The Size Distribution of Particulate Matter in the Aerosol of the Moravian-Silesian Region, Czech Republic

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Abstract

The particle size distribution in the fraction PM10 was determined by the electric low-pressure impactor ELPI+. Particles were divided into 14 classes in the range from 17 nm to 10 μm. The particle distribution was analysed during summer, autumn and winter periods of 2014 at the 10 sampling sites in the Moravian-Silesian Region, the Czech Republic. The highest particle concentrations were determined in the interval from 156 to 383 nm as well as in the wider interval up to 614 nm for all three seasons. More than 50% of the total particle amount occur in this interval except the locality Ostrava Radvanice, Ostrava Marianské Hory, Ostrava Poruba and Ostravice during the summer and Ostrava Marianské Hory during the transitional and winter season. During the summer, the distribution of the mass concentration of particles was very variable (bimodal for three localities, no significant peak for two localities, multimodal for four localities and unimodal for one locality). Seven in ten sampling sites has the bimodal distribution character of particle concentrations during transitional season, except for Ostrava–Poruba, Ostrava Marianské Hory and Třinec Oldřichovice. It was related to a resuspension of particles from soil or dust particles from transport. A second maximum is less distinctive and it occurs in the coarse fraction 2.39–4.0 μm. Entirely different character of particle distribution was determined in winter season when sampling sites had unimodal character of particle distribution. The bimodal distribution character was found for the locality Frýdek Místek and atypical character of particle distribution was confirmed for the locality Ostrava Marianské Hory (without trend). The unimodal character of particle distribution with maximum in the range from 156 to 263 nm is related to the prevailing chemical character of particles belonging to secondary aerosols (mascagnite, sal ammoniac, boussingaultite etc.).

Keywords: particulate matter, PM10, ELPI+, Moravian-Silesian Region (Czech Republic)

Introduction

Dust particles in the air can have a significant impact on human health. The degree of influence is connected partly with a particle size distribution contained in PM10 and their ability to penetrate into the body, and it also creates an environment for the adsorption of toxic and carcinogenic substances (Chung et al., 2008). Dust particles are divided according to the size into super coarse particles (> 10 μm), coarse particles (2.5–10 μm), accumulation mode particles (0.1 to 2.5 μm), Aitken mode - ultrafine particles (10 to 100 nm, they are affected by condensation and coagulation processes and occur mainly in the areas of vehicular traffic) and nucleation mode particles (15–40 nm) arising due to condensation and nucleation processes (Hsieh et al., 2009). Ultrafine particles originate from combustion, high-temperature processes and as a product of atmospheric reactions. Coarse particles are produced by the resuspension of dust (road dust and particles released by the weathering of soil), construction and demolition work, combustion and biogenic sources (Amann et al., 2006).

The percentage of dust particles in the individual particle size classes differs significantly depending on their origin and chemical composition. Total suspended particles (TSP) include particles PM_{10} 70–86%, $PM_{2.5}$ 50–70%, and PM1 53% (Alastuey et al., 2004; Keywood, et al., 1999). Particles $PM_{2.5}$ represent 70–90% of particles PM_{10}, and PM_1 particles represent 50–80% of PM_{10} (Ny and Lee, 2010; Keywood et al., 1999), PM1 accounts for 72% of $PM_{2.5}$ (Keywood et al., 1999). Air pollution caused by dust particles (PM_{10}) in the Czech Republic is a major problem, especially in the Moravian-Silesian Region. The aim of the article is to determine the relationship between the particle size distributions depending on the season.

Methods and sampling

For the collection of dust particles, the electrical low pressure impactor ELPI+ (Dekati), which

