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A six-year measurement-based analysis of traffic-related particulate matter pollution in urban areas: the case of Warsaw, Poland (2016-2021)

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Abstract: This study used PM10 and PM2.5 measurements from the State Environmental Monitoring stations in Warsaw and its suburban areas. Analysis of variability characteristics at the traffic and urban background stations was carried out for 2016-2021. A six-year analysis (2016-2021) of air quality in Warsaw, Poland, focusing highlights the persistent impact of transportation on particulate matter concentrations. Comparing a city centre traffic station with urban background locations reveals consistently higher PM10 concentrations at the traffic station throughout the year, with an annual traffic-related increase of 12.6 µg/m³ (32%). PM2.5 concentrations at the traffic station are also consistently about 1.5 µg/m³ (7%) higher. For monthly averages, the highest PM10 concentrations at the traffic station were noted in March, which may be related to the resuspention of sand and salt left over from winter snow removal processes. In the case of PM2.5, the typical annual cycle with maximum concentrations in winter and minimum concentrations in summer was not observed. Diurnal variability patterns show elevated PM10 concentrations at the traffic station from 8:00 a.m. to 10:00 p.m., attributed to the resuspension process. PM2.5 patterns exhibit a smaller amplitude at the traffic station, with nighttime accumulation due to inflow. This study emphasizes the lasting impact of transportation on air quality, providing insights into pollution control strategies in urban areas.

Introduction

The current state of air quality within urban areas poses one of the most severe environmental problems (Wojtal, 2018). High exposure to air pollution in cities is attributed to high population density and higher pollutant concentrations compared to remote areas. In Poland, primary pollutants exceeding the limit concentrations include particulate matter PM10 and PM2.5. The exceedances of PM10 and PM2.5 thresholds represent significant and unresolved issues in many European countries (Majewski, 2005).

Polish cities face a high number of emissions sources, primarily from residential and transport sectors, while industrial sources contribute significantly in many regions. This is particularly evident in the Warsaw agglomeration, where the suburbs of Poland's capital city suffer from high pollution, especially in winter. In this area, individual heating significantly impacts air quality. The industry in the Warsaw area is highly developed, characterized by a large share of foreign capital, qualified staff, and a lack of mineral resources. The most developed industries include electrical engineering, precision engineering, electronics, transport, chemicals, cosmetics, building materials, food, printing, metallurgy, machinery, and clothing (Domański, 2006).

A long-term analysis of particulate matter concentration and composition over Warsaw indicates a significant influence of air temperature, precipitation, and wind speed on the observed variability (Majewski et al., 2018). Poor air quality during the winter period is often associated with high-pressure systems characterized by small pressure gradients (Godłowska, 2019). The highest concentrations tend to occur in the suburbs, primarily due to the prevalence of individual heating installations. The urban heat island phenomenon in city centers may further prevent the substantial accumulation of pollutants (Kamiński et al., 2011).

Numerous analyses focusing on air quality in Poland's capital city primarily center on measuring aerosol composition in the Warsaw agglomeration and identifying sources. Chemical composition analyses of the air in Warsaw confirm a significant contribution from combustion and transport-related pollution in the municipal sector (Juda-Rezler et al., 2020). Modelling studies conducted in the Warsaw area shows that the primary sources of pollution are related to the municipal and transport sectors (Holnicki et al., 2017). Despite evidence of air pollution improvement presented by Markowicz et al. (2019), the quality of air in Poland still requires improvement to meet standards in many areas.

Given the size of the population residing in the Warsaw agglomeration, assessing the transport sector's impact on mortality and morbidity is crucial. The transport sector contributes 19% to air pollution in the Warsaw area in the case of PM10 and 16% in the case of PM2.5 (GIOŚ, 2022). Research suggests that the health risks from traffic congestion are significant, and additional urban traffic can increase the risk, depending on various factors such as road type and other factors (Zhang and Batterman, 2013). A study conducted in the UK analyzed the health impact of emissions from the car fleet in 1995 and 2005, revealing a 25% reduction in air pollution-related deaths from cars by 2005 (Smith et al., 2013).

This study aimed to assess the variation and pattern of pollutant concentrations between a traffic station and urban background stations, with a focus on determining the potential influence of transportation on PM10 and PM2.5 concentrations in the Warsaw agglomeration during the period from 2016 to 2021.

Data and methods

Warsaw, Poland's largest city and the capital of the country, is situated in the central part of the Central Mazovian Plain, known as the Warsaw Plain. According to data from the Central Statistical Office (GUS, 2022), it is home to 1.86 million people and covers an area of 517 km². With a motorization rate among the highest in Europe, Warsaw boasted 2,139,666 registered vehicles by the end of 2022 (Osowski, 2023). It stands as one of Poland's fastest-growing and most dynamically adapting cities.

Monitoring stations

This study used PM10 and PM2.5 measurements obtained from State Environmental Monitoring stations located in Warsaw and its suburban areas. An analysis of variability characteristics was conducted at both traffic and urban background stations for the period spanning from 2016 to 2021.

The characteristics and locations of stations measuring PM2.5 and PM10 particulate matter in the Warsaw agglomeration are presented in Figure 1 and Table 1. Both PM10 and PM2.5 fractions are measured at the traffic station MzWawAlNiepo in the city center. In addition, PM10 measurements are carried out at the urban background station MzWawWokalna. PM2.5 measurements are conducted at stations located in suburban areas of Warsaw - in Piastów MzPiasPulask and Legionowo MzLegZegrzyn.

