Car traffic or emissions from heating sources: What is responsible for IAQ?

Katarzyna Ratajczak*[1], Maciej Siedlecki

1 Poznan University of Technology
Faculty of Environmental Engineering and Energy
M.Sklodowskiej-Curie 5
Poznan, Poland
**Corresponding author:*
katarzyna.m.ratajczak@put.poznan.pl

2 Poznan University of Technology
Faculty of Civil and Transport Technology
M.Sklodowskiej-Curie 5
Poznan, Poland

ABSTRACT

The quality of indoor air in buildings depends on many factors. Some of these factors have internal sources, and some have external sources. The internal loads of the room include those generated by people: CO_2 and moisture emissions from breathing, heat emissions from room equipment: volitale organic compaunds VOC. External sources are, for example, particulate matter present in the air, which is the result of emissions from cars and the burning of fossil fuels. The scientific literature states that car traffic can contribute a large share. However, it seems that this is largely dependent on the location of the building, including in a particular country.

An evaluation of the impact of car traffic on indoor and outdoor air quality was performed in different buildings located in the same district of a large city. Temperature, relative humidity, CO_2 concentration and PM2.5 and PM10 concentrations were analyzed. The indoor air quality recorder was located in the room facing the busiest street. The way the room was used was unchanged. The external air quality recorder was located directly in front of the building. In addition to outdoor air, the number and type of vehicles that pass near the building were also recorded. Using the values of specific emissions of pollutants from vehicles of a given type, the number of pollutants emitted was determined in the vicinity of the building.

The analysis of the results addressed mainly the comparison of the concentration of particulate matter in the outside room with the value measured outside and the imposition of the number of cars and the determined emissions. The measurements were carried out over a period of month to eliminate differences in the emission of pollutants from heating sources, which was related to the temperature of the outdoor air.

The results showed that road transport does not have a significant effect on the concentration of pollutants in buildings. A discussion of the results was also held on a review of international studies. It turned out that of Poland a large share in outdoor air pollution has emissions from heat sources, which are caused by the use of nonrenewable fuels to heat houses and apartments. In Poland, there are more than half of the 50 most polluted cities in Europe. This results in increased exposure of people to the negative health effects associated with inhaling air contaminated with particulate matter.

The introduced EU regulations, including EPDB corrections and forcing thermomodernization to reduce heat demand, may result in limiting the use of fossil fuels, which will result in an improvement in the situation. The next step should be to look at the situation with regard to traffic pollution.

Research concerns Poland, where the use of low-efficiency heat sources that burn fossil fuels is a huge problem. The authors are aware that different socioeconomic conditions may occur in different countries.

KEYWORDS

Car traffic, Indoor air quality, Outdoor air quality, Poland

1 INTRODUCTION

Indoor activities and building equipment can be a burden on indoor air. In residential or public buildings, the main activities that affect indoor air are related to people staying indoors (Li et al. 2022; Sakamoto et al. 2022; Yan et al. 2023). Being indoors is associated with the emission of moisture and carbon dioxide from breathing (McMurray and Ahlborn 1982), as well as VOC (Wang et al. 2022) emissions. Moisture emission is also associated with showering and cooking (Liu et al., 2023). Furthermore, heat gains are emitted in rooms where people are present, which affect the temperature of the indoor air (Dharmasastha et al. 2023). To maintain comfortable parameters for people, installations are used to regulate air temperature - heating and air conditioning installations, while ventilation should be used to ensure proper concentration of carbon dioxide (Chai and Fan 2022; Khare et al. 2023; Ratajczak 2022; Sinacka and Mróz 2023; Sinacka and Szczechowiak 2021; Zender-wiercz et al. 2022). Air exchange in the room can take place through the use of mechanical ventilation with heat recovery or through natural ventilation, mainly through airing.