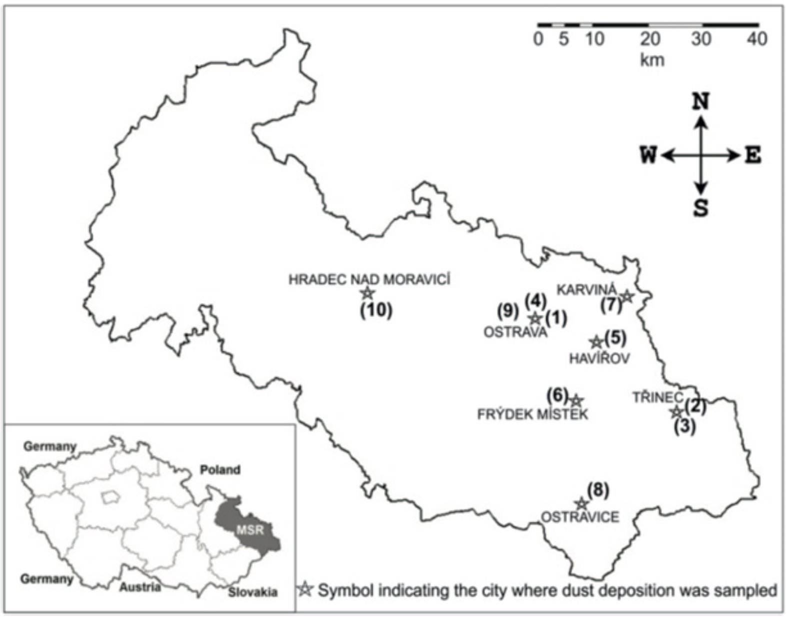


Fig. 1. Sampling sites: Ostrava Radvanice (1), Třinec (2), Třinec Oldřichovice (3), Ostrava Mariánské Hory (4), Havířov (5), Frýdek Místek (6), Karviná (7), Ostravice (8), Ostrava Poruba (9), Hradec nad Moravicí (10)

Rys. 1. Miejsca pobierania próbek: Ostrava Radvanice (1), Třinec (2), Třinec Oldřichovice (3), Ostrava Mariánské Hory (4), Havířov (5), Frýdek Místek (6), Karviná (7), Ostravice (8), Ostrava Poruba (9), Hradec nad Moravicí (10)

measures the particle size distribution in real time. ELPI+ captures particles from 17 nm to 10 microns (Lamminen, 2011; Roth et al., 2008). Particles entering the $ELPI^+$ units are first electrically charged on the basis of the aerodynamic diameter, and subsequently, they are sorted in the individual stages of the impactor, while the induced currents are recorded (Coudray et al., 2009). Dust particles were collected in three stages during 2014. The first stage took place during the summer season (9 June to 22 August), the second stage in the transitional season (25 August to 29 October), and the third stage in the winter (13 November until 19 December) at 10 selected locations with the Moravian-Silesian Region (Figure 1). The localities were divided into 4 groups based on the mineralogical analysis of the total dust deposition (the content of hematite and magnetite). Distribution of the localities:

I. Localities significantly affected by the metallurgical industry – 1, 2 and 3

II. Localities affected by the metallurgical industry – 4, 5 and 6

III. Localities less significantly affected by the metallurgical industry – 7 and 8

IV. Localities not significantly affected by the metallurgical industry – 9 and 10

Sampling of dust particles was carried out on a polycarbonate film which was always weighed on ultra-microbalance XP6U/M (Mettler Toledo) before and after sampling.

Results and discussion

PM_{10} concentration range, the mean value and the standard deviation for the groups of localities is listed in Table 1. During the summer, the highest average PM_{10} concentrations were observed for the localities affected by the metallurgical industry, with an average value of 14.3 μg/m^3. The lowest average PM_{10} concentrations in the summer were found in localities not affected by the metallurgical industry (6.23 μg/m^3), but on the contrary, during the transitional period, the highest average PM_{10} concentrations (24.1 μg/m^3) were found at these sites. The difference in the concentration is likely to be influenced by the contribution of local heating, which begins in this period. The lowest average PM_{10} concentrations were measured in a group of localities significantly affected by the metallurgical industry during the transition period. At the time of sampling, above the average high temperature was measured in these localities for this period. The resulting PM concentrations were not influenced by local heating of households. During the winter, high value of the average concentration for the group of localities significantly affected by the metallurgical industry (66.4 μg/m^3) was found. During sampling in the localities of Třinec and Třinec Oldřichovice there was an inversion.