The MzWarAlNiepo traffic station, located in the centre of Warsaw at Niepodległości Avenue, lies along the capital's main traffic artery and is surrounded by tall buildings of various purposes, including residential structures. The MzWarWokalna station serves as an urban background station located on

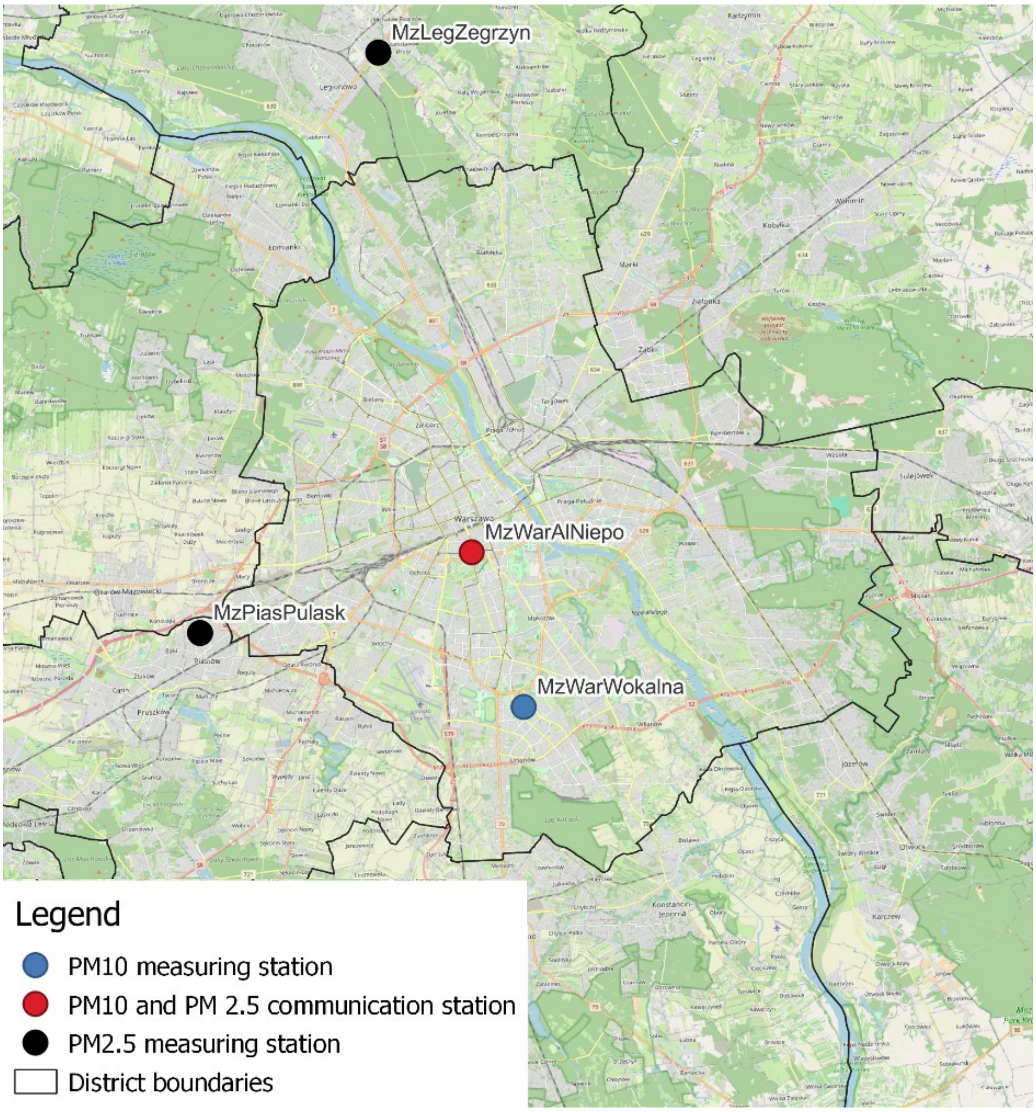

Figure. 1. Distribution of measurement stations of the State Environmental Monitoring (PMŚ) in Warsaw and its surroundings.

Table. 1. Monitoring stations analysed in the Warsaw agglomeration.

Name of station	Location	Type	Pollution		Location	
					Latitude	Longitude
MzWarAlNiepo	Warsaw, Niepodległości 227/233	communication	PM2.5	PM10	52.22	21.00
MzPiasPulask	Piastów, Pułaskiego 6/8	suburban background	PM2.5	-	52.19	20.84
MzLegZegrzyn	Legionowo, Zegrzyńska 38	suburban background	PM2.5	-	52.41	20.96
MzWarWokalna	Warsaw, Wokalna 1	urban background	-	PM10	52.16	21.03

Wokalna Street in Warsaw's Ursynów district, surrounded by multi-family buildings. In contrast, the MzLegZegrzyn station serves as a suburban background station in Legionowo. It is encompassed by low buildings, single-family houses, and several multi-family and service buildings, and is predominantly surrounded by forest and green areas. Finally, the MzPiasPulask station, also a suburban background station, is situated in Piastów on school grounds, surrounded by single-family dwellings and low-rise multi-family buildings.

Approach

To compare the variability of PM10 and PM2.5 concentrations at the traffic station and urban background stations, the following statistical parameters were calculated based on 1-hour measurement data over the six years from 2016 to 2021:

- Annual average values for each year and as a 6-year average.
- Monthly averages for each year and as a 6-year average.
- Hourly average values (daily concentrations) for each year and as a 6-year average.
- Hourly average values (daily concentrations) separately for the warm and cold periods and as a 6-year average.

In addition, the analysis included the examination of differences between traffic and urban background stations.

Results

The analysis focused on the differences between the statistical parameters of particulate matter concentrations at the traffic station and urban background stations to subtract the impact of traffic on the variability and level of PM10 and PM2.5 concentrations in Warsaw.

Annual average

Figures 2 and 3 show the annual average concentrations of PM10 and PM2.5 for the period of six years (2016-2021) at stations located in Warsaw.

In Figure 2, the annual average concentration are compared between the traffic station MzWawAlNiepo and the urban background station MzWawWokalna. The data reveals that the concentration level at the traffic station is consistently higher, with a difference of 12.58 µg/m³ (32%) compared to the urban background station. The highest pollution level was reached in 2018, with concentration of 43 µg/m³ at the traffic station and 35 µg/m³ at the urban background station. Pollution levels decreased significantly in the following years. In 2020, while the decrease continued at the traffic station, potentially influenced by the COVID-19 pandemic, the urban background station showed a slight increase. In the last year (2021), concentrations increased to 40 µg/m³ at the traffic station and slightly decreased to 23 µg/m³ at the urban background station.