The efficiency of mechanical ventilation systems is high and allows for the maintenance of proper air parameters, including the possibility of its purification. However, the effectiveness of natural ventilation is not high and depends on many external factors. Most residential buildings in Poland do not have mechanical ventilation (Grygierek and Ferdyn-Grygierek 2022) and the type and configuration of ventilation affects energy usage and comfort (Amanowicz, Ratajczak, and Dudkiewicz 2023). The main burdens for outdoor air quality are two factors: transport and pollution emitted from the burning of fossil fuels to heat buildings. The pollutants emitted from car traffic are related to the type of the tested vehicle, the year of its production (meeting the emission standard) and the efficiency of the engine and non-engine exhaust gas treatment systems, as previously discussed. The amount of pollutant emissions is also related to the intensity of vehicle traffic, the speed of movement, and whether the passage of cars is smooth or whether there are numerous changes in speed, including stopping due to traffic congestion. The combustion of petroleum fuels is associated with the imperfection of this process because of the short time and insufficient mixing of fuel with air. This involves the creation of solid particles. The quantitative and qualitative structure of toxic compounds in exhaust gases depends on many factors, including the operating conditions of the unit, the way it is operated, and the type of fuel and engine used. This is especially important in cities with heavy traffic, where people can be directly exposed to the components emitted by motor vehicles.(Rymaniak et al. 2023; Siedlecki et al. 2019, 2021; Ziółkowski et al. 2022)

Outdoor air pollution related to fuel combustion for heating buildings is mainly particulate matter (PM), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and various heavy metals related to the local combustion of mainly solid fuels. All of these compounds can have detrimental effects on healthy people (Munawer 2018). This takes place in many locations, even in large cities in Poland, although the burning of poor-quality fuels and garbage in small towns is a bigger problem. According to Forbes Reports, Poland has 29 out of 100 cities with the worst air quality in the world. This is related to the burning of fossil fuels, especially in the south of the country. The quality of outdoor air is linked to the quality of indoor air (Leung 2015), especially considering that the exchange of indoor air by introducing outdoor air is mainly through ventilation, which has been the subject of previous research (Basińska et al. 2021). In this case, air with a concentration of pollutants present in the outdoor air is introduced into the buildings. For countries with high outdoor air pollution, there is a high risk that indoor air will also be polluted. For these situations, solutions that will allow one to clean the air introduced into the room, e.g. through air purifiers or the installation of forced ventilation equipped with air filters (Rawat and Kumar 2023). However, it would be better to think about the reason for poor outdoor air quality and look for solutions on a larger scale than your own home.

The research was carried out in one district of a city in Poland, where four measurement points were located. A map with the location of the measurement points is shown in Fig. 1. Several aspects of indoor and outdoor air quality were recorded, and the number of cars passing near the analyzed building was recorded as well. Furthermore, the quality of the outdoor air in the district was recorded in the period before and after the experiment, to provide a general background for the quality of the outdoor air in this district.

2 METHODS

2.1 Experiment Locations and Background

The research was carried out in Poznan, Poland. It is a city with a population of 500,000. According to data from the Inrix report, which aims to verify traffic volume in cities, Poznan is ranked 44th globally, 120th among European cities, and 2nd compared to other cities in Poland. According to statistics, drivers in Poznan spend an average of 74 hours a year in traffic jams. In 2020, 527.5 thousand registered in Pozna. motor vehicles, including 415,000 passenger cars, which translates into 756 passenger cars per 1,000 inhabitants in Poznan.

The city has a heating network powered by a combined heat and power plant that generates heat in cogeneration, with a non-renewable primary energy input factor of 0.9. About 60% of city dwellers (40% of addresses) are supplied with heat from this source. Thanks to this solution, the emission of pollutants related to the preparation of heat for residents is small and does not significantly affect the quality of the outdoor air in the city (Xi et al. 2019).

About 40% of residents declare that they heat their buildings by burning solid fuels, the same percentage uses gas, and about 12% use electricity (mainly through heat pumps). Most multifamily buildings are connected to district heating, whereas single-family buildings use all four types of heat sources. However, the city has poor air quality during the winter, as previously described (Basińska et al. 2021).

The research was planned and conducted in a district of single-family homes. The choice of buildings was related to their location on streets with different intensities of traffic. The location of buildings, car traffic, and outdoor air quality measurement points is shown in Fig. 1a. The measurement point where the outdoor air parameters were continuously measured from April to June was also marked as a district baseline.