Particle size distribution for 10 sampling sites during three distinguished seasons is illustrated in Figure 2. During the summer, the distribution of

Tab. 1. PM10 concentrations in µg/m3 for different seasons and localities affected by the metallurgical industry
Tab. 1. Koncentracja PM10 [µg/m^3] spowodowana przez przemysł metalurgiczny w różnych miejscach i różnych porach roku

	Summer period		Transition period		Winter period	
	The mass PM concentration range	Average+ standard deviation	The mass PM concentration range	Average+ standard deviation	The mass PM concentration range	Average+ standard deviation
I. Localities significantly affected by the metallurgical industry	8.1 - 16.40	12.00 ± 4.17	13.25 - 22.88	12.22 ± 5.04	30.23 - 98.26	66.43 ± 34.22
II. Localities affected by the metallurgical industry	7.88 - 19.58	14.28 ± 5.92	17.58 - 21.54	19.24 ± 2.06	17.70 - 32.84	25.10 ± 7.58
III. Localities less significantly affected by the metallurgical industry	11.24 - 15.15	13.19 ± 2.76	17.68 - 23.58	20.63 ± 4.18	19.54 - 24.42	21.98 ± 3.45
IV. Localities not significantly affected by the metallurgical industry	5.03 - 7.43	6.23 ± 1.7	22.04 - 26.18	24.11 ± 2.93	18.37 - 23.11	20.74 ± 3.35

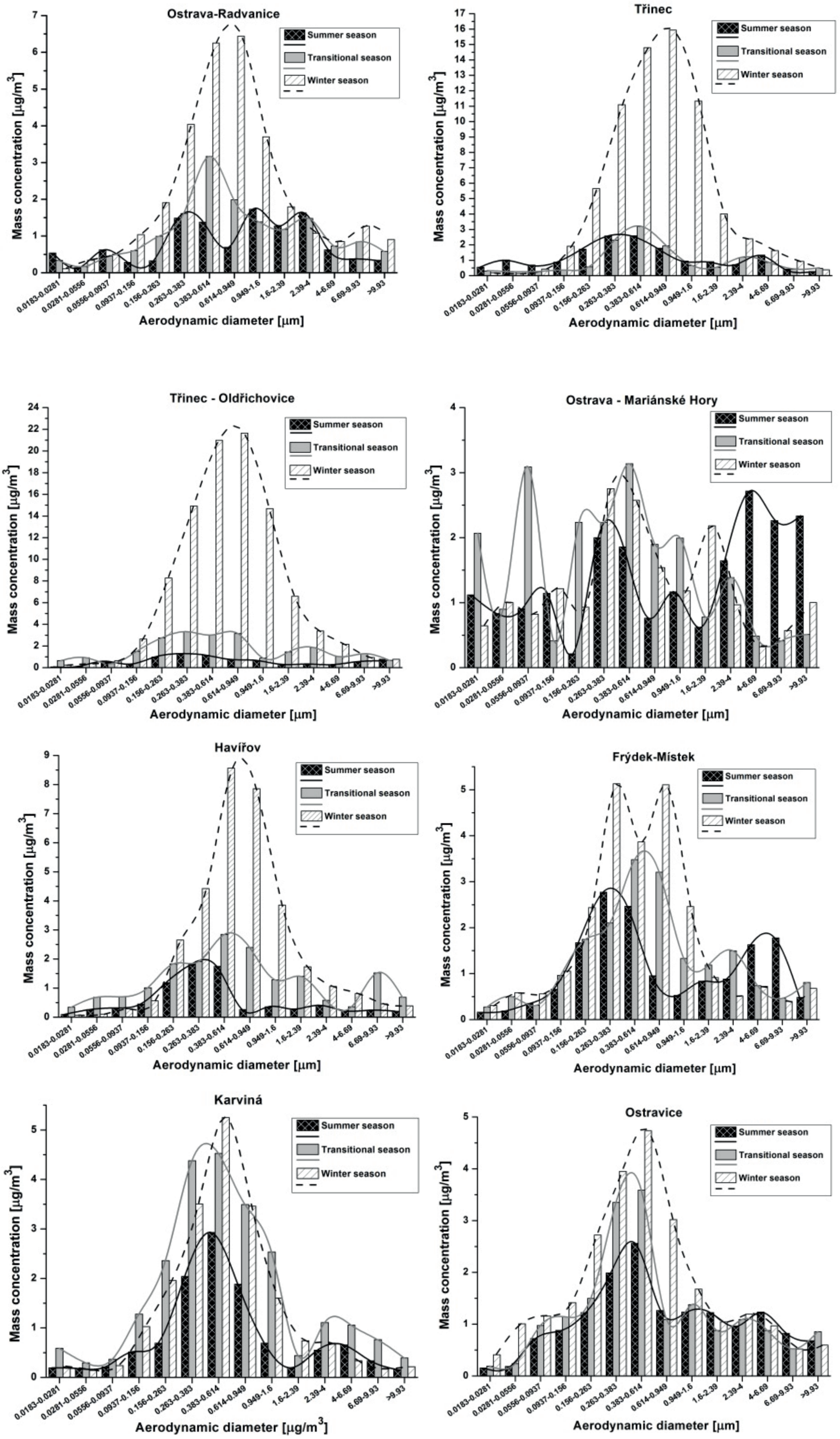
the mass concentration of particles was very variable. Pronounced bimodal nature in the coarse-grained class (about 4 µm) was demonstrated in the localities: Frýdek Místek, Karviná and Třinec. In the localities of Třinec Oldřichovice and Hradec nad Moravicí, there were no significant peak concentrations of particles in the fine-grained class. The localities of Ostrava Radvanice and Ostrava Marianské Hory, Ostrava Poruba and Ostravice reflected the multimodal character of the size distribution in the particle size classes. Unimodal character of the distribution of particles was only shown in Havířov.

