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Geochemical and isotopic analyses of PM₁₀ in Lower Silesia - preliminary data

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PM₁₀ dust, carbon isotopic analyses,
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ABSTRACT

The main aim of the study was to determine the origin of particulate air pollution in Lower Silesia. Samples of PM₁₀ dust were collected on quartz filters Whatman QM-A by employees of Voivodship Inspectorate for Environmental Protection (VIEP) in Wrocław in 2011. As a pilot researches in Lower Silesia were selected two monitoring points of VIEP: (i) Osieczów and (ii) Zgorzelec. Air sampling point in Osieczów is a point of regional background and it is an excellent reference base for the analyses of PM₁₀ in Lower Silesia. The aim of monitoring in this point is to assess the exposure of ecosystems to air pollution. Sampling point in Zgorzelec reflects the urban background and the measurements will be compared, in the future, to the results of the sampling points investigated the impact of industry and local transport on air quality in the whole Lower Silesia. For further geochemical and isotopic analyses were selected 25 samples from each sampling

point, average every two weeks measurement. The concentration of PM₁₀ dust for Osieczów ranged from 7 µg·m⁻³ (11.10.2011r.) to 89 µg·m⁻³ (4.03.2011r.) with an average of 24 µg·m⁻³ and for Zgorzelec between 10 µg·m⁻³ (11.10.2011r.) and 85 µg·m⁻³ (9.11.2011r.) with an average of 26 µg·m⁻³. The mean percentage contribution of carbon in PM₁₀ samples from Osieczów was 47%, while in Zgorzelec 42%. The obtained values of δ¹³C (PM₁₀) in Osieczów varied from -31.1‰ (5.02.2011r.) to -25.5‰ (26.10.2011r.) with an average of -27.6‰, whereas in Zgorzelec between -28.6‰ (15.07.2011r.) and -25.2‰ (6.01.2011r.) with an average of -26.8‰. At the current stage of research is clearly discernible the different carbon isotope record in the material dust (qualitative information), despite the identical range of concentrations of PM₁₀ in both analysed points (quantitative information). This confirms the appropriateness of the choice both research method and monitoring points.

Introduction

In XXI century air pollution is a very important civilization issue. All of substances which have negatively influence on people's health, properly working ecosystems or for people's products (buildings, sculptures etc.) are called pollution (VIEP 2011). Due to their physical character they are distinguished for dust and gaseous pollution. Gaseous pollutants are i.a. sulphur dioxide (SO_2), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), while dust pollutants are TSP (total suspended particles), PM_{10} (particulate matter with particle diameter less than $10\ \mu\text{m}$), $\text{PM}_{2.5}$ ($<2.5\ \mu\text{m}$) and PM_1 ($<1\ \mu\text{m}$). A group of elevated risk: children, elderly people and pregnant women are mainly subjected to negative influence of dust pollutants. Dust concentration cutting in atmospheric air is also very important issue because very often very high value of dust regional background are measured. According to Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (also known as CAFÉ Directive) 24-hour standards of maximum levels for the content of PM_{10} in Poland is $50\ \mu\text{g}\cdot\text{m}^{-3}$ - maximum 35 times per year (black line on Fig. 3) but yearly average limit is $40\ \mu\text{g}\cdot\text{m}^{-3}$. Currently for $\text{PM}_{2.5}$ are allowed to exist some overruns but till 2015 the level of $\text{PM}_{2.5}$ must be $25\ \mu\text{g}\cdot\text{m}^{-3}$ and till 2020, the level could not exceed $20\ \mu\text{g}\cdot\text{m}^{-3}$ (CAFE Directive). Among all air pollution dust hazards are one of the most dangerous for the environment and human health because of their mobility and can affect all ecosystem elements - water, air, soil and life forms.

