Particulate Matter PM2.5 and PM10 and Its Impact on Air Quality in Urban and Rural Areas

Simona Kirešová[a], Milan Guzan[a] and Volodymyr Rusyn[b]

[a] *Technical University of Košice, Letná 9, Košice, 042 00, Slovak republic*
[b] *Yuriy Fedkovych Chernivtsi National University, Kotsybynsky str. 2, Chernivtsi, 58012, Ukraine*

Abstract

In this paper we calculate AQI for PM2.5 and PM10 for measurements obtained over several months, from December 2021 to April 2022. There were several measurement locations divided into urban and rural areas. The results have found that AQI for PM2.5 pollutant consistently had a higher value than AQI for PM10 pollutant, which reflects the fact that negative impact of PM2.5 on human health is stronger than that of PM10. The measurements show that higher AQIs and worse air quality were found in the rural areas. A more pronounced difference between urban and rural areas is with PM2.5 pollutant, which may be caused by heating with solid fuel in the villages. The current rising of electricity and gas prices is also an important factor on the worsening of air quality, since more people are looking into alternative sources of heating, such as solid fuel combustion.

Keywords 1

Air quality index, measurement, particulate matter, SPS30

1. Introduction

Particulate matter (PM) are small solid or liquid particles of varying size and composition. According to the size of the particles, there are several categories of PM:

- PM10, or particles with aerodynamic diameter less than 10 μm,
- PM2.5-10, or coarse particles, which are smaller than 10 μm but larger than 2.5 μm,
- PM2.5, also known as fine particles, which are smaller than 2.5 μm
- and PM0.5, also known as ultrafine particles, which are smaller than 0.5 μm [1].

PM can be described by its mass concentration, number concentration, surface area and size distributions. Different metrics are suitable for describing different sizes. For example, ultrafine particles are more suited for measuring the number concentration, while larger particles are often described by their mass concentration [2]. Particularly the mass concentration of PM10 and PM2.5 is important from the standpoint of public health.

PM10 and PM2.5 are classified as air pollutants [3]. The health effects of PM are well researched. Particulate matter has negative effects primarily on the respiratory and cardiovascular systems. Among difficulties caused by high concentrations of PM are decreased lung function and increased respiratory symptoms such as coughing and difficulty breathing. As for the negative health effects on the cardiovascular system, exposure to PM has been linked to irregular heartbeat or non-fatal heart attacks [4] – [9]. Particularly vulnerable groups include people with pre-existing lung or heart conditions, elderly people, and children. There is no evidence of a safe level of exposure or a threshold below there are zero negative health effects of exposure to particulate matter [2]. How strongly PM affects the human health also depends on the size of the particles. Smaller particles can penetrate deeper into respiratory system and even enter the bloodstream, which exacerbates the negative effects of PM on human health [2]. Exposure to ultrafine particles is also linked to diabetes and cancer [4] – [9]. There

ITTAP’2022: 2nd International Workshop on Information Technologies: Theoretical and Applied Problems, November 22–24, 2022, Ternopil, Ukraine
EMAIL: simona.kiresova@tuke.sk (A. 1); milan.guzan@tuke.sk (A. 2); rusyn_v@ukr.net (A. 3)
ORCID: 0000-0001-7285-3609 (A. 1); 0000-0003-2054-7559 (A. 2); 0000-0001-6219-1031 (A. 3)

is evidence that exposure to PM concentration increases the morbidity and mortality, including premature death of individuals with lung or heart problems [11] – [14].

The sources of PM can be natural or anthropogenic. One of the major anthropogenic sources of PM is the residential wood combustion, which contributes to higher concentrations of PM during the heating season in fall, winter, and spring, especially in rural areas [1], [15]. In urban areas, among the major sources of PM is road transport [1], [16]. Another source of PM are emissions from energy and manufacturing industries, but their effect is often less pronounced than that of road transport [1]. The exception are certain cities close to industrial environments, such as Košice, Slovakia. In Košice-Šaca, there is an industrial complex focused on iron metallurgy and steel production. Road traffic is a secondary source of air pollution in Košice [3], [17]. As for natural sources of particulate matter, this category includes windblown dust, sea salt aerosols, volcano eruptions and wildfires [1], [17].