In Figure 3, PM2.5 concentrations at the analyzed stations exhibit similarity, with no clear trend observed in concentration changes over time. During the COVID-19 pandemic year, although traffic decreased significantly, concentrations were affected by exceptionally high temperatures during winter and very cold periods in March 2020. In 2017 and 2019, PM2.5 concentrations at the traffic station were approximately 5 µg/m³ higher than those at the urban background stations. However, concentrations

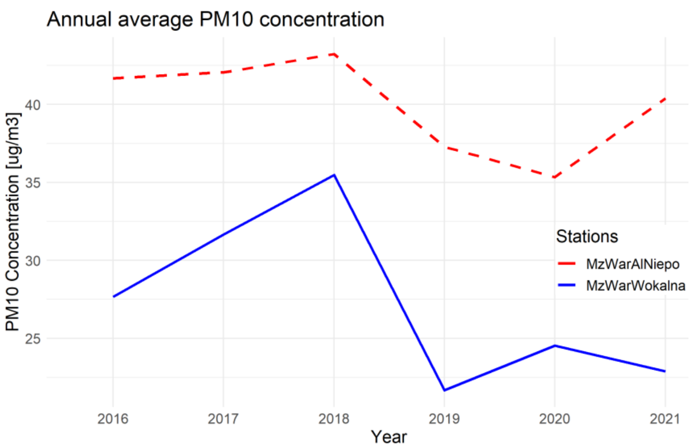

Figure. 2. Annual average PM10 concentrations at MzWarAlNiepo and MzWarWokalna stations.

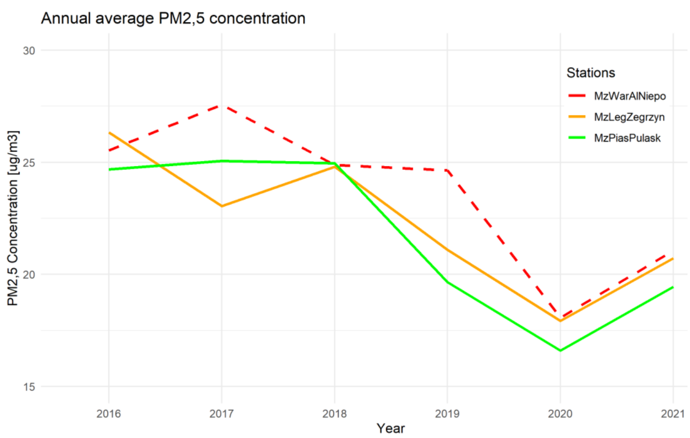

Figure. 3. Annual average PM2.5 concentrations at MzLegZegrzyn, MzPiasPulask and MzWarAlNiepo stations.

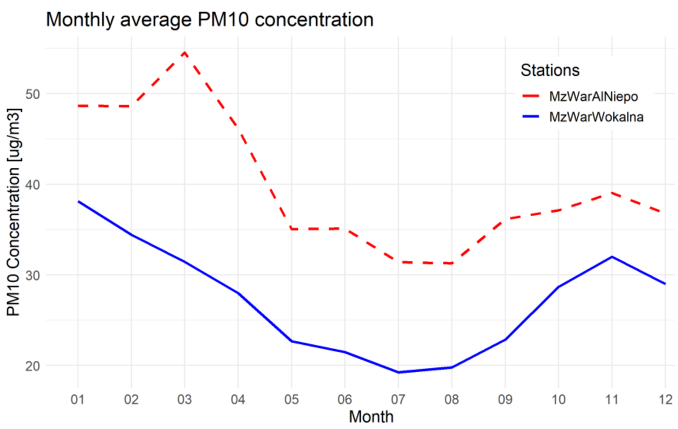

Figure. 4. Monthly average PM10 concentrations averaged for the period 2016-2021 at MzWarAlNiepo and MzWarWokalna stations.

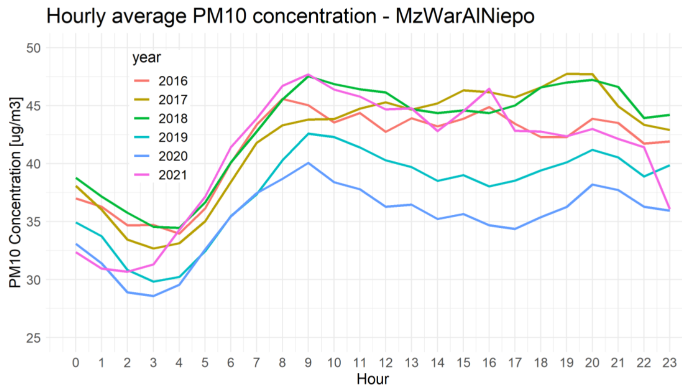

Figure. 6. Hourly average concentrations of PM10 at the station at Niepodległości Avenue in Warsaw in 2016-2021.

across all stations were very similar in the remaining years. From 2018 to 2020, a noticeable downward trend in concentrations was observed, with concentrations increasing in 2021. On average, concentrations at the traffic station were higher by 1.6 µg/m³ (7%) compared to the urban background station.

Multi-year monthly average

Figures 4 and 5 show monthly averages of PM10 and PM2.5 concentrations in Warsaw over the multi-year period (2016-2021).

In Figure 4, the monthly concentrations of PM10 particulate matter averaged over six years show an annual cycle. Values at the traffic station in the city center are significantly higher than those at the station located away from the center throughout the year. This disparity is likely attributed to the more intense impact of transport in the city center. The highest pollution values at the traffic station were observed in March, while the lowest occurred in July and August, with a notable difference of 23 µg/m³ between the highest and lowest concentrations. At the urban background station, data analysis showed that the month with the highest concentrations was January, with the lowest concentrations recorded in July. The difference between these months amounted to 19 µg/m³.

In Figure 5, the monthly concentrations of PM2.5 particulate matter averaged over the six-year-period (2016-2021) reached similar values. However, concentrations at the traffic station in the center of Warsaw were slightly higher than those at the other urban background stations, with an average difference of 1.5 µg/m³. This disparity may be attributed to the transport sector. Across all analyzed stations and years, concentrations were highest in July and lowest in April. Concentrations in winter were very similar at the stations in Piastów and Legionowo. There were also exceedances of the permissible concentration of PM2.5. Interestingly, the typical annual cycle with maximum concentrations in winter and minimum concentrations in summer was not observed.

