Impact of meteorological conditions on the spatial distribution of PMx concentration in the Wrocław and Bydgoszcz agglomerations in the light of mobile measuremants

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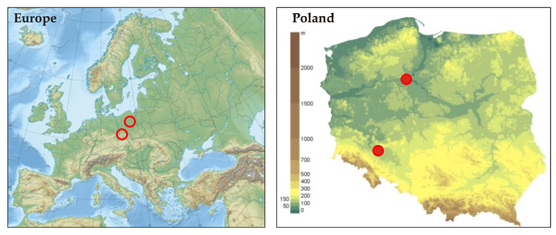
Study area

Wroclaw is the fourth largest Polish city in terms of population (637,000 inhabitants), Bydgoszcz, on the other hand, belongs to medium-sized cities with a population of 347,000 inhabitants. In both cities the air quality in their area is close to the EU permissible level - the average PM_{10} concentration for the years 2011-2019 was 34.2 μgm^{-3} in Wrocław, and 37,4 μgm^{-3} in Bydgoszcz. In some years, depending on meteorological conditions in winter season, PM_{10} concentrations slightly exceeds annual permissible level of 40 μgm^{-3}.

Such high concentrations of PM are primarily due to the widespread use of solid fuels for household heating, which is confirmed by a very high number of days with excess of the daily limit of 50 μgm^{-3} - an average of 57 days in Wrocław and 67 days in Bydgoszcz, per cold season.

Despite such bad aerosanitary conditions, official air quality information in Wroclaw and Bydgoszcz is based only on data from stationary measurements conducted at a few measurement stations - three in Wrocław (two - traffic station and urban background station operated by General Inspectorate of Environmental Protection, and one station operated by University of Wrocław) and two in Bydgoszcz (traffic and urban background station, both operated by General Inspectorate of Environmental Protection). Information from these stations gives only a general picture of the conditions in the cities, not taking into consideration the specific conditions of its individual districts and meteorological conditions related eg. to the dispersion of pollutants in the city area. It is true that in recent years this data has been supplemented by data from commercial measurement networks based on low-cost sensors, but they are of uncertain quality and often not fully available.

For this reason, in order to identify in detail the spatial differentiation of PM concentration in the area of the studied cities, especially in zones not covered by standard monitoring, mobile measurements are carried out. These measurements are carried out under the LIFE-MAPPINGAIR/PL Project. In the case of Wrocław, they are a continuation of the measurements started in 2016 as part of the LIFE-APIS/PL Project, in the case of Bydgoszcz, the surveys began at the beginning of 2020.