During the transitional seasons, in seven of the ten localities, bimodal distribution of the mass concentration of PM was identified. The main peak in all 7 locations ranges from 156 to 614 nm (more than 50% of the particles can be found is in this range), and the second, less significant peak is represented by coarse particles ranging from 2.39 to 4 µm (7–15%). The highest concentration of particles for 7 locations is found in the class 263 to 383 nm. The locality of Ostrava Poruba is characterized by tri-modal data layout with the main peaks in the range 156 to 263 nm (18% of the total number of particles) and 383–614 nm (17%) and the third peak for the size of 4 µm (5%). The locality of Ostrava Marianské Hory is characterized by multimodal particle distribution, and for the locality of Třinec Oldřichovice, no significant concentration in any particle size class was detected.

During the winter season, eight of the ten sites showed a significant unimodal distribution of mass concentration of particulate matter with a peak in the range of 263–949 nm. The unimodal distribution of particles was found in Frýdek Místek and Ostrava Marianské Hory. In the interval from 263 to 949 nm, more than 54% of the total amount of particles are present. The highest concentration of particles in the class 263–383 nm was found in the locality of Havířov, Karviná, Ostravice, Ostrava Poruba, and Hradec nad Moravicí. In the localities of Ostrava Radvanice, Třinec, and Třinec - Oldřichovice, the highest concentration of particles was detected in the class from 383 to 614 nm. The locality of Ostrava Marianské Hory and shows no trend, and in the locality of Frýdek Místek, a significant bimodal character of particle size distribution with peaks in the class of 156–263 nm and 363–614 nm was found.

Similar results were also found for the Polish city of Zabrze during the winter and summer sampling campaign in 2007. During the summer, the distribution of PM concentrations was tri-modal with the main peak in the range of 0.26 to 0.65 µm (33% of the total number of particles), the second peak in the range of 2.5–4.4 µm (19%) and the third peak of 10 µm (13%). The winter sampling demonstrated unimodal distribution of concentrations with a peak concentration in the range of 0.17–1 µm, in which 74% of the total particles occur (Rogula-Kozłowska et al., 2012).

The distribution of particles into the individual particle size classes does not always show the same dependence within the monitored period. Only in 2 localities of Karviná and Ostravice,


Ostrava-Radvanice
Třinec
Třinec - Oldřichovice
Ostrava - Mariánské Hory
Havířov
Frýdek-Místek
Karviná
Ostravice
Summer season
Transitional season
Winter season
Mass concentration [μg/m3]
Aerodynamic diameter [μm]
Aerodynamic diameter [μg/m3]
0.0183-0.0281
0.0281-0.0556
0.0556-0.0937
0.0937-0.156
0.156-0.263
0.263-0.383
0.383-0.614
0.614-0.949
0.949-1.6
1.6-2.39
2.39-4
4-6.69
6.69-9.93
>9.93

