze – the western part of the Upper Silesian agglomeration – the measuring point was located in the premises belonging to the Institute of Environmental Engineering, M. Skłodowskiej-Curie 34, in the town centre. About 500 m north there is a four-lane, quite busy, national 88 road. About 500 m east, behind not very trafficked six-lane Korfanty Lane; high blocks of flats and houses are situated. Towards the south and south-east stretches the diversified housing and industry of the Zabrze downtown. In the west, the Institute borders with high blocks of the M. Skłodowska-Curie housing estate. The surrounding buildings are heated by the central network or by combusting hard coal.
2. Częstochowa – the northern part of the Silesian region – the measuring point was located within premises belonging to the Regional Inspectorate of Environmental Protection, Rząsawska Street 24–28, in Wyczerpy, the north-eastern part of Częstochowa. About 100 m away, there is Rząsawska Street – a local road with moderate traffic. The sampler was located on a grassy yard in front of the building of the Regional Inspectorate of Environmental Protection. The site is neither affected by traffic nor by industry. In the adjacent areas there are large storehouses.
3. Katowice – the central part of the Upper Silesian agglomeration – the measuring point was located within premises belonging to the Institute for Ecology of Industrial Areas, Kossutha Street, the Witos residential quarter, the western part of Katowice.

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Blocks of flats, railway line, the DTŚ highway and the Tysiąclecia housing estate in the north, market areas in the east, the Witos quarter in the south and in the west living quarters and industrial terrains abandoned by the hard coal mine "Kleofas" surround the site.

All the sites represent urban background conditions. They are surrounded by housing estates and blocks of flats. Each site lies about 500 m away from a busy road which might be also a source of suspended dust. All the three points are described in [10–15].

Concentrations of PM2.5 and PM2.5–10 in Zabrze were measured from April to December 2006 and during every second month, starting from January, in 2007. In Katowice, the concentrations were measured every second month of 2007 starting from February. In Częstochowa – during the whole year 2005 except for maintenance break.

Arrangement of the measuring points within Silesia is presented in Figure 1.

Fig. 1. Location of the measuring sites

METHOD

Application of a sequential two-channel Rupprecht and Patashnick's Dichotomus Partisol®Plus 2025 sampler allowed to pair wise measuring of concentrations of coarse (PM2.5–10) and fine (PM2.5) particles. PM2.5–10 was collected on glass, PM2.5 on Teflon filters. The stream of dust was split into two fractions by a virtual impactor. The sampler recorded the meteorological parameters and volume of sucked air. PM2.5/PM10 ratio, concentrations of PM10 and statistical parameters of series of results were computed. Concentrations were determined gravimetrically (Mettler Toledo micro scales, electric charge neutralizer) according to the method described in [19–25].

Air humidity and temperature in the weighing room were controlled and kept equal to about 50% and 20°C, respectively. Before weighing, filters were conditioned for 48 hours in the weighing room.

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RESULTS

Częstochowa

Table 1 presents basic statistical parameters of the series of PM2.5, PM2.5–10, PM10 concentrations and PM2.5/PM10 ratios for Częstochowa in 2005.

Table 1. Statistical parameters of the series of daily dust concentrations in Częstochowa, 2005