The indoor air recorders were placed in a room facing the street where the outdoor air parameters were measured. All rooms had no mechanical ventilation and air exchange was carried out by infiltration or opening a window. The occupants of the premises were to follow their normal mode of use of the premises. The map of the location of the measuring equipment is shown in Fig. 1b.

2.2 Location and dates of measurements

The measurements were carried out over a period of one month. A period of the year was selected in which the heat sources operate only for the preparation of domestic hot water. The study period was selected when the average outside air temperature was higher than 12 °C, at the time when the heating season ended in the city. The average outdoor air temperature measured at the district baseline point (Fig.1) for the first week of measurements was 13.5°C and the concentration of articulate matter was 15.7 $\mu g/m^3$, while on the second week of measurements it was 20.7°C and 14.6 $\mu g/m^3$, respectively.

In each location (A-D), measurements were carried out for one day from 8:00 am to 4:00 pm. Measurement dates: location A – April 26; location B – April 27; location C – May 20, location D – May 21.

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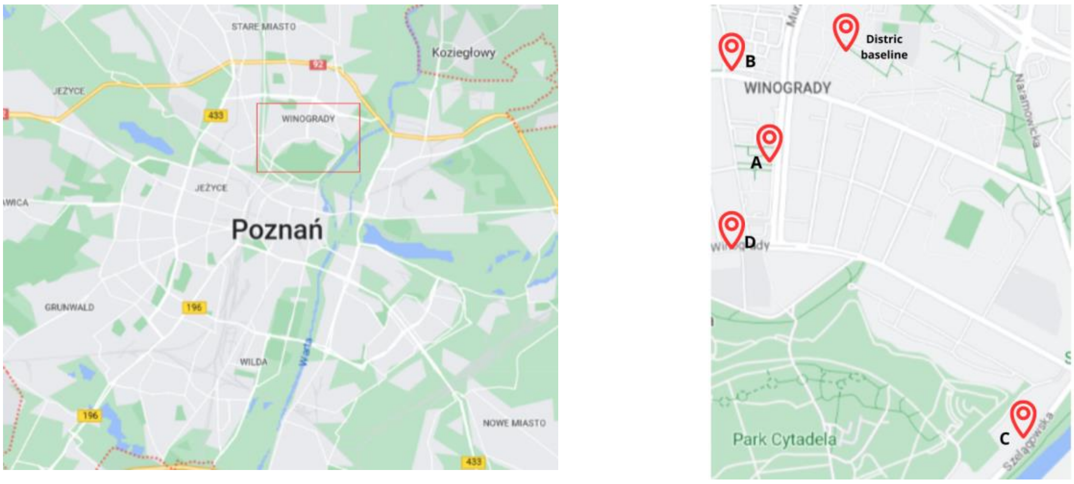

(a) (b)

Figure 1: Analysed district of Poznan City (a) and localisation of measurement points (b) [Source: Google Maps]

2.3 Method of evaluating car traffic and pollutant emissions from car traffic

A device for measuring traffic intensity, i.e. Topo Vitronic, was used for the research. It is a compact device that contains properly configured measuring instruments (Fig. 2). This device uses high-frequency waves, which, after reflection, allow evaluating passing vehicles in several respects.

Figure 2: Device for traffic measurements - Topo Vitronic

The Topo Vitronic device, due to the fact that it uses technology that changes the frequency of waves, allows one to obtain measurements also in tunnels, roadwork zones, or curves. The basic data of the device are presented in Table 1.

Table 1: Description of the Topo Vitronic device

Size	Temperature range	Working time	Communication	Data transfer
42x35x18 cm	−30 to +50 °C	7 days	Bluetooth, GPRS	GSM, GPS

Six vehicle classes were analyzed: Class 1 - PC vehicle, Class 2 - motorcycle or very small vehicle, Class 3 - van and truck, Class 4 - vehicle with trailer, Class 5 - bus or vehicle combination, Class 6 - unclassified vehicle (bicycle, tram).

To evaluate the emission from car traffic previously obtained, unit emission of particulate matter was taken: 7 12 mg PM/km per each car.