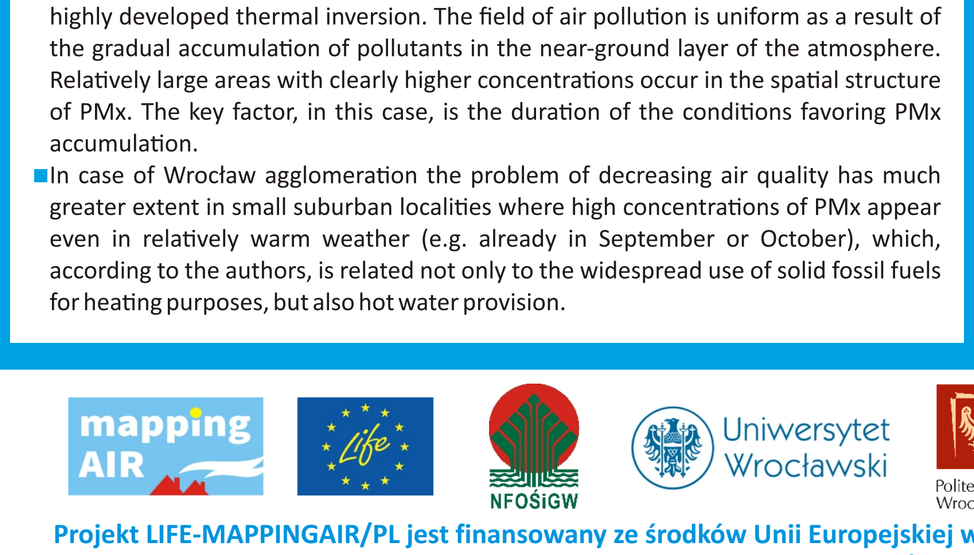
Aims of the study

The main aim of the study was to determine spatial variability of PM concentrations in the city of Wrocław together with its metropolitan area (SW Poland) and in the city of Bydgoszcz (NW Poland) in various weather conditions. The results of the measurements are used to detail and enrich the air pollution data obtained in stationary measurements. Such detailed data enable to provide tools for optimal air quality management and build social awareness. Furthermore, the results are used to verify and provide additional input data for air quality modeling system developed within the LIFE-APIS/PL Project and continued within the LIFE-MAPPINGAIR/PL Project.

Material and methods

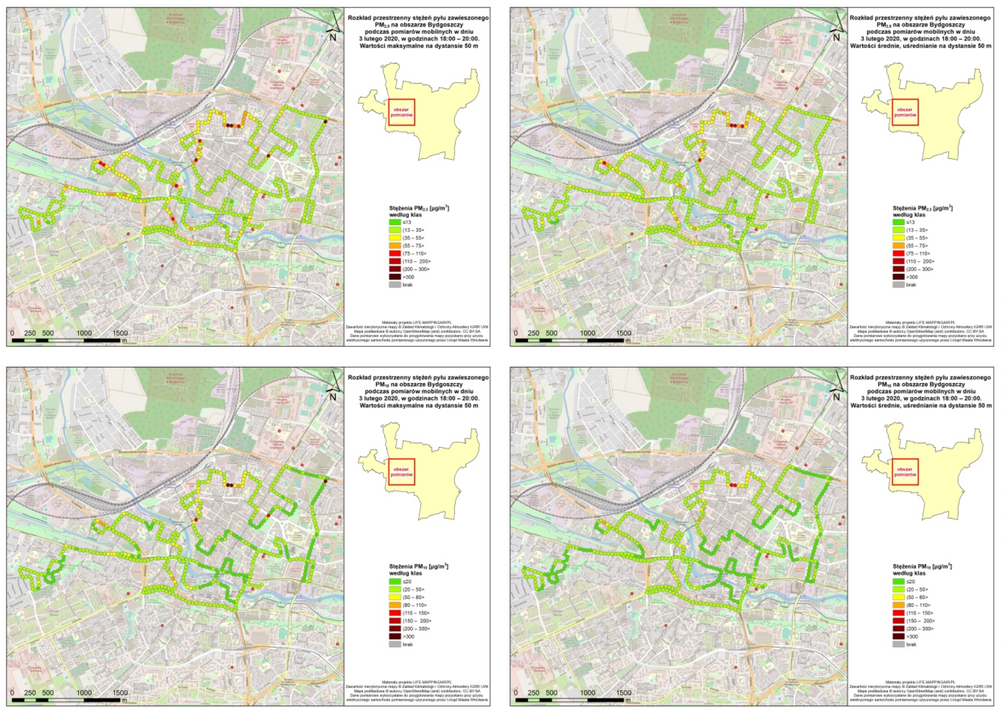
The measurements were carried out with use of mobile research stations based on electric drive and petrol cars (Nissan eNV200 – Wrocław; Renault Kangoo, Fiat Dobo – Bydgoszcz and vicinity of Wrocław). All three cars were equipped with measurement stations, consisting of an optical dust meter DustTrak II with a heated measuring track and air inlet installed at car rooftop, at the height of approx. 2.5 m a.g.l. Additionally, a meteorological station was installed on each of the cars to measure the meteorological background. For reference and background the data from mobile measurements were supplemented by the results of stationary air quality measurements (State Environmental Monitoring system stations and Meteorological Observatory of University of Wrocław) and detailed meteorological data recorded at the Meteorological Observatory of University of Wroclaw and within the Institute of Meteorology and Water Management network.The measurement transects were performed mainly in the evening hours (between 6.00 p.m. and 11.00 p.m.) and in the mornings (between 6.00 a.m. and 10.00 a.m.), during the periods of increased demand for heat at houses, resulting in increased emissions of pollutants from heating systems. Each mobile measurement session lasted approx. 3 hours. The average speed did not exceed 30 kph. With the assumed logging frequency of 1 sec. the results were obtained with a spatial resolution of 8 m. The measurements were carried out during two winter seasons 2019/2020 and 2020/2021. Alltogether 82 measurement transects were held, covering all districts of Wroclaw and Bydgoszcz together with adjacent areas. This poster presents a detailed analysis of four case studies representing characteristic situations:

- Winter ‘hotspot pattern’ in the city center of Bydgoszcz
- Winter ‘hotspot area patern’ in one of the housing estates in Wrocław
- Autumn ‘hotspot pat tern’ in Wrocław metropolitan area
- Winter ‘hotspot pattern’



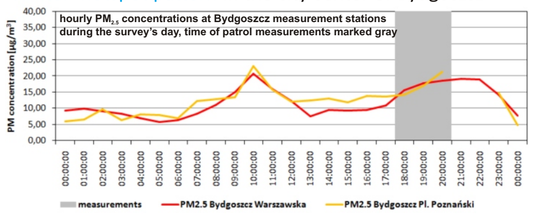
Conclusions

- The obtained results show that the spatial structure of PMx concentrations in the studied areas is determined by the emission level and the number of emitters, as well as concomitant weather conditions.
- Two characteristic types of spatial distribution of concentrations have been distinguished: "hotspot pattern" and "hot area pattern".
- The main features of the ‘hotspot pattern’ are low variability of the background of PMx concentrations on one hand, and the presence of single spots where PMx concentrations may significntly exceed the background.The hot spots are formed in the close vicinity of the emitters, the PMx concentration decreases very quickly when moving away from them. Such spatial structure occurs during dynamic weather.
- ‘Hot area pattern’ occus in stable weather conditions, especially anti-cyclonic, with highly developed thermal inversion. The field of air pollution is uniform as a result of the gradual accumulation of pollutants in the near-ground layer of the atmosphere. Relatively large areas with clearly higher concentrations occur in the spatial structure of PMx. The key factor, in this case, is the duration of the conditions favoring PMx accumulation.
- In case of Wrocław agglomeration the problem of decreasing air quality has much greater extent in small suburban localities where high concentrations of PMx appear even in relatively warm weather (e.g. already in September or October), which, according to the authors, is related not only to the widespread use of solid fossil fuels for heating purposes, but also hot water provision.



03.02.2020 - Bydgoszcz

Winter ’hotspot pattern’ in the city center of Bydgoszcz



Bydgoszcz area - cyclonic weather, warm, but low wind speed, little rainfall during the measurements in the evening.

Meteorological characteristics during the survey (from measurement station in te centre of Budgoszcz, established for the survey needs)

avg T = -5.5°C

avg V = 0.8 m/s

Average PM values for patrol measurements time span (from National Monitoring Network)

Warszawska station (urban background)