In our previous research, we have focused on measuring the mass concentration of PM [18] – [21] due to the negative health effects of PM. The short-term analysis of PM mass concentrations has found that the air in rural areas is often more polluted and has worse quality than in urban areas, which was also supported by calculating hourly averages of PM mass concentrations. These were our first measurements in November and December 2021, during the peak of the heating season [18]. Other articles dealt with finding out, how much the distance from the source of PM affects the air quality [19] as well as analyzing how often we should measure PM [20]. The correlation between PM and meteorological factors (temperature, humidity, pressure) was a subject of [18], [21]. In our last published paper on PM [21], it was found that looking into long-term analysis of PM is necessary, as the air quality across months in different locations can vary. The metric with most telling value in this case is AQI (air quality index), calculated from daily averages of air pollutants (PM10 and PM2.5).

This paper will deal with the long-term analysis of PM2.5 and PM10 (specifically, the AQIs calculated from the daily averages of mass concentrations) for measurements which took place over several months (December 2021 to April 2022) at several locations, both urban and rural. The purpose of this comparison is to confirm, whether the conclusion from [18] (namely that air quality in rural areas is worse than in urban areas due to the impact of wood combustion being a more prominent source of heating) still stands with more measurements over longer periods of time.

2. Methodology

This chapter will deal with the description of the measurement system built for the purpose of measuring PM, the locations of measurement, data processing, calculating AQI.

2.1. Measurement System

To collect data, a measurement system based on Arduino Nano board was built. The sensory part of the measurement system was consisting of PM sensor SPS30 (the accuracy is shown in Table 1, temperature and humidity sensor SHT30, and temperature and atmospheric pressure sensor MS5611.

Table 1
Accuracy of SPS30 [21].

Parameter	Conditions	Accuracy
Mass concentration of PM1 and PM2.5	<100 μg/m^3	±10 μg/m^3
	>100 μg/m^3	±10 %
Mass concentration of PM4 and PM10	<100 μg/m^3	±25 μg/m^3
	>100 μg/m^3	±25 %
Number concentration of PM1 and PM2.5	<1000 particles/cm^3	±100 particles/cm^3
	>1000 particles/cm^3	±10 %
Number concentration of PM4 and PM10	<1000 particles/cm^3	±250 particles/cm^3
	>1000 particles/cm^3	±25 %

SHT30 and MS5611 sensors were included due to the calculations of correlation between PM and meteorological factors (temperature, humidity, pressure), which is not a subject of this paper. The correlation between particulate matter and meteorological factors was a focus of our previous papers [18], [21]. Data was logged in a *.csv file on a microSD card (which communicated with Arduino Nano via microSD module) every 5 seconds. Each measurement was timestamped by RTC module DS3231.

2.2. Locations of Measurement

The measurements were carried out during several months (from November 2021 to April 2022) at several locations, in both urban and rural areas. Urban areas were situated in Košice, which is the 2nd largest city in Slovakia. The first Košice location was Department of Theoretical and Industrial Electrical Engineering at Technical University of Košice (DTIEE). The department building is located at university campus near a small road, which is not very busy. The distance between DTIEE and the nearest busy road (four-lane road) is approx. 250 m. The highway is separated from DTIEE by a small park. The measurements at DTIEE were carried out outside the window on the 1st floor of the building. The window faces the aforementioned park. Most urban measurements took place in this location. Next Košice location was the balcony on the 11th floor of MEI Hostel, which is located 1.64 km by air to the south-west of DTIEE. The hostel is situated between a busy road on one side and the park on the other side of the building. The balcony was facing towards the park. The final Košice location was the neigborhood "Dargovských hrdinov" (which translates to "The Dargov Heroes") also known as Furča. The neighborhood is located approx. 2.5 km by air to the east of DTIEE. The measurements were carried out on the balcony of the11th floor. The balcony faces a four-lane road.

Rural areas were situated in two small villages. The first village was located 80 km by air to the north-east of Košice. The measurement took place outside the window on the first floor of a family house, which uses wood combustion as the primary source of energy. Many other houses are located close-by, which also heat with wood. The second and final rural location was village located 28 km to the south-east of Košice. The measuring set-up was placed on the balcony of a family house. Similarly to the previous rural location, at the same street there are 5 family houses close-by. All of them use wood combustion as a primary heat source. Most rural measurements took place in this location.

2.3. Calculating Air Quality Index

AQI indicates the levels of air pollutants from a public health perspective. Several air pollutants are used to calculate AQI; namely PM2.5, PM10, CO, SO_2, NO_2, O_3. Because each air pollutant impacts human health differently at different levels of concentration, calculating AQI can tell us more about the air quality than just the measured concentrations of air pollutants, or their averages. PM2.5 have more pronounced negative effects on human health [2] at lower concentrations than PM10, which will project onto a higher value of AQI for PM2.5. AQI can be characterized by one of 6 categories: good, moderate, unhealthy for sensitive groups (which are defined for each air pollutant in Table 2), unhealthy, very unhealthy, and hazardous. Table 3 shows the categories of AQI and what level of air pollutant concentrations correspond to them [23], [24].