2.4 Method for assessing air parameters

Outdoor air quality measurements were made using the NEMo Outdoor recorder (Ethera, France) to measure outdoor air parameters and NEMo Mini XT recorder (Ethera, France) for measuring indoor air parameters. The recorders measured and recorded the air quality parameters at 10-minute intervals. The parameters measured and measurement method are summarized in Table 2. A room with windows facing the street was selected for the location of the indoor unit. The external device with a shield was located directly next to the vehicle traffic measurement apparatus, in the immediate vicinity of the building where the indoor air parameters were measured.

Table 2: Measurments of outdoor air parameters

Parameter	Carbon dioxide	Temperature	Relative humidity	PM2.5, PM10
Detection method	Non-dispersive infrared spectrometry	Complementary Metal-Oxide-Semiconductor	Capacitive	Laser-based light scattering
Measuring range	0−5000 ppm	(−55)−(+120) °C	0−95%	0−1000 μg/m^3
Resolution	1 ppm	0.08 °C	0.08 %	1 μg/m^3
Accuracy	±50 ppm	±0.5 °C	±3 %	±5 %
Used in device	Mini XT	Mini XT; Outdoor	Mini XT; Outdoor	Mini XT; Outdoor

2.5 Assessment criteria

The choice of measurement date was assessed by evaluating the temperature of the outside air and the concentration of PM2.5 and PM10 at the measurement point for the district.
Because the high concentration of particulate matter in the heating season does not determine what is the reason for poor indoor air quality car traffic or combustion from heating source, the criterion for answering the question: Car traffic or emissions from heating sources: What is responsible for IAQ? will be assessing whether the concentration of particulate matter is low or high compared to the WHO standards. The criterion is the following:

- low concentration of particulate matter in the off-heating season period with high traffic intensity - car traffic does not generate high pollution,
- high concentration of particulate matter in the off-heating season period - car traffic generates a lot of pollution

For each measurement point, the following was assessed:

- a number of vehicles passing the building and PM2.5 concentration in the outdoor air,
- range of PM2.5 and PM10 concentrations in indoor and outdoor air,
- range of indoor CO_2 concentration values as the indicator of ventilation.

Historical data described in the publication (Basińska et al. 2021) where similar measurements were carried out, but in the colder period of the year, were also assessed.
The criterion to assess whether car traffic or heating sources have an impact on indoor air quality. The PM2.5 and PM10 concentration in locations with various vehicle traffic (based on the number of vehicles counted during the measurement period) will be evaluated.

3 RESULTS

3.1. Number of vehicles near the building

Using Topo Vitronic measuring equipment, the number of cars passing in 4 locations from 7:00 to 15:00 was calculated. The results for each location are presented in Fig. 3 and in Fig. 4 the total sum of vehicles is presented.