Period	Statistical parameter	Concentration [μg/m³]			PM2.5/PM10
		PM2.5	PM2.5–10	PM10	
I quarter	average	46.4	6.7	53.0	0.86
	minimum	17.6	0.2	23.0	0.75
	maximum	106.4	17.1	123.5	1.00
	number of measurements	13			
II quarter	average	33.8	14.1	48.0	0.6
	minimum	0.1	0.0	10.1	0.0
	maximum	139.6	72.0	140.5	1.0
	number of measurements	72			
III quarter	average	22.3	17.3	39.6	0.6
	minimum	2.7	1.4	6.4	0.1
	maximum	69.3	139.8	153.5	1.0
	number of measurements	86			
IV quarter	average	42.4	9.2	51.6	0.8
	minimum	9.7	0.0	12.2	0.5
	maximum	98.6	28.7	113.5	1.0
	number of measurements	57			
Winter (I and IV quarter)	average	43.1	8.8	51.9	0.8
	minimum	9.7	0.0	12.2	0.5
	maximum	106.4	28.7	123.5	1.0
	number of measurements	70			
Summer (II and III quarter 2005)	average value	27.6	15.9	43.4	0.6
	minimum	0.1	0.0	6.4	0.0
	maximum	139.6	139.8	153.5	1.0
	number of measurements	158			
2005	average value	32.3	13.7	46.0	0.7
	minimum	0.1	0.0	6.4	0.0
	maximum	139.6	139.8	153.5	1.0
	number of measurements	228			

Zabrze – 2006

Table 2 presents basic statistical parameters of the series of PM2.5, PM2.5–10, PM10 concentrations and PM2.5/PM10 ratios for Zabrze in 2006.

Table 2. Statistical parameters of the series of daily dust concentrations in Zabrze, 2006

Period	Statistical parameter	Concentration [μg/m³]			PM2.5/PM10
		PM2.5	PM2.5–10	PM10	
I quarter	average value	maintenance interval			
	minimum				
	maximum				
	number of measurements	0			
II quarter	average value	23.0	11.6	34.6	0.7
	minimum	5.0	1.4	9.2	0.2
	maximum	76.9	69.2	99.8	0.9
	number of measurements	85			
III quarter	average value	18.8	12.3	31.1	0.6
	minimum	3.6	2.2	9.3	0.3
	maximum	54.5	29.6	82.9	0.9
	number of measurements	92			
IV quarter	average	49.9	12.2	62.1	0.8
	minimum	5.4	2.5	8.2	0.5
	maximum	171.1	29.9	196.9	0.9
	number of measurements	90			
Winter (IV quarter)	average	49.9	12.2	62.1	0.8
	minimum	5.4	2.5	8.2	0.5
	maximum	171.1	29.9	196.9	0.9
	number of measurements	90			
Summer (II and III quarter)	average	20.8	12.0	32.8	0.6
	minimum	3.6	1.4	9.2	0.2
	maximum	76.9	69.2	99.8	0.9
	number of measurements	177			
2006	average	30.6	12.0	42.7	0.7
	minimum	3.6	1.4	8.2	0.2
	maximum	171.1	69.2	196.9	0.9
	number of measurements	267			

Zabrze – 2007

Table 3 presents basic statistical parameters of the series of PM2.5, PM2.5–10, PM10 concentrations and PM2.5/PM10 ratios for Zabrze in 2007.

In 2007, the sampler worked alternately in Zabrze and Katowice, its location was changed monthly. The numbers of measurements at both sites were close and numbers of summer and winter measuring days comparable. In Zabrze, measurements were carried out in January, March, May, July, September and November. The quarterly averages in Table 3 refer to particular months as follows:

- quarter I – January, March,
- quarter II – May,
- quarter III – July, September,
- quarter IV – November.

Table 3. Statistical parameters of the series of daily dust concentrations in Zabrze, 2007