Table 2
Sensitive groups defined for each air pollutant [24].

Air pollutant	Sensitive groups
O_3	People with lung disease, children, older adults, people who are active outdoors (including outdoor workers), people with certain genetic variants, and people with diets limited in certain nutrients.
PM2.5 & PM10	People with heart or lung disease, older adults, children, people of lower socioeconomic status.
CO	People with heart disease.
SO_2 & NO_2	People with asthma, children, and older adults.

Table 3
AQI categories and their corresponding levels of air pollutants [24].

O_3** (ppm)	O_3*** (ppm)	PM2.5* (μg/m³)	PM10* (μg/m³)	CO** (ppm)	SO_2*** (ppb)	NO_2*** (ppb)	AQI	Category
0.000 - 0.054	-	0.0 - 12.0	0 - 54	0.0 - 4.4	0 - 35	0 - 53	0 - 50	Good
0.055 - 0.070	-	12.1 - 35.4	55 - 154	4.5 - 9.4	36 - 75	54 - 100	51 - 100	Moderate
0.071 - 0.085	0.125 - 0.164	35.5 - 55.4	155 - 254	9.5 - 12.4	76 - 185	101 - 360	101 - 150	Unhealthy for sensitive groups
0.056 - 0.105	0.165 - 0.204	55.5 - 150.4	255 - 354	12.5 - 15.4	186 - 304	361 - 649	151 - 200	Unhealthy
0.106 - 0.200	0.205 - 0.404	150.5 - 250.4	355 - 424	15.5 - 30.4	305 - 604	650 - 1249	201 - 300	Very unhealthy
-	0.405 - 0.504	250.5 - 350.4	425 - 504	30.5 - 40.4	605 - 804	1250 - 1649	301 - 400	Hazardous
-	0.505 - 0.604	350.5 - 500.4	505 - 604	40.5 - 50.4	805 - 1004	1650 - 2049	401 - 500	Hazardous

*24-hour average, **8-hour average, ***1-hour average.

AQI sub-indices [24] are calculated for each air pollutant using truncated 24-hour, 8-hour or 1-hour averages corresponding with Table 3. For AQI calculation to be valid, at least 75 % of the interval must be measured [24]. Specifically, this means that to calculate AQI sub-indices of PM2.5 and PM10, the measurements each day must last for at least 18 hours.

Sub-indices are calculated using the following equation [24]:

$$AQI_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}\left(C_p - BP_{Lo}\right) + I_{Lo}\ , \qquad (1)$$

where AQI_p = index for pollutant p,
C_p = truncated concentration of pollutant p,
BP_{Hi} = concentration breakpoint greater than or equal to C_p,
BP_{Lo} = concentration breakpoint less than or equal to C_p,
I_{Hi} = AQI value corresponding to BP_{Hi},
I_{Lo} = AQI value corresponding to BP_{Lo}.

From then, total AQI is determined as:

$$AQI = \max\left(AQI_{PM2.5}, AQI_{PM10}, AQI_{O_3}, AQI_{CO}, AQI_{SO_2}, AQI_{NO_2}\right)\ , \qquad (2)$$

Only PM2.5 and PM10 were measured, therefore we can only calculate sub-indices $AQI_{PM2.5}$ and AQI_{PM10}. Although we cannot calculate AQI for all air pollutants that are typically considered, even $AQI_{PM2.5}$ and AQI_{PM10} have still an informational value for us regarding the impact of particulate matter on air quality.

2.4. Data processing

The measured data was processed with MATLAB scripts and functions. First, raw data from *.csv files are imported. Then we check for validity of measurements for each day – if at least 18 hours of measurements per day are recorded, we can calculate daily averages of particulate matter. If the measurement was shorter than 18 hours per day, the measured data is unusable for calculating AQI. Using MATLAB script, we get rid of invalid measurements. The next step is to calculate daily averages of PM2.5 and PM10 from the valid measurements and truncate the result appropriately (one decimal for PM2.5, no decimals for PM10). From daily averages of PM2.5 and PM10, it is possible to calculate their AQI sub-indices. We have created MATLAB function called *aqicalc* to process large amounts of data at once using equation (1). The function calculates AQI for a given category of particulate matter (PM2.5 or PM10) and it also returns the distribution of air quality categories (i.e., how many AQI sub-indices fell under the good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy, or hazardous category). The last step is to plot the calculated AQI sub-indices in a bar graph and visualize the development of air quality in time.