Diurnal variability

Figures 6, 7, 8, 9, 10 present summaries of the average daily variability of PM10 and PM2.5 concentrations over the entire analyzed multi-year period from 2016 to 2021. The diurnal variability pattern at each station was similar throughout the multi-year period.

PM_{10}

From 2016 to 2021, hourly average concentrations of PM10 at the traffic station on Niepodległości Avenue in Warsaw showed a notable increase during peak hours of heavy vehicle traffic from 8:00 a.m. until 10:00 p.m. The concentrations during an "average day" remained relatively stable (Figure 6).

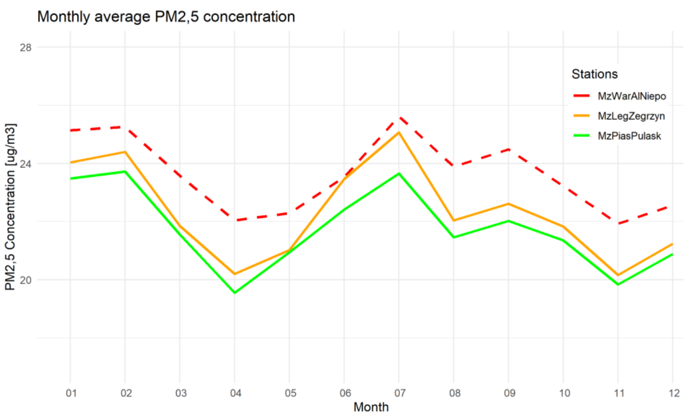

Figure. 5. Monthly average PM2.5 concentrations averaged for the period 2016-2021 at MzWarAlNiepo, MzLegZegrzyn and MzPiasPulask stations.

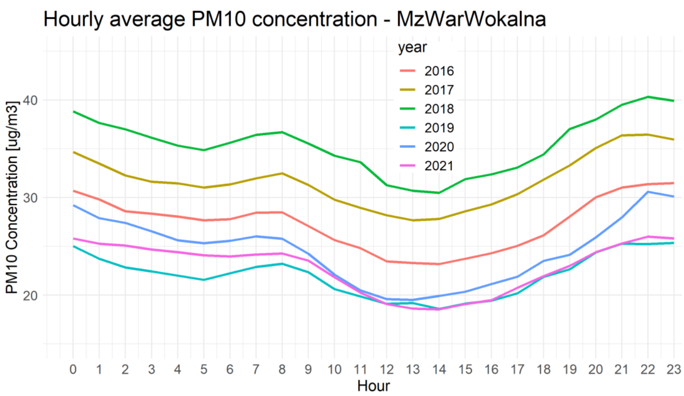

Figure. 7. Hourly average concentrations of PM10 at the station at in Wokalna Street in Warsaw in 2016-2021.

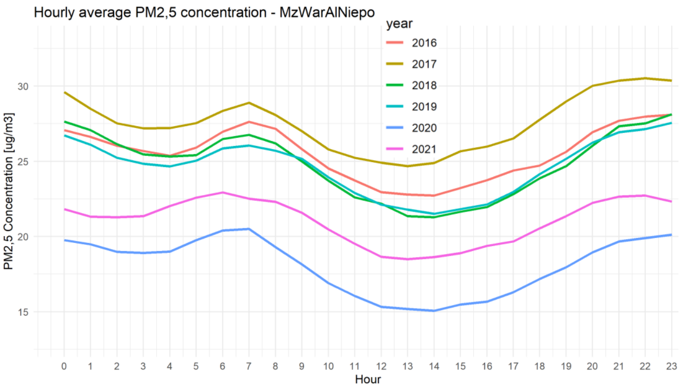

Figure. 8. Hourly average concentrations of PM2.5 at the station at Niepodległości Avenue in Warsaw in 2016-2021.

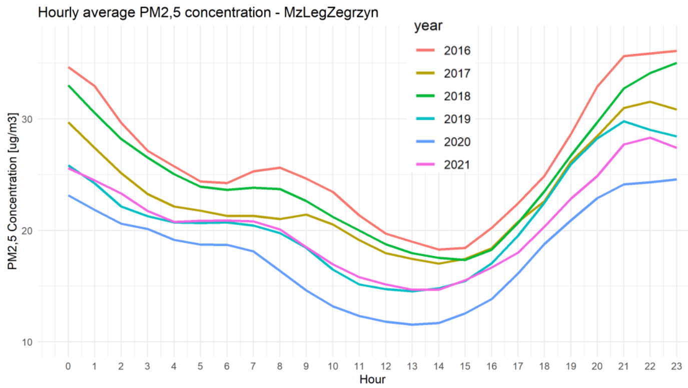

Figure. 10. Hourly average concentrations of PM2.5 at the Legionowo station in 2016-2021.

The highest level of pollution was recorded in 2018, while the lowest in 2020. There was a decrease in PM10 concentrations between 2019 and 2020, followed by an increase in the last year analyzed, 2021.

Between 2016 and 2021, there was an apparent increase in the hourly average concentration of PM10 particulate matter at the station on Wokalna Street in Warsaw, particularly during peak hours of heavy vehicle traffic from 7:00 to 9:00 and from 18:00 to 23:00, with the maximum concentration during nighttime (Figure 7). The daily amplitude is much lower than in the case of the traffic station. The highest pollution level was reached in 2018, while the lowest was observed in 2019. The difference between the minimum and maximum pollution levels averaged 2.2 µg/m³ during the morning hours and 0.8 µg/m³ during the night hours.

PM2.5

The diurnal variability of PM2.5 concentrations, averaged yearly, consistently depicts a similar pattern across all stations. The variability closely resembles that of PM10 at the urban background station located on Wokalna Street. The highest concentrations of PM2.5 occur during the morning and night hours.