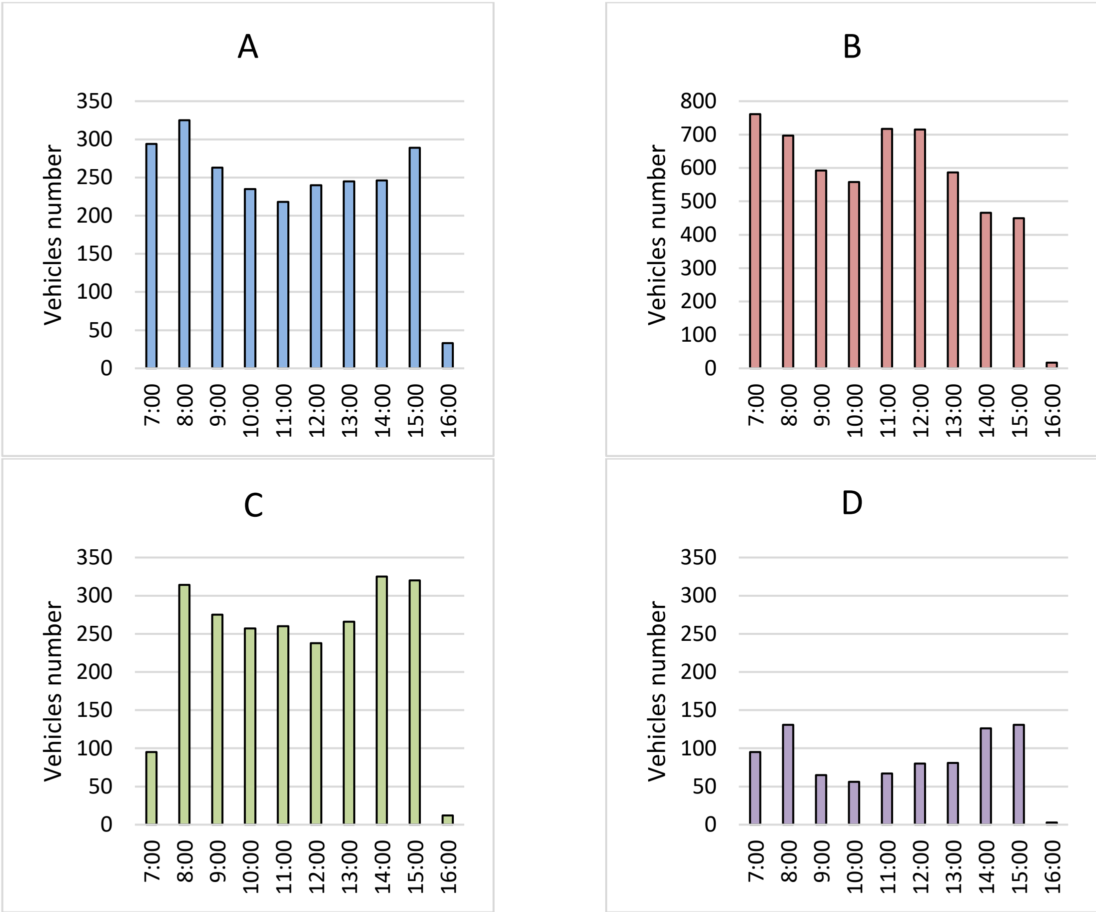

Figure 3: Number of vehicles at each location A, B, C, D during measurement day

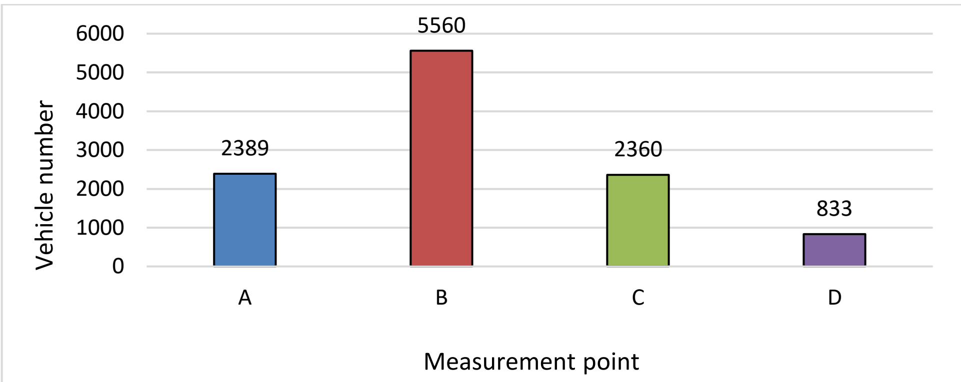

Figure 4: Total number of vehicles at each location A, B, C, D during measurement day

Measurement point B is located on a very busy street. The number of vehicles that passed the measurement point was almost as high as the total number of vehicles observed at the other three locations. Locations A and C are located on broad streets with moderate car traffic, while location D is not a main street. Car traffic in four chosen locations differs, so it should be seen in the results of air parameter measurements.

3.2. PM2.5 and PM10 in indoor and outdoor air

Indoor and outdoor concentrations of PM2.5 and PM10 were measured and the ranges of these parameters in each location are presented in Figure 5.