Period	Statistical parameter	Concentration [μg/m³]			PM2.5/PM10
		PM2.5	PM2.5–10	PM10	
I quarter	average	43.3	12.9	56.2	0.8
	minimum	4.9	1.3	11.2	0.2
	maximum	215.6	123.7	277.0	0.9
	number of measurements	63			
II quarter	average	15.2	3.0	18.2	0.8
	minimum	6.0	0.0	7.4	0.4
	maximum	39.5	19.1	58.6	1.0
	number of measurements	27			
III quarter	average	19.3	11.1	30.4	0.6
	minimum	4.2	1.8	7.7	0.4
	maximum	68.6	25.3	88.4	0.9
	number of measurements	62			
IV quarter	average	55.4	9.0	64.3	0.8
	minimum	6.5	2.8	10.4	0.3
	maximum	173.1	21.7	189.7	0.9
	number of measurements	30			
Winter (I and IV quarter)	average value	47.2	11.6	58.9	0.8
	minimum	4.9	1.3	10.4	0.2
	maximum	215.6	123.7	277.0	0.9
	number of measurements	93			
Summer (II and III quarter)	average	18.1	8.6	26.7	0.7
	minimum	4.2	0.0	7.4	0.4
	maximum	68.6	25.3	88.4	1.0
	number of measurements	89			
2007	average	33.0	10.2	43.1	0.7
	minimum	4.2	0.0	7.4	0.2
	maximum	215.6	123.7	277.0	1.0
	number of measurements	182			

Katowice – 2007

Table 4 presents basic statistical parameters of the series of PM2.5, PM2.5–10, PM10 concentrations and PM2.5/PM10 ratios for Katowice in 2007.

Measurements were carried out in Katowice in February, April, June, August, October and December. The quarterly averages in Table 3 refer to particular months as follows:

- quarter I – February,
- quarter II – April, June,
- quarter III – August,
- quarter IV – October, December.

Table 4. Statistical parameters of the series of daily dust concentrations in Katowice, 2007

Period	Statistical parameter	Concentration [μg/m³]			PM2.5/PM10
		PM2.5	PM2.5–10	PM10	
I quarter	average	43.3	10.5	53.8	0.8
	minimum	9.3	4.3	24.1	0.1
	maximum	85.0	53.8	102.2	0.9
	number of measurements	27			
II quarter	average	19.1	15.0	34.0	0.6
	minimum	6.9	0.0	6.0	0.3
	maximum	75.1	40.1	105.5	1.0
	number of measurements	46			
III quarter	average	17.4	13.0	30.4	0.6
	minimum	9.7	6.2	18.0	0.3
	maximum	28.1	23.1	41.6	0.8
	number of measurements	26			
IV quarter	average	43.0	10.4	53.3	0.8
	minimum	5.6	3.1	18.9	0.2
	maximum	125.4	31.1	141.3	0.9
	number of measurements	61			
Winter (I and IV quarter)	average	43.1	10.4	53.5	0.8
	minimum	5.6	3.1	18.9	0.1
	maximum	125.4	53.8	141.3	0.9
	number of measurements	88			
Summer (II and III quarter)	average	18.5	14.3	32.7	0.6
	minimum	6.9	0.0	6.0	0.3
	maximum	75.1	40.1	105.5	1.0
	number of measurements	72			
2007	average	32.0	12.2	44.1	0.7
	minimum	5.6	0.0	6.0	0.1
	maximum	125.4	53.8	141.3	1.0
	number of measurements	160			

DISCUSSION

Each of Figures 2, 3 and 4 compares PM2.5/PM10 at the examined sites in appropriate measuring periods.

