RECEPTOR ORIENTED MODELING FOR REVEALING AIR POLLUTION EMISSION SOURCES AFFECTING AN URBAN AREA

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Abstract:
In this study, we have determined PM (particulate matter) emission sources and some of the criteria air pollutant transport contribution at various locations in the Belgrade area by applying advanced receptor-oriented models, as well as the pre-processing of concentrations and air back trajectories. As shown, the monitoring locations were most directly exposed to PM emissions from the nearest surrounding. Further, the background levels and air pollution transport mostly contributed to the observed SO_2 (70%) and NO_2 levels (45%).

Keywords:
Particulate Matter, Air Pollution Transport, Receptor Oriented Models.

INTRODUCTION

Low air quality represents a particular problem in urban areas due to overpopulation, a large number of emission sources, and topographic features which prevent the dispersion of pollution. The cities, in which around 85% of global economic activity takes place, currently contain 55% of the world's population, and it is expected that two-thirds of the world's population will live in metropolitan areas by 2050. The World Health Organization estimates that the highest number of deaths related to atmospheric pollution was registered as a consequence of ischemic cardiovascular diseases, heart attacks and strokes (80%), and chronic obstructive pulmonary disease (11%), while a significantly lower number of deaths occurred as a consequence of lung cancer (6%) and acute inflammation of the lower respiratory tract in children (3%). The health effects of air pollutants vary depending on the type of pollutant, i.e., size and composition of suspended particles, the concentration of species, and the length of exposure.

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The concentrations of pollutants in the air on the territory of Belgrade area are a consequence of intensive emissions mainly from local anthropogenic sources, which can be related to the increase in population, in the number of motor vehicles, inadequate investment in the energy sector, and outdated technologies in the economic sector.

In terms of sources of pollutant emissions in the city, the following can be emphasized as significant: fossil fuel burning for energy production (heating plants, thermal power plants, boiler rooms, individual furnaces, i.e., around 300,000 individual chimneys), some industrial facilities, traffic, as well as small and medium production processes.

On the other hand, air circulation in complex topographic and meteorological conditions of the urban environment potentially leads to long retention or accumulation of pollution in certain locations, which further causes large differences in the exposure of the population in spatially close locations.

The aim of this paper is to determine emission sources of suspended particulate matter at various locations in Belgrade area by applying advanced receptor-oriented models, as well as the pre-processing of concentrations and air back trajectories.

2. MATERIALS AND METHODS

The analysis of regional transport and the assessment of pollutant emission sources was conducted by using receptor-oriented models developed within the project "Mapping of sources of toxic, mutagenic, and carcinogenic volatile organic compounds in the city of Belgrade", funded by the Green Fund of the Ministry of Environmental Protection of Serbia. The description of the methods can be found elsewhere [1].

The analysis of the contribution of regional transport was done by using the method of concentration weighted boundary layer - CWBL [2]. The method provides data on the three-dimensional distribution of pollutants based on the measured concentrations at the receptor site (measurement site), the air mass transport path and the height of the planetary boundary layer along the transport path. Based on [3], [4], [5], [6], [7], and [8], using CWBL, it is possible to estimate the regional transport of pollutants within the planetary boundary layer by determining concentrations at higher altitudes above the Earth's surface. The description of the method is presented elsewhere [2].

3. RESULTS AND DISCUSSION

Within the analysis of air quality, it is crucial to separate the different contributions to the total measured concentrations at the selected monitoring site. One way to do it is to distinguish between the contribution of emissions from local sources in the immediate vicinity of the measuring location, the contribution of regional and long-range transport, and the share of air pollution background. As can be seen in the time series of PM_{10} and SO_2 concentrations (Figure 1), narrow and high peaks are superimposed on a wider and much lower base level. The peaks probably originate from the local emission in the immediate vicinity of the measuring point, whereas the baseline level can be assumed to originate from the transported air pollution and the background.

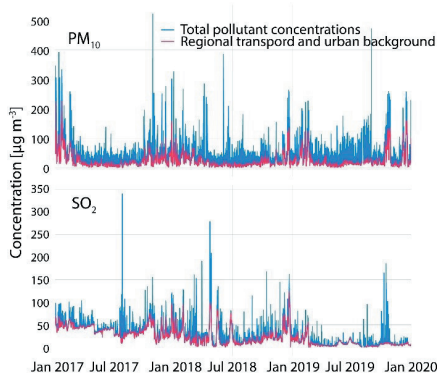

Figure 1 - An example of separating the contribution of emissions from local sources from regional transport and the background of the urban environment at the measuring point of the City Institute for Public Health Belgrade in the period from 2017 to 2019

The example shown in Figure 1 shows a different structure of PM_{10} and SO_2 concentration time series. Unlike PM_{10}, SO_2 concentrations are characterized by the less frequent occurrence of narrow peaks superimposed at the baseline level. This can be an indicator of the high contribution of background and/or regional transport to the total concentrations in the urban environment. The most important sources of SO_2 in urban areas are related to the combustion of fossil fuels for heating purposes. The position of stationary, point sources (chimneys) that are more distant and mostly distributed in a wider area without a direct impact on the monitoring station leads to the less pronounced pollutant concentration dynamics. In addition to the specificity of the emission sources, the position of the

monitoring station at the Institute for Public Health Belgrade in the canyon type street can also be the cause of high levels of urban background due to the retention and accumulation of air pollution.