avg PM_{10} = 32.7 µg/m^3

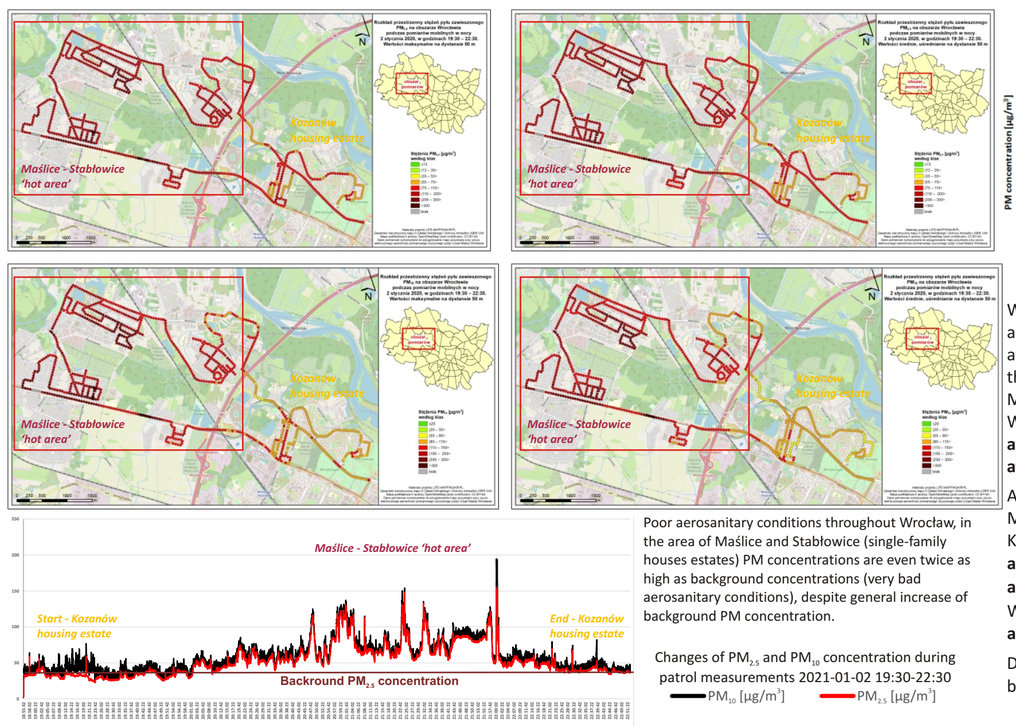
avg $PM_{2.5}$ = 17.3 µg/m^3

Pl. Poznański station (traffic)

avg $PM_{2.5}$ = 28.8 µg/m^3

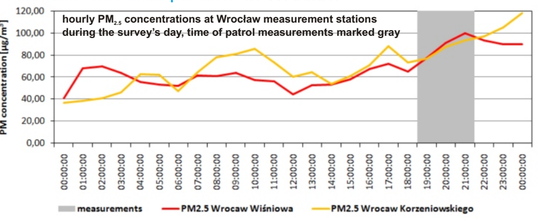
avg $PM_{2.5}$ = 17.5 µg/m^3

Good aerosanitary conditions in the most part of the surveyed area, clear ‘hot spots’ in the vicinity of active emitors, with PM concentrations above 100 µg/m^3 (very bad aerosanitary conditions).



02.01.2020 - Wrocław

Winter ‘hot area pattern’ in Wrocław



Wrocław area on the nortnern edge of a batrometric high, a clear advection of air masses from the west - south-west. Frosty evening, after a day with positive air temperature, development of evening thermal inversion, low wind speed.

Meteorological characteristics during the survey (from University of Wrocław Observatory, Wrocław-Biskupin)

avg T = - 3.7°C

avg V = 1.1 m/s

Average PM values for patrol measurements time span (from National Monitoring Network)

Korzeniowskiego station (urban background)

avg PM_{10} = 86.0 µg/m^3

avg $PM_{2.5}$ = 95.6 µg/m^3

Wiśniowa station (traffic)