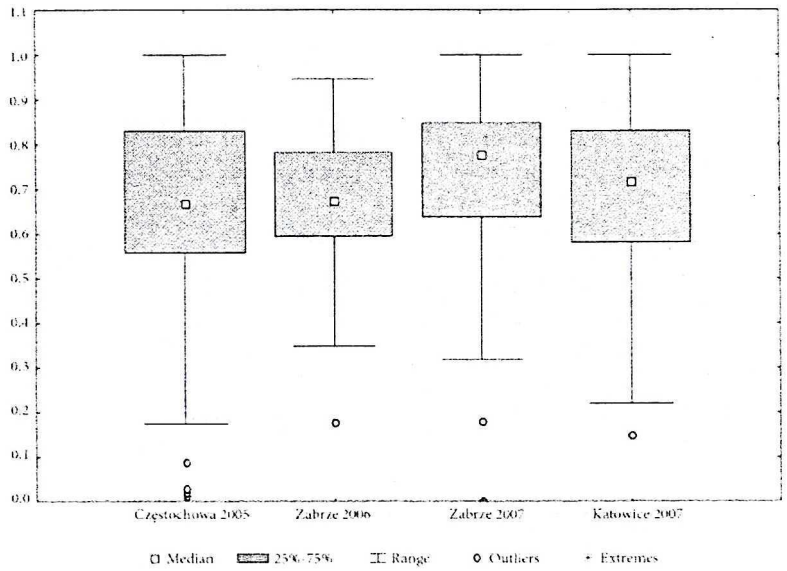

Fig. 2. The box plots for PM2.5/PM10 in winter seasons

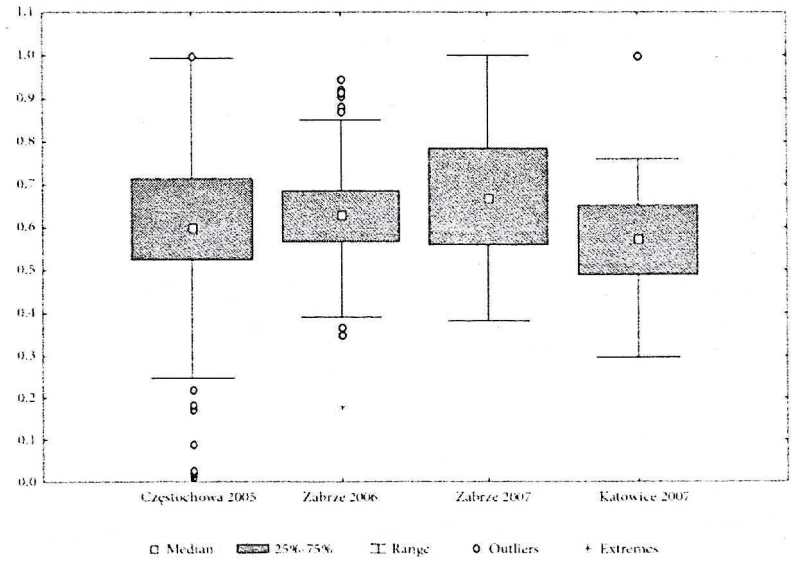

Fig. 3. The box plots for PM2.5/PM10 in summer seasons

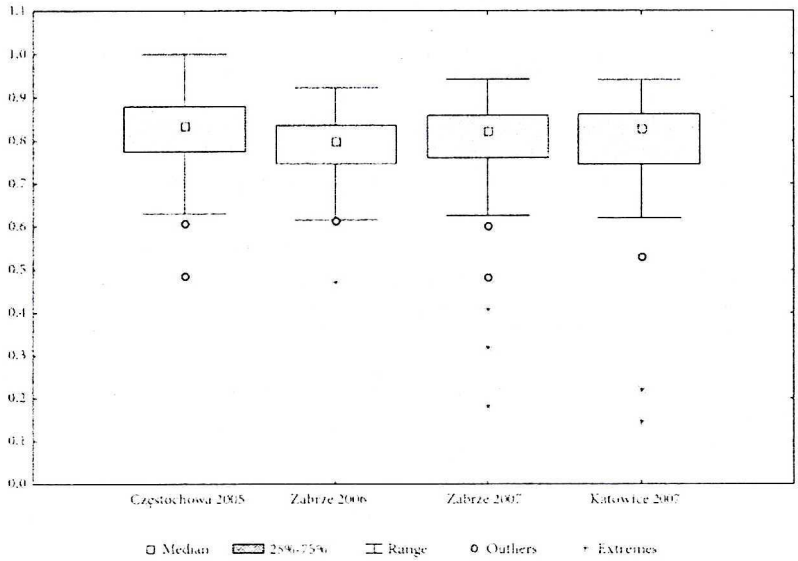

Fig. 4. The box plots for PM2.5/PM10 in 2005, 2006, 2007

The winter PM2.5/PM10 ranges are quite similar for all sites. All lower quartiles are about 0.75, upper – 0.88. Medians for all sites and periods are almost equal (about 0.8). The PM2.5/PM10 ratio is high – a probable effect of residential heating. The winter PM2.5/PM10 ratio is statistically specific of kind of the three places – urban background. Parameters of winter PM2.5/PM10 distributions for Zabrze in 2006 and 2007 are close, for Katowice and Zabrze in 2007 nearly the same.