It should be emphasized that the $\text{PM}_{2.5}$ is up to 90% of PM_{10} . At the same time there is no clarified threshold below which effects of $\text{PM}_{2.5}$ is not harmful to humans. So fine particles have the ability to penetrate the human respiratory system down to the level of the alveoli and further into the bloodstream. They are causes of respiratory diseases (silicosis, asthma, chronic allergies) and circulatory system acid (Juda-Rezler 2000). European Union Member States shall make every effort to reduce air pollution, especially in areas densely populated by humans. In the cities people are exposed mainly to the negative effects of pollution from industry, transport, and from the so-called low emissions from the home furnances. Outside the cities the problem of air pollution may come from agriculture, biomass burning and in coastal areas from sea spray. Network monitoring of the PM_{10} and $\text{PM}_{2.5}$ concentration is well developed in Poland by Voivodship Inspectorates for Environmental Protection measuring stations. They measure only the amount of harmful substances but not indicate the origin of analysed pollutants whether the direction of transport. The aim of this study was to determine the geochemical composition of the dust in Lower Silesia basing on isotopic analyses of $\delta^{13}\text{C}$. The analyses of isotopic ratios of the substances help to determine the origin of air pollutants. In earlier studies of carbon isotope composition of PM_{10} it is recognized that basing on known isotopic signal is possible to distinguish the individual dominant sources of pollution in the atmosphere (Widory et al. 2004, Kelly et al. 2005, López-Veneroni 2009).

Fig. 1 Monitoring points of Voivodship Inspectorates for Environmental Protection selected for studies: Osieczów and Zgorzelec.



Study area and sampling

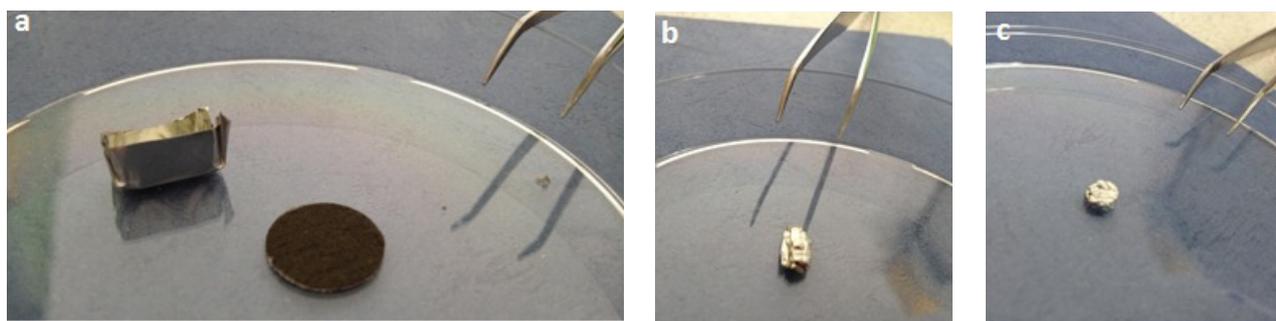
The study of this work is part of a larger project carried out for the whole province of Lower Silesia which covers nine points. For the pilot researches two points of air monitoring in Lower Silesia were selected:

- (i) Osieczów - point of regional background where ecosystems exposure to atmospheric pollution is studied; it is an excellent basis for comparison of the entire study area; latitude: E 15° 25'54", longitude: N 51° 09'04"
- (ii) Zgorzelec - point of urban background where the impact of anthropogenic pollution in the urban environment of Zgorzelec city is studied; it is a background for comparison with other similar points in Lower Silesia; latitude: E 15° 01'30", longitude: N 51° 08'40".

For this studies were selected samples with PM₁₀ dust deposited on a Whatman quartz filters gathered approximately every two weeks in 2011 by employees of the Voivodship Inspectorate for Environmental Protection in Wrocław. Geochemical and isotopic analyzes were carried out for 25 samples inclusively of both points. The samples with diameter of 6 mm were filters and packed in tin capsules with dimensions of 6 x 6 x 12 mm.

Concentrations of C and N were carried out by Elemental analyzer NC Instruments NC 2500, while isotopic analyses of $\delta^{13}\text{C}$ were carried out by IsoPrime100 CF-IRMS coupled to an elemental analyzer Vario Micro Cube. Analyses were carried out at Université du Québec à Montréal.

Fig. 2 Sample prepared for analyse.



Results

Fig. 3 Concentration of PM₁₀ dust in Osieczów (blue) and Zgorzelec (green) in 2011 (data of VIEP).