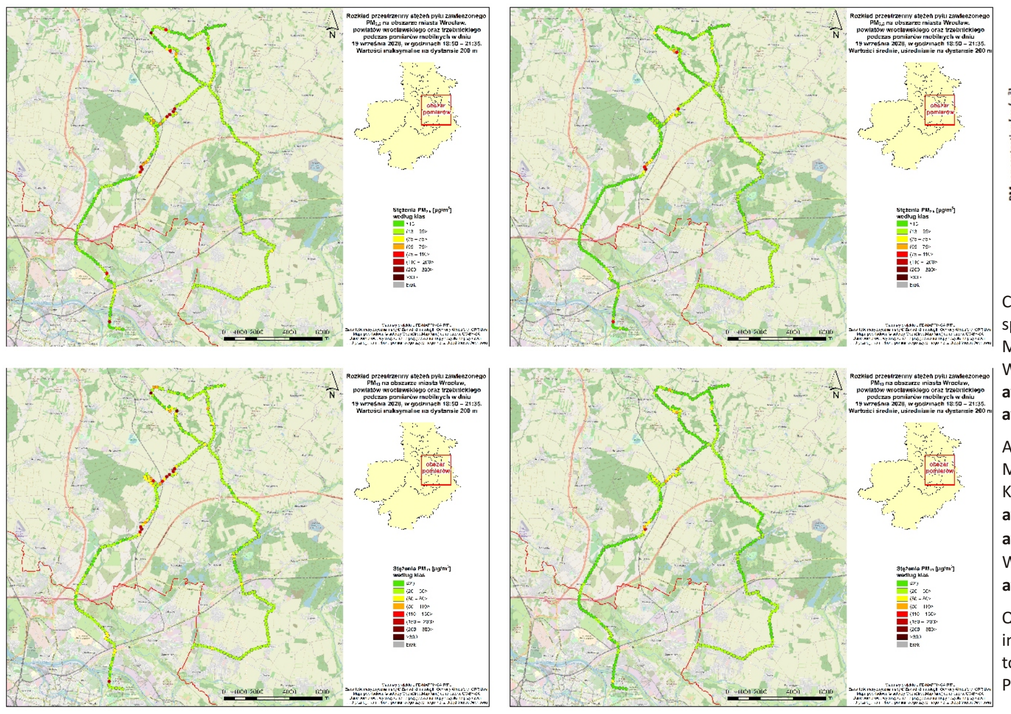
avg $PM_{2.5}$ = 89.5 µg/m^3

During the survey, an increase in PM concentrations at the urban background station by about 20 µg/m^3.

Poor aerosanitary conditions throughout Wrocław, in the area of Maślice and Stabłowice (single-family houses estates) PM concentrations are even twice as high as background concentrations (very bad aerosanitary conditions), despite general increase of background PM concentration.

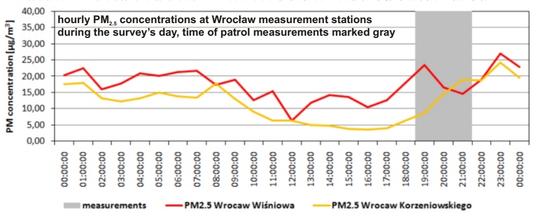
Changes of $PM_{2.5}$ and PM_{10} concentration during patrol measurements 2021-01-02 19:30-22:30

PM_{10} [µg/m^3] $PM_{2.5}$ [µg/m^3]



19.09.2020

Autum ’hotspot pattern’ in Wrocław metropolitan area



Cool evening after a warm day, stable anticyclonal weather, low wind speeds, development of a strong near-ground thermal inversion.

Meteorological characteristics during the survey (from University of Wrocław Observatory, Wrocław-Biskupin)

avg T = 11.9°C

avg V = 0.9 m/s

Average PM values for patrol measurements time span (from National Monitoring Network)

Korzeniowskiego station (urban background)