The share of regional transport and background averaged at all monitoring locations of automatic monitoring (Figure 2) is the highest in the case of SO_2 when compared to all other analyzed pollutants (70%). The estimated contribution of regional transport and the background to the measured concentrations of suspended particles and nitrogen oxides is moderate and ranges from 45% to 55%. In the case of suspended particles, the existence of frequent short-term peaks in the time series (Figure 1) is an indicator of the dominance of local emission sources. The reason for this dynamics can be the direct exposure of the monitoring station to a certain type of emissions (mobile sources - traffic and transport, resuspension, and local economic activities), but also the processes of dry and wet deposition that contribute to faster removal of particles from the air. Of nitrogen oxides, it was estimated that the share of regional transport and air pollution background is the highest in the case of NO_2, which is a consequence of greater stability of the compound and therefore, the possibility of its transport over long distances, but also the formation of this compound as a secondary pollutant in the reactions of photochemical transformations in the atmosphere.

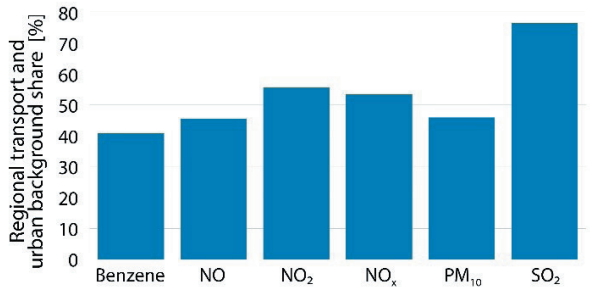

Figure 2 - The share of regional transport and the background of the urban environment with the measured concentrations of pollutants in Belgrade in the period from 2017 to 2019

By applying multireceptor-oriented models to PM10 concentrations measured at 6 automatic monitoring locations in the period from 2017 to 2019, the distribution of regional sources and sources located on the periphery of the agglomeration, which affect air quality in central urban area was obtained (Figure 3).

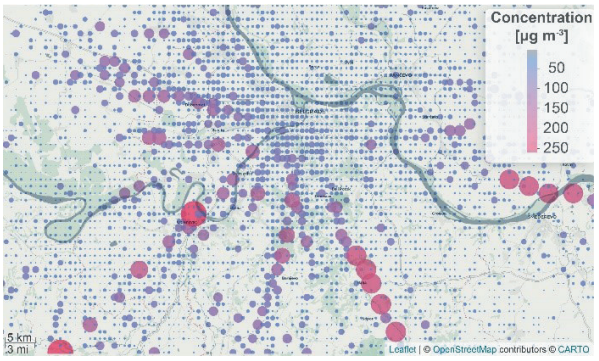

Figure 3 – The distribution of regional sources of PM_{10} emissions on the territory of Belgrade and neighboring municipalities in the period from 2017 to 2019

The results of the analysis show that the area of Belgrade is exposed to the impact of regional sources of PM_{10} emissions located south, southwest, and southeast of the city, as well as slightly less impact of sources located in the areas west and east of the analyzed area. Significant emission sources in the southwestern areas on the outskirts of the agglomeration can be associated with the thermal power plant "Nikola Tesla" near Obrenovac, as well as with somewhat more distant mining basins near Veliki Crljeni. Apart from that, a source in the southeastern area that has an impact on the urban zone of Belgrade can be attributed to the Vinča city landfill, whereas several identified sources on the left bank of the Danube, outside the agglomeration, can be linked to agricultural activities in Banat. Regional sources of suspended particles whose impact is estimated to be significant, and which are located southeast at a greater distance, can be connected with "Železara Smederevo", as well as with the thermal power plant and coal mine "Kostolac". In the western region of Belgrade, along the international highway E-70, sources of slightly lower intensity have been identified, which can be attributed to traffic activities. Also, it should be taken into consideration that a large number of facilities of small economic activities (production plants, processing and storage of goods) have been built in this area in recent years, whose emissions also contribute to air pollution. Figure 3 also shows PM_{10} emission sources located south of Belgrade, which most likely represent the contribution of more remote areas, or even part of the long-distance cross-border transport route.

4. CONCLUSION

Apart from the influence of local sources, the air quality in the area of Belgrade is affected by various distant sources of emissions. The impact of strong local sources was least noticed in the case of sulfur dioxide, while monitoring locations were most directly exposed to suspended particulate emissions from the immediate environment (mobile sources - traffic and transport, resuspension, and local economic activities). On the other hand, the share of background and transport of air pollution was the highest in the case of SO_2 - 70% (combustion of fossil fuels for heating and pollutant transport from remote power plants) and NO_2 - 45% (pollutant transport and formation in photochemical atmospheric transformations).

The analysis of the contribution of regional pollutant transport to the measured PM_{10} concentrations has shown a significant impact of sources located southeast ("Železara Smederevo" and thermal power complex "Kostolac") and southwest (thermal power plants "Nikola Tesla" and mining basin "Tamnava") from Belgrade. The contribution of somewhat weaker sources located in the western area of Belgrade, can be related to traffic activities along the international highway E-70 and economic activities in its surroundings. For detailed characterization of the identified emission sources, and thus the improvement of insufficiently updated emission inventories, it is necessary to include other pollutants in the analysis and to apply the most advanced artificial intelligence methods.

5. ACKNOWLEDGEMENTS

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