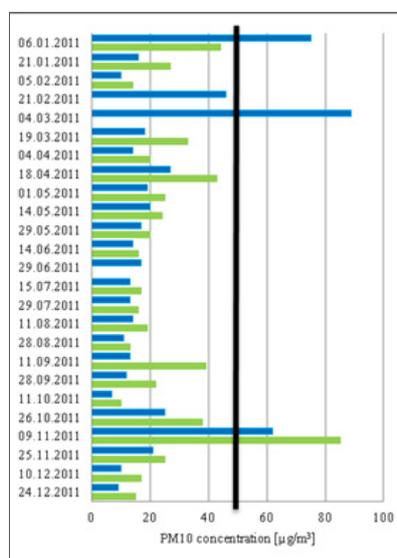
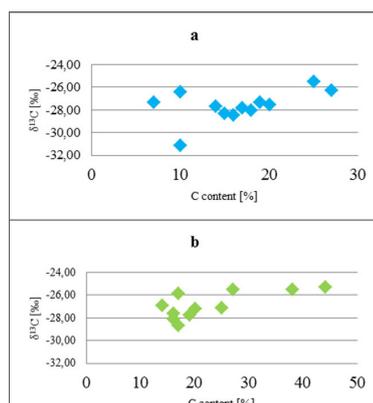


Fig. 4 Relationship of percentage contents of C in PM₁₀ dust and $\delta^{13}\text{C}$ values in PM₁₀ dust samples (a – Osieczów, b – Zgorzelec).

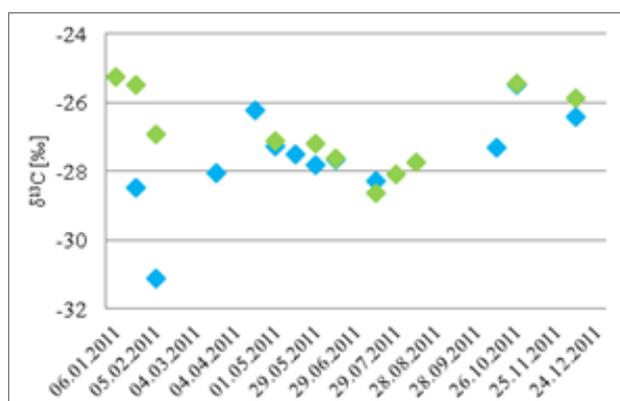


The levels of PM₁₀ concentrations of chosen points in 2011: (i) Osieczów (blue) and (ii) Zgorzelec (green) are presented in Fig. 3. In Osieczów in 2011 concentration of PM₁₀ ranged from 7 $\mu\text{g}\cdot\text{m}^{-3}$ to 89 $\mu\text{g}\cdot\text{m}^{-3}$ (4.03.2011) to with mean value of 24 $\mu\text{g}\cdot\text{m}^{-3}$. In Zgorzelec in 2011 concentration of PM₁₀ ranged from 10 $\mu\text{g}\cdot\text{m}^{-3}$ (11.10.2011) 85 $\mu\text{g}\cdot\text{m}^{-3}$ (9.11.2011) to with mean value of 26 $\mu\text{g}\cdot\text{m}^{-3}$.

In Osieczów (Fig. 4a) percentage contents of C ranged from 32.97 % (14.05.2011r.) to 77.84 % (11.10.2011r.) with mean value of 47 %. In Zgorzelec (Fig. 4b) percentage contents of C ranged from 30.78 % (1.05.2011r.) to 60.73 % (21.01.2011r.) with mean value of 42 %. The $\delta^{13}\text{C}$ values (PM₁₀) in Osieczów varied from -31.1‰ (5.02.2011r.) to -25.5‰ (26.10.2011r.) with mean value of -27.6‰ (Fig. 5 blue solid symbols). The $\delta^{13}\text{C}$ values (PM₁₀) in Zgorzelec varied from -28.6‰ (15.07.2011r.) to -25.2‰ (6.01.2011r.) with mean value of -26.8‰ (Fig. 5 green solid symbols).

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Fig. 5 Isotopic composition of $\delta^{13}\text{C}$ in PM10 dust in 2011 (blue solid symbols – Osieczów, green solid symbols - Zgorzelec).



Discussion

The aim of this study was to identify potential sources of dust in Lower Silesia using $\delta^{13}\text{C}$ isotopic analyses of PM10 dust and to try to assess effect of human impact in the study area. To this pilot researches two points were determined: (i) the regional background in Osieczów and (ii) urban background in Zgorzelec.