3. Results

We will consider AQI sub-indices for PM2.5 and PM10 for urban as well as rural areas (locations of measurement were described in detail in chapter 2.2 Locations of Measurement) and the impact of each air pollutant on air quality (via the category of AQI they fall under).

3.1. Air Quality in Urban Areas

As mentioned in chapter 2.2 Locations of Measurement, urban measurements were carried out in several locations in Košice, namely DTIEE, MEI Hostel and Košice-Furča. Most of these measurements took place at DTIEE. Only one measurement took place at MEI Hostel (15 December 2021) and two measurements took place in Košice-Furča (24 January and 14 February 2022). All urban measurements are shown in Figure 1, where a total of 39 AQIs for valid measurements are plotted (valid measurements lasting 18 hours per day or more). In reality, more measurements were carried out. However, during many days, the measurements lasted less than 18 hours, thus rendering them invalid and unusable for the purposes of this paper. The red bars in Figure 1 represent $AQI_{PM2.5}$, the black bars represent AQI_{PM10} and the horizontal dashed lines are the limit values of AQI categories: G - good, M - moderate, U (SG) – unhealthy for sensitive groups, U- unhealthy, which correspond to Table 3. No measurements fell in the very unhealthy or hazardous category; therefore, we did not visualize those categories in Figure 1. Table 4 and Table 5 show the distribution of AQI (for PM2.5 and PM10 respectively) by month, measured in urban areas.

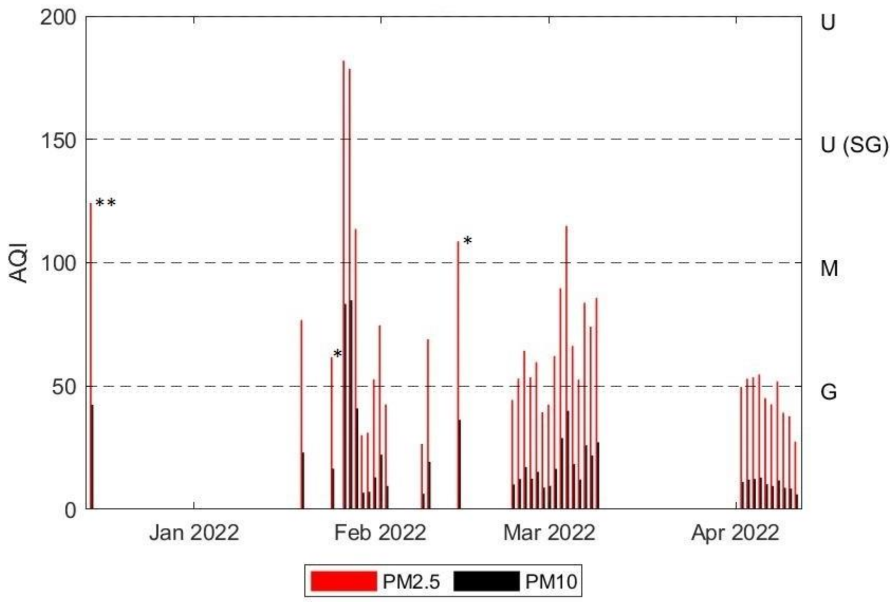

Figure 1: AQI in urban areas: all measurements were carried out at Department of Theoretical and Industrial Electrical Engineering (DTIEE) at Technical University of Košice with the exceptions of 2 measurements carried out in Košice-Furča (24 Jan and 14 Feb 2022, marked with asterisk*) which is located 2.45 km by air to the east of DTIEE and 1 measurement carried out at MEI Hostel, Košice (15 Dec 2021, marked with double asterisk**) which is located 1.64 km by air to the south-west of DTIEE.