Hourly average concentrations of PM2.5 particulate matter, recorded between 2016 and 2021, at the traffic station on Niepodległości Avenue in Warsaw, were significantly higher between 4 a.m. and 9 a.m. and again from 5 p.m. to 10 p.m. The highest pollution level was observed in 2017, while the lowest in 2020. A decrease in PM2.5 pollution was evident between 2017 and 2020, with an increase in the last year analyzed, 2021. The average difference between the highest and lowest concentrations per day is 10 µg/m³.

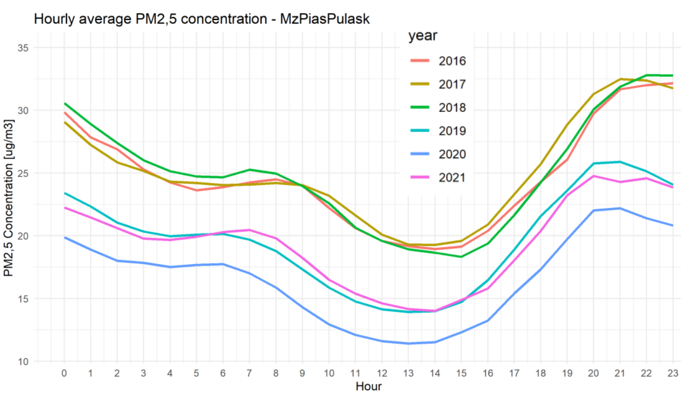

Figure. 9. Hourly average concentrations of PM2.5 at the Piastow station in 2016-2021.

Figure 9 shows that the highest concentrations of PM10 at the MzPiasPulask station were observed in 2016, 2017, and 2018, while the lowest concentration occurred in 2020. The decrease in concentration in 2020 could be attributed to the effects of economic closure and anomalously warm winter months. Concentrations in 2019 and 2021 were very similar. The systematic and consistent differences observed from one year to the next may indicate influences from meteorological factors and the Clean Air Program (Jagiello et al., 2023). On average, the difference between the highest and lowest daily concentrations is 12 µg/m³.

At Legionowo station, the highest concentrations were recorded in 2016 and 2018, with a noticeable increase each year around 9 a.m. and from 7 p.m. to 11 p.m. (Figure 10). The highest level of pollution was observed in 2016, and the lowest in 2020. From 2016 to 2020, there was a steady decrease in PM2.5 pollution, followed by an increase from 2019 to 2021 . The concentrations in 2019 and 2021 are very similar. The average difference between the highest and lowest concentrations per day is 11 µg/m³. This may indicate an accumulation of emissions from the transport sector, primarily from the residential/commercial sector.

The pattern observed for the statistics of MzPiasPulask and MzLegZegrzyn is similar.

Season-dependent diurnal variability

The diurnal variation profiles were divided into warm (IV-IX) and cool (I-III, X-XII) seasons to address better seasonal variability.

PM10

The PM10 concentration averages for the cool season months (January-March, October-December) from 2016 to 2021 at urban background stations show slight fluctuations throughout the day. At the traffic station, Niepodległości

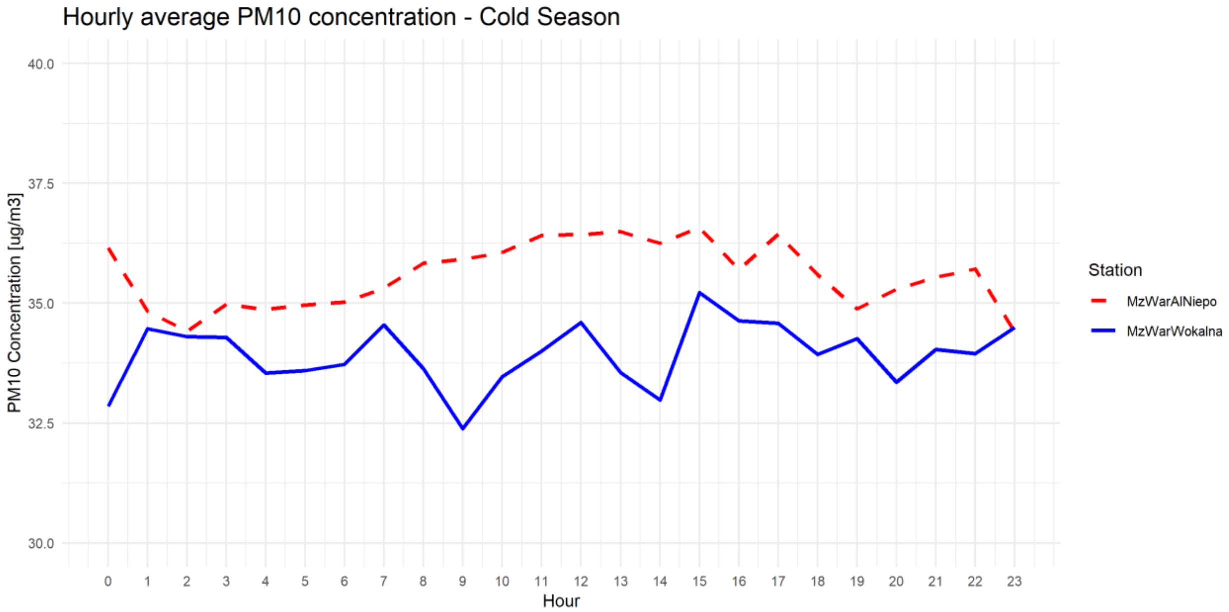

Figure. 11. Hourly average PM10 pollution during the cold season (I-III, X-XII) from 2016 to 2021.