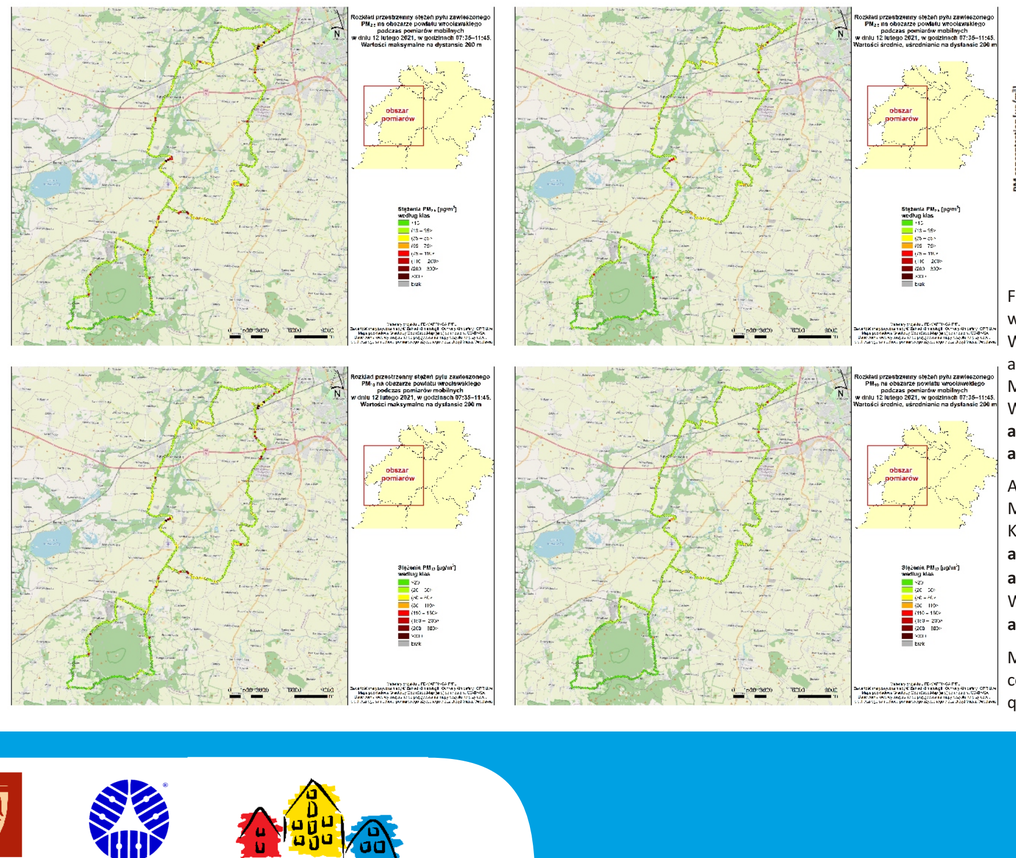
avg PM_{10} = 30.7 µg/m^3

avg $PM_{2.5}$ = 14.1 µg/m^3

Wiśniowa station (traffic)

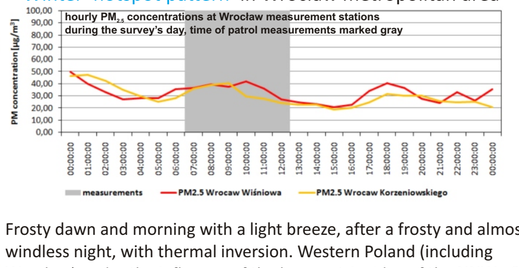
avg $PM_{2.5}$ = 18.2 µg/m^3

Quite favorable aerosanitary conditions in the area of Wrocław and in in rural areas outside the city, significant deterioration of air quality in towns and villages near Wrocław, despite relatively warm weather. Possible cause: in addition to house heating, domestic water heating.



12.02.2021

Winter ’hotspot pattern’ in Wrocław metropolitan area



Frosty dawn and morning with a light breeze, after a frosty and almost windless night, with thermal inversion. Western Poland (including Wrocław) under the influence of the barometric ridge of the NNW - SSE axis, wind direction in the Wrocław area from the NW sector.

Meteorological characteristics during the survey (from University of Wrocław Observatory, Wrocław-Biskupin)

avg T = - 9,6°C

avg V = 2,2 m/s

Average PM values for patrol measurements time span (from National Monitoring Network)

Korzeniowskiego station (urban background)

avg PM_{10} = 41.2 µg/m^3

avg $PM_{2.5}$ = 32.9 µg/m^3

Wiśniowa station (traffic)

avg $PM_{2.5}$ = 36.5 µg/m^3

Moderate aerosanitary conditions in the area of Wrocław, good conditions in rural areas outside the city, significant deterioration of air quality in towns and villages near Wrocław.

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More at: mappingair.meteo.uni.wroc.pl