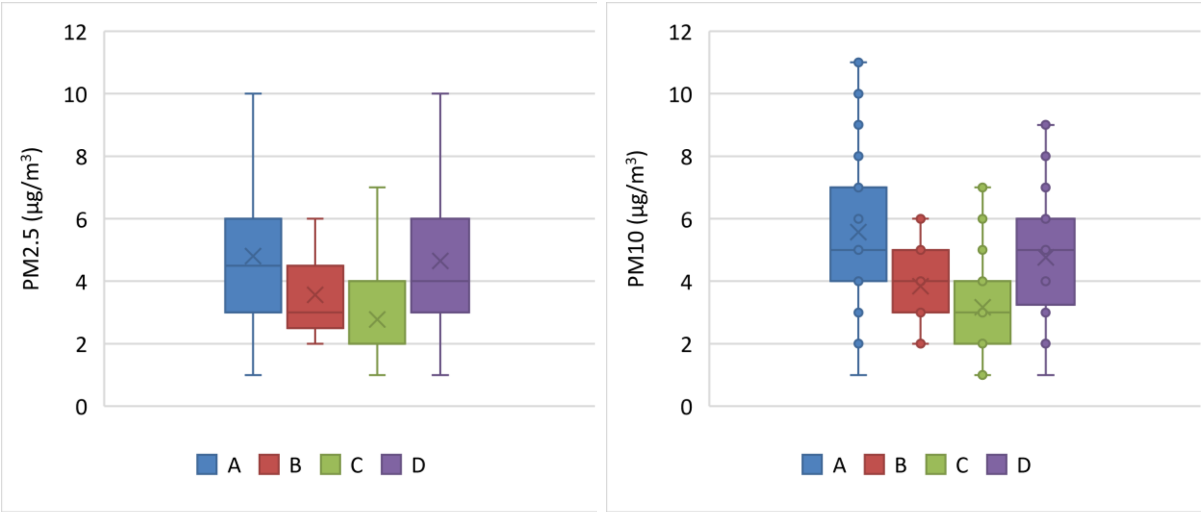

Figure 5: PM2.5 and PM10 in indoor air in locations A, B, C, D

As suspected, the concentration of particulate matter PM2.5 is lower than the concentration of PM10. Because the recommended values for PM2.5 are lower than for PM10, the results for PM2.5 will be discussed. The PM2.5 concentration was low in each location, with the average value ranging from 2.7 to 4.7 µg/m^3. It is below the value recommended by the World Health Organization - 15 µg/m^3. The maximum value was 10 µg/m^3. This suggests good air quality. The average carbon dioxide concentration during measurement day was for locations A, B, C and D 1102 ppm, 777 ppm, 806 ppm and 550 ppm, respectively. The difference in units results from the way the rooms are used and the number of people present in the room. This indicates that the air quality is not bad. But CO_2 concentration is not the topic of this study.

3.3. Concentration of PM2.5 outdoor air

To assess whether car traffic is responsible for air pollution in selected district of large city, the evaluation of concentration of PM2.5 in outdoor air is illustrated in Fig. 6.

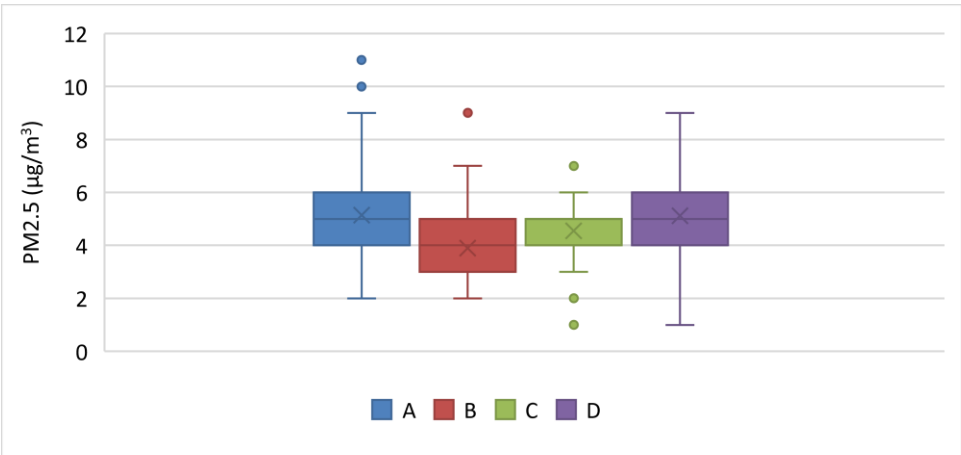

Figure 6: PM2.5 concentration in outdoor air in locations A, B, C, and D

The concentration of PM2.5 in the outdoor air is slightly higher than the concentration of this compound in the indoor air, with the average value for locations A, B, C and D 5.2 µg/m^3, 3,9 µg/m^3, 4,6 µg/m^{3,} and 5.1 µg/m^3. The highest concentration occurred at location D, while the lowest was at location B. PM2.5 did not correspond to the number of vehicles passing near the air parameter recorder. However, the concentration of PM2.5 corresponds well to the concentration in indoor air.