The situation changes a little in summer (Fig. 3). The summer PM2.5/PM10 ratios are lower for each place and year. The highest ratio, about 0.79, is for Zabrze 2007. The ratio ranges are wider than in winter at each site and year. The lower quartiles differ noticeably, upper ones – significantly. The medians also differ for each place and year. Statistically, Częstochowa 2005, Zabrze 2006, Zabrze 2007 and Katowice 2007 differ in summer more than in winter in terms of the PM2.5/PM10 ratio. In summer, the number of higher PM2.5/PM10 values is greater in Zabrze 2007 than in Zabrze 2006. The Katowice 2007 summer PM2.5/PM10 ratios are lower than in Zabrze 2007 and less diversified.

Comparison of the winter PM2.5/PM10 ratios for Częstochowa 2005, Zabrze 2006, Zabrze 2007 and Katowice 2007 to the summer ones (Figs 2 and 3) suggests a large effect of municipal emission. In winter its impact dominates and traffic jams emission, equalizes the ratios. In summer, when there is no municipal emission, diversified influence of traffic occurs.

The yearly PM2.5/PM10 ratio series (Fig. 4) have high upper quartiles, exceeding 0.8, differing only a little for Częstochowa 2005, Zabrze 2007 and Katowice 2007. The upper quartiles for Zabrze 2006 is lower than 0.8. Medians for Częstochowa 2005, Zabrze 2007 and Katowice 2007 do not differ much. Medians for Zabrze 2006 and Zabrze 2007 differ more.

CONCLUSIONS

1. In winter, PM2.5 highly contributes to PM10 – it is a direct significant effect of the municipal emission.
2. Lowering of the share of PM2.5 in PM10 in summer suggests increased contribution of mineral fraction to immission.
3. The results of measurements in Częstochowa, Zabrze and Katowice are specific of urban background.
4. In the period under investigations, singular values of the PM2.5/PM10 ratio significantly differed from averages, but generally, the averages were close to averages in other European agglomerations.

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STRUKTURA AEROZOLU ATMOSFERYCZNEGO NA GÓRNYM ŚLĄSKU – UDZIAŁ PM2,5 W PM10 W CZĘSTOCHOWIE, ZABRZU I KATOWICACH W LATACH 2005–2007

Stosunek PM2,5/PM10 jest wskaźnikiem udziału pyłu pochodzenia antropogenicznego w zanieczyszczonym pyłem powietrzu na danym obszarze. Przeprowadzone w ostatnich latach badania w terenach silnie zurbanizowanych pokazują bardzo wysoki udział PM2,5 w PM10. Celem pracy jest zestawienie otrzymanych na przestrzeni trzech lat wyników jednoczesnych pomiarów PM2,5 i PM2,5–10 i porównanie udziałów PM2,5 w PM10 w trzech różnych punktach charakterystycznych dla tła miejskiego na Górnym Śląsku (Zabrze, Katowice, Częstochowa). Wyniki pomiarów prowadzonych w Częstochowie, Zabrzu i Katowicach są reprezentatywne dla obszarów tła miejskiego aglomeracji. W okresie badań stosunek PM2,5/PM10 w badanych miejscach niekiedy przyjmował pojedyncze wartości znacznie odbiegające od średnich, generalnie jednak wartości średnie nie odbiegają od średniego notowanego stosunku tych frakcji w aglomeracjach miejskich Europy.