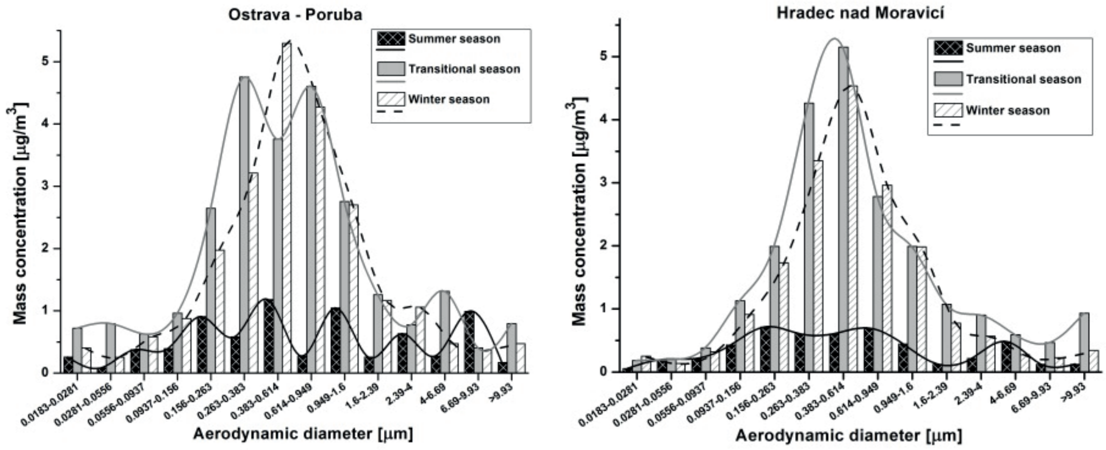


Fig. 2. Concentration of particles in the particle size classes for 10 localities

Rys. 2. Koncentracja pyłu o różnym uziarnieniu dla 10 miejsc pobierania próbek

maximum concentrations of particles in the particle size class of 263 to 383 nm was demonstrated over the entire period. Other sites may be affected by various factors (pollution source, long-distance transport, climatic conditions, etc.). The results of the particle distribution in the transitional period and in the winter period indicate that combustion processes result in the presence of particles of a size from 263 to 383 nm (60% of the measurement of the winter and intermediate season). The particle size class of 400 to 650 nm is characterized by the highest concentration of sulphates, nitrates, chlorides, and ammonium ions, in the particle size class of 200 to 400 nm, a concentration of nitrates is lower (Rogula-Kozlowska et al., 2013).

Conclusions

In the winter period, unimodal distribution of dust particles was demonstrated with a maximum in the class of 263–614 nm. In five localities, the maximum concentration of particles was found in the class of 263–383 nm, and in 3 localities significantly affected by the metallurgical industry (Ostrava Radvanice, Třinec, Třinec Oldřichovice), the highest concentration was found in the class of 383–614 nm. During the transition period, 7 of 10 localities showed the highest concentration of particles in the class of 263–383 nm. Seven localities showed a bimodal distribution of particle concentrations with a significant proportion of coarser particles (about 4 µm), which accounted for up to 15% of PM_{10}. In the summer period, the particle size distribution showed the highest variability in the particle size classes. Some localities appeared to have no significant maximum concentration for one particle size class, somewhere multimodal character prevailed. Only two locations (Karviná and Ostravice) showed the same maximum of the concentration of particles during all three sampled periods in class 263–383 nm. No relationship between particle size distribution and pollution that comes from the metallurgical industry was proven.