The highest concentration of PM10 in Osieczów in 2011 was $89 \mu\text{g}\cdot\text{m}^{-3}$ with an average of $24 \mu\text{g}\cdot\text{m}^{-3}$, while in Zgorzelec the highest concentration of PM10 was $85 \mu\text{g}\cdot\text{m}^{-3}$ with an average of $26 \mu\text{g}\cdot\text{m}^{-3}$. In sampling points in Lower Silesia overruns of maximas were noted three times for Osieczów and one for Zgorzelec (Fig. 3). It should be remembered that for this studies were selected only 25 days in 2011. At the sampling point in Osieczów there were expected to get the minimum number of days per year with exceeded of limits, because it is a point of regional background, which means that it should be the least contaminated. Basing on a number of previous studies on particulate matter we know that dust pollution are not only issued in situ, but they can come up with some long-range transport (Cachier et al., 1986, Grivas et al. 2008). To ensure there are needed additional modeling analyses of movement of air masses. Sampling point in Zgorzelec showed once exceeding the limit values for dust among measurement days selected for the analyses, and the yearly average concentration was slightly higher than in the case of the regional background in Osieczów.

The values of isotopic composition of $\delta^{13}\text{C}$ in sampling points differed greatly depending on the sampling point. In Osieczów $\delta^{13}\text{C}$ (PM10) values varied from -31.1‰ to -25.5‰ , which point at presence of many potential

sources of dust pollution on studied area (Fig. 4a). Basing on the known values of $\delta^{13}\text{C}$ for individual emitters in Osieczów source of contamination can be determined from plant fragments (about -31.1‰) (Kelly et al. 2005). In 2003-2005 Górka and Jędrysek obtained values of $\delta^{13}\text{C}$ for pollutants in Wrocław, Lower Silesia. Values of $\delta^{13}\text{C}$ for fragments of plants were: for grass -30.5‰ and for leaves -27.3‰ (Górka and Jędrysek 2008). From the combustion of diesel and other liquid fuels ($-26.5\text{‰} \pm 0.5$) as well as from the combustion of coal (about -25‰) (Widory et al. 2004). In Wrocław For the combustion of fossil fuels $\delta^{13}\text{C}$ values were obtained: low-quality coal -24.2‰ , high-quality coal -25.7‰ , diesel and gasoline soot -28.3‰ and -26.8‰ respectively (Górka and Jędrysek 2008). Assuming that sampling point in Osieczów is chosen as regional background point it was expected that there will not be one dominant source, but a mixture of pollutants, both anthropogenic and natural, what could be observed in Fig. 5. In Zgorzelec can be observed a seasonal variability of dust pollution sources depending on the season. During the heating season (January-April and October-December) $\delta^{13}\text{C}$ values range from -26.90‰ to -25.24‰ , while in the growing season -28.63‰ (Fig. 4b, Fig. 5). Enrichment of ^{13}C isotope during the heating season clearly underlines the dominant contribution of pollutants from the combustion of fossil fuels and transport (Widory et al. 2004). Significant depletion in ^{13}C during the growing season indicates a natural origin of dust (eg. plant fragments) (Kelly et al. 2005).

Summary

An important signal is the absence of one dominant source of dust pollution in Osieczów, which indicates the presence of a mixture of natural and anthropogenic pollutants in the studied area. Osieczów is therefore an ideal point for regional background where a comparison with the remaining area of Lower Silesia is observed. The seasonal variability of the distribution of dust in Zgorzelec at urban background point is observed. During the winter in the city the dominant source of PM₁₀ are impurities from the low emissions, mainly from burning coal and from transport. During

the summer there are observed depletion in ¹³C: (i) sources derived from combustion of liquid fuels - transport or (ii) the fragments of C₃ plants.

Results of pilot researches show that sampling points (i) the regional background in Osieczów and (ii) the urban background in Zgorzelec have been well selected for analyses and will become points of reference for further research into the origins of dust in Lower Silesia. Overruns of PM₁₀ dust concentrations on studied area require reduction and qualitative researches of atmospheric pollution may be a very useful tool.

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