As can be seen from Figure 1 as well as Table 4 and Table 5, AQI for PM10 takes on a consistently lower value than AQI for PM2.5. This agrees with the current research into particulate matter, which says that negative health effects cause by the exposure to PM2.5 are more severe than the exposure to the same levels of concentration to PM10 [2]. 37 out of 39 AQI_{PM10} (Table 5) reach good levels of air quality and only 2 reach moderate levels of air quality, which were recorded in January 2022. Compare $AQI_{PM2.5}$ (Table 4), where only 13 $AQI_{PM2.5}$ reach good quality, 20 (a majority) reaches moderate air quality and there are also 4 instances of air quality unhealthy for sensitive groups and 2 even instances of unhealthy air quality. In the months of January to March 2022, the majority of $AQI_{PM2.5}$ were moderate. From December 2021 and March 2022 $AQI_{PM2.5}$ unhealthy for sensitive groups were recorded. Unhealthy air quality was recorded twice in January 2022. April 2022 was different from previous months in that the most $AQI_{PM2.5}$ during April measurements were good, which might have been caused by the end of heating season.

Table 4
Distribution of AQI for PM2.5 in urban areas in 2021-2022 (Figure 1) by month.

$AQI_{PM2.5}$	Good	Moderate	Unhealthy for sensitive groups	Unhealthy	Very unhealthy	Hazardous	Total
December	0	0	1	0	0	0	1
January	2	3	1	2	0	0	8
February	4	6	1	0	0	0	11
March	1	7	1	0	0	0	9
April	6	4	0	0	0	0	10
Total	**13**	**20**	**4**	**2**	**0**	**0**	**39**

Table 5
Distribution of AQI for PM10 in rural areas in 2021-2022 (Figure 1) by month.

AQI_{PM10}	Good	Moderate	Unhealthy for sensitive groups	Unhealthy	Very unhealthy	Hazardous	Total
December	1	0	0	0	0	0	1
January	6	2	0	0	0	0	8
February	11	0	0	0	0	0	11
March	9	0	0	0	0	0	9
April	10	0	0	0	0	0	10
Total	**37**	**2**	**0**	**0**	**0**	**0**	**39**

3.2. Air Quality in Rural Areas

Most rural measurements took place in a village to the south-east of Košice, with the exception of three measurements (8 December 2021, 14-15 December 2021, and 30-31 January 2022) which took place in a different village, to the north-east of Košice. Measurements carried out in December – February were short and relatively isolated. A longer measurement lasted from 12 to 31 March (except that AQIs for 21 March are missing since less than 18 hours were recorded that day). Figure 2 shows all valid AQI calculated for PM2.5 (red bars) and PM10 (black bars). Horizontal dashed lines represent AQI category thresholds, which, just like in Figure 1, correspond to Table 3.

Table 6 and Table 7 show the distribution of PM2.5 and PM10 AQIs by month, measured in rural areas. AQI was calculated for a total of 30 valid days (at least 18 hours measured per day) from December 2021 to March 2022. For PM2.5 (Table 6), most $AQI_{PM2.5}$ fell under the moderate category (17), followed by the unhealthy for sensitive groups category (10), followed by the unhealthy category (2) and only one measurement (in January 2022) showed good air quality. Very unhealthy or hazardous air quality was not recorded for PM2.5. As for PM10 (Table 7), 26 out of 30 days showed good air quality and only 4 AQI_{PM10} were in the moderate category (February and March 2022). No AQI_{PM10} in rural areas was in the unhealthy for sensitive groups, unhealthy, very unhealthy or hazardous category.

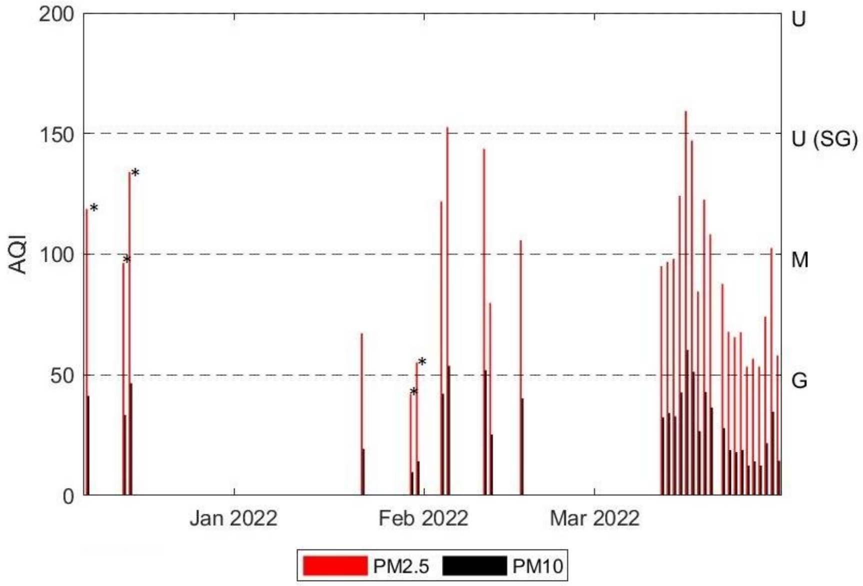

Figure 2: AQI in rural areas all measurements were carried out in a small village located by air 28 km to the south-east of Košice, except for 3 measurements (8 Dec, 14-15 Dec 2021 and 30-31 Jan 2022, marked with an asterisk*) carried out in a village located 80 km by air to the north-east of Košice.