Acknowledgements

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Literatura – References

1. ALASTUEY, A., QUEROL, X., RODRÍGUEZ, S., PLANA, F., LOPEZ-SOLER, A., RUIZ, C. AND MANTILLA, E. 2004. "Monitoring of atmospheric particulate matter around sources of secondary inorganic aerosol." *Atmospheric Environment* 38: 4979-4992.
2. AMANN M., DERWENT R., FORSBERG B., HURLEY F., KRZYZANOWSKI M., KUNA-DIBBERT, B., LARSSEN S., DE LEEUW, F., LIU, S.J., SCHNEIDER, J., SCHWARZE, PER E., SIMPSON, D., STEDMAN, J., STRAEHL, P., TARRASÓN, L., AND VAN BREE, L. 2006. *Health risks of particulate matter from long-range transboundary air pollution.* Denmark.
3. COUDRAY, N., DIETERLEN, A., ROTH, E. AND TROUVÉ, G. 2009. "Density measurement of fine aerosol fractions from wood combustion sources using ELPI distributions and image processing techniques." *Fuel* 88: 947–954.
4. HSIEH, L-Y., KUO, S-CH., CHEN, CH-L. AND TSAI, Y.I. 2009. "Size distributions of nano/micron dicarboxylic acids and inorganic ions in suburban PM episode and non-episodic aerosol." *Atmospheric Environment* 43: 4396–4406.
5. CHUNG, W., SHARIFI, V.N, SWITHENBANK, J., OSAMMOR, O. AND NOLAN, A. 2008. "Characterisation of Airborne Particulate Matter in a City Environment." *Modern Applied Science* 2.
6. KEYWOOD, M.D., AYERS, G.P., GRAS, J.L., GILLETT, R.W. AND COHEN, D.D. 1999. "Relationships between size segregated mass concentration data and ultrafine particle number concentrations in urban areas." *Atmospheric Environment* 33: 2907–2913.
7. LAMMINEN, E. 2011. "Accurate measurement of nanoparticle charge, number and size with the ELPI™ instrument." *Journal of Physics: Conference Series*.
8. NY, M.T, AND LEE, B.-K. 2010. "Size Distribution and Source Identification of Airborne Particulate Matter and Metallic Elements in a Typical Industrial City." *Asian Journaul of Atmospheric Environment* 4: 9–19.
9. ROGULA-KOZŁOWSKA, W., KOZIELSKA, B., BŁASZCZAK, B. AND KLEJNOWSKI, K. 2012. *The Mass Distribution of Particle-Bound PAH Among Aerosol Fractions: A Case-Study of an Urban Area in Poland, Organic Pollutants Ten Years After the Stockholm Convention - Environmental and Analytical Update*. Dr. Tomasz Puzyn (Ed.).
10. ROTH, E., KEHRLI, D., BONNOT, K. AND TROUVÉ, G. 2008. "Size distributions of fine and ultrafine particles in the city of Strasbourg: Correlation between number of particles and concentrations of NO_x and SO_2 gases and some soluble ions concentration determination." *Journal of Environmental Management* 86: 282–290.

Skład ziarnowy pyłu zawieszonego w Regionie Śląsko-Morawskim, Czechy

Rozkład wielkości cząstek pyłu zawieszonego PM10 oznaczano miernikiem niskociśnieniowym ELPI. Cząstki podzielono na 14 grup w zakresie od 17 nm do 10μm. Rozkład cząstek analizowano w okresach letnich, jesiennych i zimowych w 2014 roku. Próbki pobrano w 10 miejscowościach w regionie morawsko-śląskim, w Czechach. Największe stężenie cząstek oznaczono w przedziale od 156 do 383 nm, a także w szerszym przedziale do 614 nm we wszystkich trzech sezonach. Powyżej 50% całkowitej ilości cząstek występuje w tym przedziale, z wyjątkiem miejscowości Ostrava Radvanice, Ostrava Mariańskich Hory, Ostrava Poruba i Ostrawica latem i Ostrawie Mariańskich Górach czasie przejściowym i zimowym. Latem rozkład stężenia masowego cząstek był bardzo zmienny (rozkład bimodalny dla trzech miejscowości, bez znaczącego piku dla dwóch miejscowości, multimodalny dla czterech miejscowości i unimodalny dla jednej miejscowości). Siedem na dziesięć miejsc pobierania próbek ma dwumodalny charakter rozkładu stężenia cząstek w sezonie przejściowym, z wyjątkiem lokalizacji Ostrava-Poruba, Ostrava Mariańskich Hory i Třinec Oldrzychowice. Wiązało się to z ponownym unoszeniem cząstek pyłu z gleby lub z transportu. Drugie maksimum jest mniej charakterystyczne i występuje w gruboziarnistej frakcji 2.39-4.0 μm. Zupełnie inny charakter rozkładu cząstek określono w sezonie zimowym, kiedy rozkład cząstek miał charakter unimodalny. Bimodalny charakter rozkładu został stwierdzony w miejscowości Frydek Mistek, nietypowy charakter rozkładu cząstek został potwierdzony w miejscowości Ostrava Mariańskie Hory (bez trendu). Jednorodny charakter rozkładu cząstek z maksimum w przedziale od 156 do 263 nm jest związany z występowaniem aerozoli wtórnych (maskagnitu, soli, amoniaku, itp).

Słowa kluczowe: pył, PM10, ELPI+, Region Śląsko-Morawski (Republika Czeska)