4 EVALUATION OF THE RESULTS

Previously described research on indoor and outdoor air quality in the same district, in the location located about 500 m from location A showed that there is a relationship between the PM2.5 concentration and the season, or more precisely, between the period of the heating season and the lack of the heating season. The results showing the relation between outdoor air temperature and PM2.5 concentration are presented in Fig. 7.

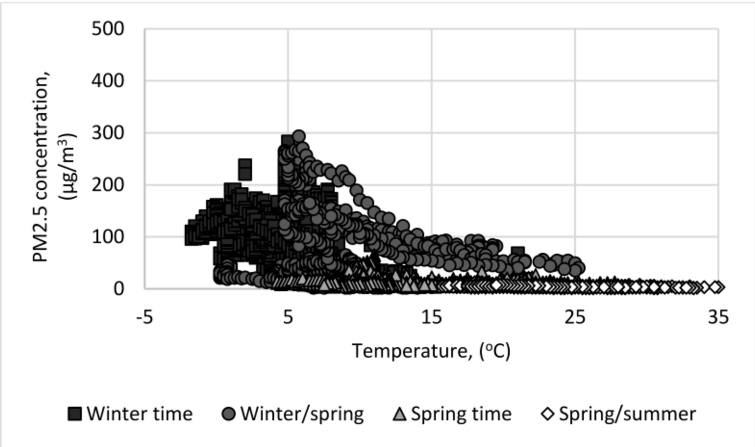

Figure 7: Concentration of PM2.5 in outdoor air in previously published research, based on (Basińska et al. 2021)

The research carried out, described in this article, was aimed at checking whether car traffic near the building affects the parameters of external and indoor air. A short experiment conducted showed that car traffic does not have an effect. Taking into account previous studies in which the seasonality of PM2.5 concentration in outdoor air occurs, it can be concluded that in the analysed location, the responsibility for air quality lies in the combustion of fuels for heating purposes. However, the results are not consistent with other studies conducted in Poland (Zender-Świercz and Polański 2022), but, the city where the other studies were conducted were in a more polluted part of Poland. This indicates the need for further research towards this objective.

The authors realize that the conducted experiment was short and included a small number of air parameters. But with their research, they wanted to draw attention to the fact that a significant problem related to air quality is the burning of fuels to heat buildings.

In this light, the provisions of the European Union related to the need to introduce more ecological ways of supplying buildings with heat seem necessary. By reducing the use of fossil fuels and replacing them with renewable fuels, while taking care to modernize buildings by reducing heat losses, it may be possible to achieve a state in which the quality of outdoor air will improve.

Research and analysis, however, require continuance.

5 CONCLUSIONS

In the studies described, it was important to assess air quality outside the heating season. The difference in the measured concentration of particulate matter in locations with fewer and more car traffic. Using the apparatus for measuring the number of passing vehicles and recorders of air parameters the quality of indoor and outdoor air was assessed in four locations located in one district of the big city.

The concentration of PM2.5 inside buildings indicates good indoor air quality. The maximum concentration of PM2.5 was 10 µg/m^3, and the average was approximately 4 µg/m3. In location B, where the greatest traffic of vehicles occurred, the sum of vehicles that passed the measurement point at this point was 5,560 and was almost as high as the total number of vehicles in the other three locations. It was a point with the largest car traffic. At the same time, in this location, the measured concentration of PM2.5 in the outdoor air was the lowest and amounted to 3.9 µg/m^3. Whereas at location D, where the vehicle traffic was the PM2.5 lowest (833 vehicles), the concentration was 5.1 µg/m^3.

In the experiment carried out, it was assessed that traffic in the examined district does not affect the quality of indoor air in rooms located on the side of the busiest street. But by analyzing historical data, it can be concluded that poor air quality in winter is caused by the fuels used to heat buildings.

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