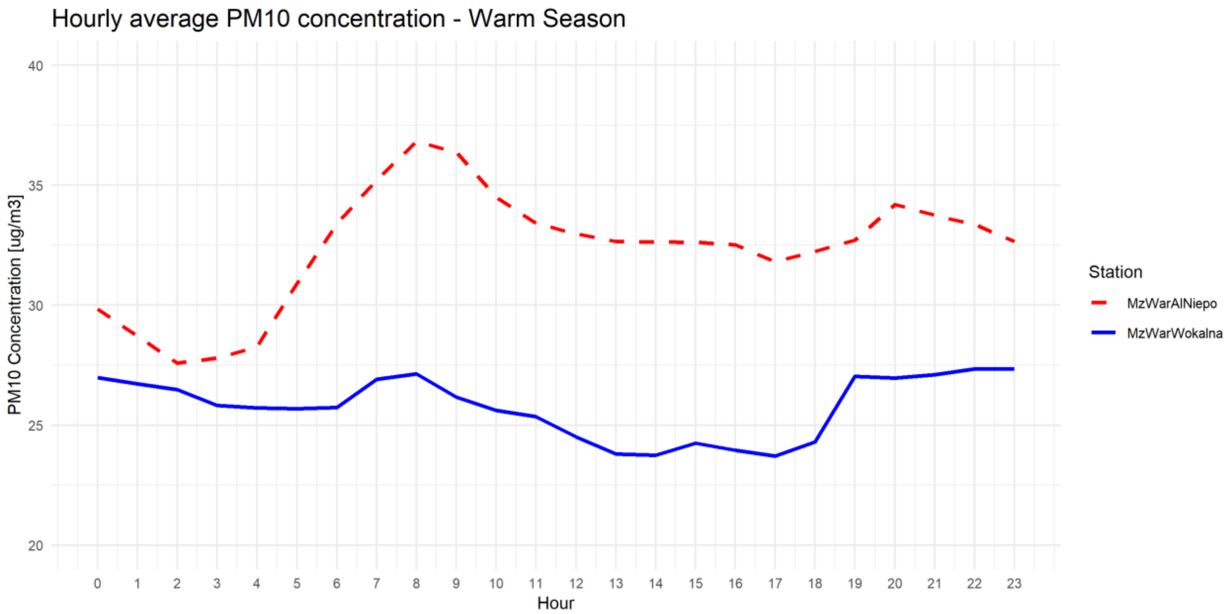

Figure. 12. Hourly average PM10 pollution during the warm season (IV-IX).

Avenue, concentrations are consistently higher. The increase begins around 7:00 a.m. and continues until 7:00 p.m., with concentrations exceeding 35 µg/m³ during this period (Figure 11).

Averaging PM10 concentrations from 2016-2021 during the warm season months (April-September) shows a slight increase in pollution during nighttime hours at the urban background station (Figure 12). At the traffic station on Niepodległości Avenue, high concentrations persist throughout the day from 8:00 a.m. to 9:00 p.m., with a noticeable increase around 7:00 a.m. This pattern is attributed to the station's location in the city center and the increased vehicle traffic during the day. The difference in patterns between warm and cool seasons is mainly due to the impact of residential heating in the cold period.

PM2.5

Averaging PM2.5 concentrations from 2016 to 2021 during the cold season months (January-March, October-December) show an increase in pollution during nighttime hours at urban background stations. The highest level is reached between 18:00 and 22:00. In contrast, no clear trend is observed at the traffic station on Niepodległości Avenue (Figure 13).

PM2.5 concentrations averaged from 2016 to 2021 during the warm season months (April-September) show increased pollution during nighttime hours at all three analyzed stations (Figure 14). Pollution levels at the stations located in Legionowo and Piastów are very similar. Higher pollution levels, on average 2.8 µg/m³, are found at the traffic station in the city center. These elevated concentration levels occurred from 5:00 to 9:00 and from 20:00 to 23:00.

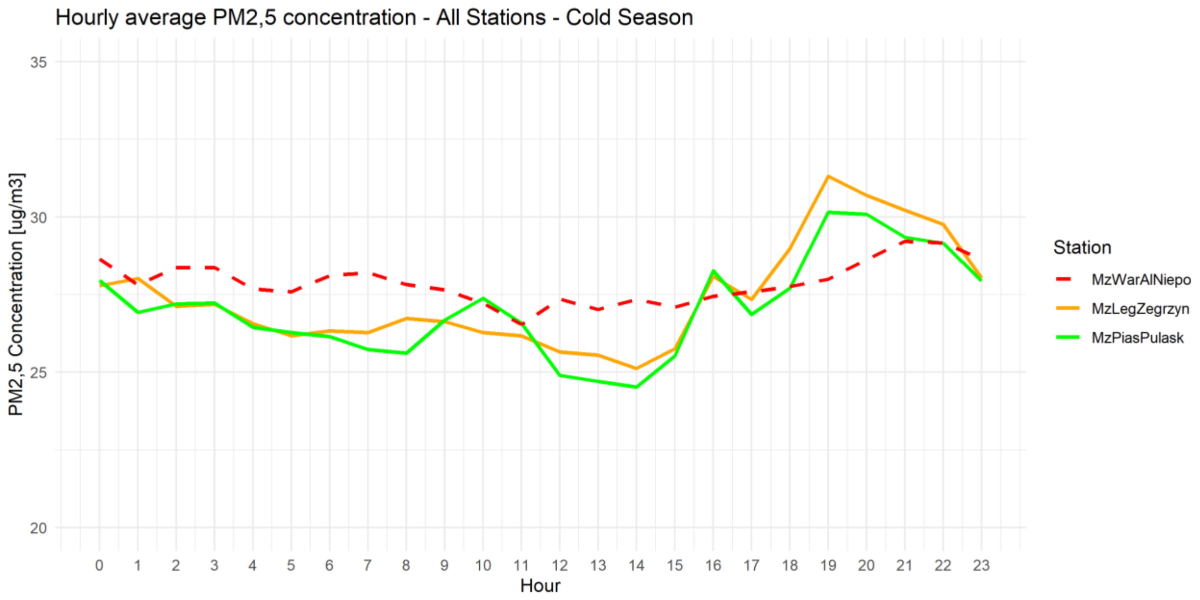

Figure. 13. Hourly average PM2.5 pollution during the cold season (I-III, X-XII).

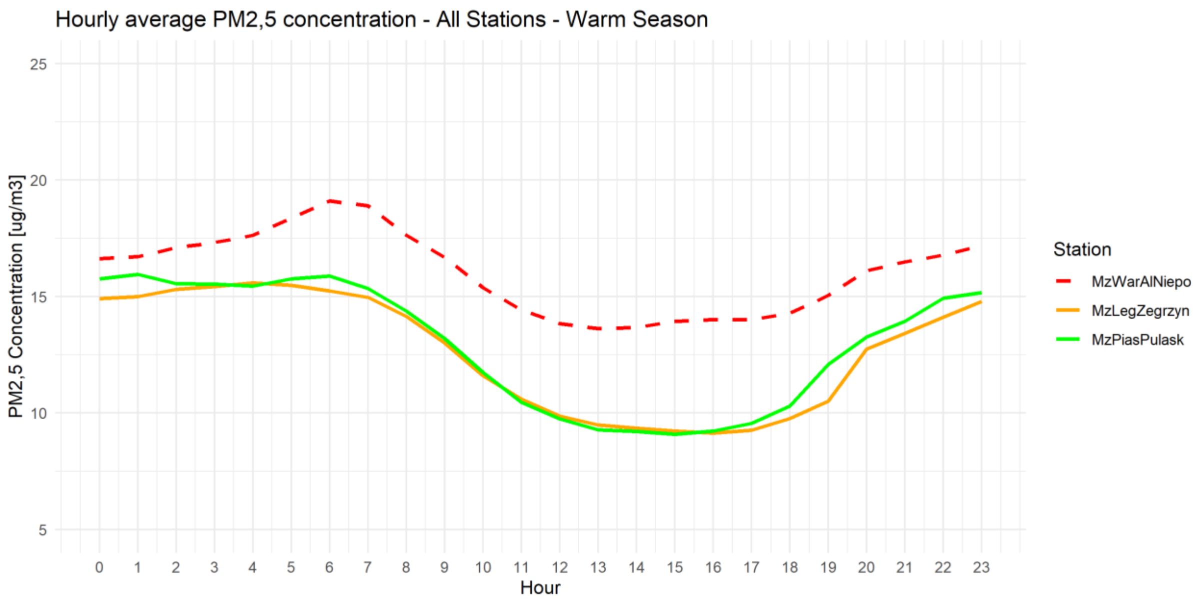

Figure. 14. Hourly average PM2.5 pollution during the warm season (IV-IX).

Discussion

An attempt was made to determine the increment of concentrations associated with emissions from road transport. Regarding the six-year average of PM10, there is a concentration difference of 12.58 µg/m³ between the traffic station in the center of Warsaw and the average from all urban background stations. Meanwhile, for PM2.5, this surplus is smaller, averaging 1.6 µg/m³ per year. These values are close to the roadside increments reported in (Harrison et al., 2021) for Paris and Istanbul for PM10, and for Berlin and Istanbul for PM2.5, as well as with the PM10 surplus value reported in Wang et al. (2022).

Regarding monthly averages over six years, the most significant increases in PM10 concentrations at the traffic station occur in March (23.1 µg/m³) and April (18.1 µg/m³). These increases may be related to the resuspension of sand and salt left over from winter snow removal processes (Table 2). Similar effects have been reported in the Nordic countries (Pirjola et al., 2009; Gustafsson et al., 2008; Kupiainen et al., 2016). Lower traffic increment values, less than 10 µg/m³, occurred from October to December.

In the case of PM2.5, during the coldest months - January and February - concentrations at the traffic station are lower than at urban background stations, which is related to increased emissions from individual heating systems. However, during the warm season from May to September, the increase in PM2.5 concentrations at the traffic station ranges from 3.05 to 3.55 µg/m³. Compared to the rise for PM10 of 11.5 to 13.5 µg/m³, this indicates a roughly constant contribution of PM2.5

Table. 2. Difference in average monthly concentrations between the traffic station in the center of Warsaw and the average of all urban background stations.

Month	Difference in average monthly concentrations	
	PM2.5 [μg/m³]	PM10 [μg/m³]
1	-3.75	10.6
2	-0.45	14.2
3	0.45	23.1
4	1.8	18.1
5	3.05	12.4
6	3.3	13.6
7	3.55	12.1
8	3.15	11.5
9	3.45	13.3
10	2.45	8.4
11	1.45	7.1
12	0.45	7.8

Table. 3. Daily emission profile of hourly differences in concentrations averaged over six years for the whole year and warm and cold seasons.

Hour	Daily emission profile of hourly					
	PM2,5 [μg/m³]			PM10 [μg/m³]		
	Warm season	Cold season	Year	Warm season	Cold season	Year
0:00	0.35	-4.1	-1.85	5.4	4.4	4.9
1:00	0.7	-2.4	-0.9	4.8	4.2	4.4
2:00	1	-0.65	0.15	3.7	3.4	3.4
3:00	1.6	0.4	1.05	4.1	3.2	3.6
4:00	2.25	1.55	1.9	5.9	3.7	4.7
5:00	3.05	2.25	2.6	8.8	6.1	7.4
6:00	4.15	2.7	3.45	12.8	8.5	10.6
7:00	4.55	2.8	3.6	15.1	10.1	12.6
8:00	4.35	2.75	3.55	17.6	11.9	14.7
9:00	3.9	3.3	3.55	18.7	15.4	16.9
10:00	3.75	3.8	3.75	17.5	18.1	17.6
11:00	3.95	4.45	4.2	17.1	20.4	18.6
12:00	4.07	5	4.55	17.8	20.7	19
13:00	4.275	5.1	4.75	18.4	20.2	19.1
14:00	4.605	5	4.75	18.1	19.2	18.4
15:00	4.93	4.6	4.85	18.4	19	18.4
16:00	4.945	2.95	3.9	18.9	17.6	17.9
17:00	4.66	0	2.35	17.8	15.4	16.3
18:00	4.335	-2.8	0.75	16.8	14.4	15.3
19:00	3.6	-5.7	-1.1	16.3	13.1	14.4
20:00	2.3	-7.4	-2.6	16.1	11.6	13.7
21:00	0.85	-7.65	-3.45	13.6	9.6	11.4
22:00	0.3	-7.4	-3.55	10.7	7.6	9
23:00	0.5	-6.35	-3	10.3	6.8	8.4

to PM10 due to traffic during these months, accounting for about 26%.

An attempt has been made to approximate the daily emission profile based on hourly concentration differences averaged over six years for the whole year and warm and cold seasons. In the case of PM2.5, the annual profile and the cold season profile are very similar in shape, with the highest values occurring between 10 CET and 16 CET, contributing to concentrations at the traffic station by up to 4.75-5 μg/m³ due to increased traffic activity. The differences are negative during night hours, indicating the predominant impact of residential emissions at the analyzed urban background stations. In the summer period, the hourly differences between the traffic station and the average of two background stations show a clear diurnal pattern with a double maximum in the peak hours of 6-7 CET and 15-16 CET (i.e., 16-17 CEST), consistent with the traffic intensity reported by Polednik (2021). The maximum impact of traffic sources is also estimated at 4.55 - 4.95 μg/m³. For PM10 in the cold season, the annual profile shows a clear positive difference between 9 CET and 18 CET, with traffic increments in the range of 15-20 μg/m³, and the difference between the cold period and the whole year is about 1 μg/m³. In the warm season, the excess of PM10 concentrations at the traffic station is slightly lower - from 15 to 18.8 μg/m³ but occurs longer - from 7 CET to 20 CET.

While studies conducted in Eastern and Central Europe have shown that PM10 and PM2.5 concentrations are typically twice as high in the cold season compared to the warm season (Cembrzynska and Krakowiak, 2012), the impact of traffic in Warsaw appears to remain relatively constant throughout the year.

Conclusions

Analysis of available measurements of PM10 and PM2.5 concentrations at monitoring stations in the Warsaw agglomeration from 2016 to 2021 indicates that transportation significantly and variably impacts air quality. PM10 concentrations at a traffic station located in the city center consistently exceed those at urban background stations across all averaging periods throughout the analysis period.

The annual PM10 traffic increment averaged 12.6 μg/m³ (32%) over the entire period. On a monthly basis, the greatest differences between the traffic station and urban background occurred from February to April, with a maximum increment of 23 μg/m³ observed in March. For PM2.5, concentrations at the traffic station were approximately 1.5 μg/m³ (7%) higher than at the urban background stations. Monthly averages revealed that concentrations at the traffic station were systematically slightly higher for most of the year, averaging 1.6 μg/m³, with minimal difference observed in June and July.

At the traffic station, PM10 concentrations exhibit elevated concentrations levels throughout the day from 8:00 a.m. until 10:00 p.m. Interestingly, concentrations during peak traffic hours are not significantly higher than during other hours, suggesting a persistent presence of particulate matter in the atmosphere due to resuspension process. In winter, the highest concentrations occur in the early afternoon, while in the warm season, they occur during peak traffic hours. These patterns contrast with those observed at the urban background station on Wokalna Street, indicating marked difference in diurnal variability between the two locations.

The diurnal variability of PM2.5 concentrations differs between the traffic station and urban background stations. At the traffic station, there is a smaller daily amplitude, with a slight increase during the morning rush hour and a flattened concentrations during nighttime hours, possibly due to inflow and nighttime accumulation. During winter, PM2.5 concentrations are comparable between the traffic station and urban background stations, albeit with higher levels at the traffic station during daytime hours and at the urban background stations during nighttime hours. However, in the warm season, PM2.5 concentrations are systematically higher at the traffic station by an average of 2.8 µg/m³.

The analysis of hourly variability revealed interesting pattern in the differences between concentrations at the traffic station and background stations. For PM2.5 during the summer, there was a strong correlation with traffic intensity, indicating higher increments coinciding with increased traffic. However, for PM10, traffic increments appeared relatively consistent across all hours during warm, cold, and annual periods, with the maximum observed from 8 CET to 17 CET, ranging from 15 to 20 µg/m³. In contrast, for PM2.5, the increment was similar and relatively constant only during the day, specifically from 9 to 15 CET, ranging from 3 to 5 µg/m³).

While the concentration differences observed cannot be solely attributed to the transportation sector's impact, they nonetheless provide a reasonable estimate of traffic increment. Pollution levels at the traffic station are influenced by various factors, including emissions from the residential sector. Additionally, air protection programs implemented in Poland resulted in a visible improvement over the analyzed six-year period. A significant decrease in PM concentrations at all stations was recorded in 2020, directly linked to the COVID-19 lockdown.

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Sześcioletnia analiza zanieczyszczenia pyłem zawieszonym związana z ruchem drogowym w obszarach miejskich: Przypadek Warszawy, Polska (2016-2021)

Streszczenie. W badaniu wykorzystano pomiary pyłu PM10 i PM2,5 ze stacji Państwowego Monitoringu Środowiska w Warszawie i jej okolicach. Analizę charakterystyk zmienności na stacjach komunikacyjnych i tła miejskiego przeprowadzono dla lat 2016-2021. Sześcioletnia analiza (2016-2021) jakości powietrza w Warszawie podkreśla stały wpływ transportu na stężenie pyłu zawieszonego. Porównanie stacji komunikacyjnej w centrum miasta z lokalizacjami tła miejskiego ujawnia stale wyższe stężenia PM10 na stacji komunikacyjnej przez cały rok, z rocznym wzrostem związanym z ruchem drogowym o 12,6 $\mu g/m^3$ (32%). Stężenia PM2,5 na stacji komunikacyjnej są również stale wyższe o około 1,5 $\mu g/m^3$ (7%). W przypadku średnich miesięcznych, najwyższe stężenia PM10 na stacji komunikacyjnej odnotowano w marcu, co może być związane z resuspencją piasku i soli pozostałych po zimowych procesach odśnieżania. W przypadku PM2,5 nie zaobserwowano typowego cyklu rocznego z maksymalnymi stężeniami zimą i minimalnymi latem. Wzorce zmienności dobowej wykazują podwyższone stężenia PM10 na stacji komunikacyjnej od 8:00 do 22:00, przypisywane procesowi resuspensji. Wzorce PM2.5 wykazują mniejszą amplitudę na stacji komunikacyjnej, z nocną akumulacją spowodowaną napływem. Badanie to podkreśla trwały wpływ transportu na jakość powietrza, zapewniając wgląd w strategie kontroli zanieczyszczeń na obszarach miejskich.