Table 6
Distribution of AQI for PM2.5 in rural areas (Figure 2) by month.

$AQI_{PM2.5}$	Good	Moderate	Unhealthy for sensitive groups	Unhealthy	Very unhealthy	Hazardous	Total
December	0	1	2	0	0	0	3
January	1	2	0	0	0	0	3
February	0	1	3	1	0	0	5
March	0	13	5	1	0	0	19
Total	**1**	**17**	**10**	**2**	**0**	**0**	**30**

Table 7
Distribution of AQI for PM10 in rural areas (Figure 2) by month.

AQI_{PM10}	Good	Moderate	Unhealthy for sensitive groups	Unhealthy	Very unhealthy	Hazardous	Total
December	3	0	0	0	0	0	3
January	3	0	0	0	0	0	3
February	3	2	0	0	0	0	5
March	17	2	0	0	0	0	19
Total	**26**	**4**	**0**	**0**	**0**	**0**	**30**

4. Conclusion

Some areas only had a few measurements (MEI Hostel, Košice-Furča, the village to the north-east of Košice), which means we cannot make conclusions from only a few days' worth of measurements. Most measurements took place at DTIEE (urban area) and the village to the south-east of Košice (rural area), however, these measurements were not carried out simultaneously.

While the shorter measurements (e.g., MEI Hostel, Košice-Furča) may be sufficient for short-term analysis, they are not well suited for the long-term analysis. There need to be more measurements carried out at more places, simultaneously. Those measurements should be continuous and last several months (ideally at least a year) to be able to draw better and more reliable conclusions about the air quality from the long-term perspective. This will be possible to achieve if the sensors are available, which are currently difficult to procure due to the semiconductor shortage.

One thing which is repeated with great consistency throughout all measurements is $AQI_{PM2.5}$ having a higher value than AQI_{PM10}, thus we conclude that PM2.5 has a more negative impact on the air quality than PM10, which is consistent with current research on the effects of particulate matter on human health. This is regardless of whether the measurements were carried out in an urban or a rural area and regardless of when the measurements took place.

It is difficult to draw conclusions about how the seasons affect measurements of PM due to insufficient amount of data. However, from the March and April measurements (which are carried out more consistently than previous months), there appears to be a decreasing trend in AQIs for both PM2.5 and PM10. This coincides with the end of the heating season, which may be a factor impacting the levels of PM mass concentrations.

Most measurements for both urban and rural areas together were carried out in March 2022. From these measurements we can see that the AQIs are higher, and the air quality is worse in the rural areas than in the urban areas. This is also the case for some of previous months with less measurements, (namely in February 2022) as well as the combined measurements in December 2021 to March 2022 (since no measurements in April 2022 were carried out in the rural areas, we will not take April measurements in urban areas into consideration when comparing the air quality in the urban and rural areas). This difference in the air quality between the urban and rural areas is more pronounced in PM2.5 pollutant, which is the more important factor on the air quality out of PM2.5 and PM10. This may also be linked to the greater usage of wood combustion as a heat source in the villages than in the large cities.

It is also important to consider that the measurements were carried out in late 2021 and early 2022. The prices of gas and electricity rose since then and are expected to keep rising in the future. It is reasonable to expect that more and more people will look for alternative sources of heating, e.g., wood combustion, which will have further negative impact the air quality. Thus, we conclude that continuing the measurement and monitoring of particulate matter in the future is of the great importance. The future research will be focused on correcting the shortcomings of this paper (such as the lack of long-term and continuous measurements in some of the measurement places) as well as further developing the measurement system into a more complex and connected device using IoT (Internet of Things) and WSN (Wireless Sensor Network) technologies with an option to visualize the measured data in real time.

5. References

[1] Harrison, R. M. et al.: Airborne particulate matter: sources, atmospheric processes and health. Royal Society of Chemistry, UK, 2016, ISBN: 978-1-78262-491-2.

[2] Kwoon, H., Ryu, M. Carlsten, C.: Ultrafine particles: unique physiochemical properties relevant to health and disease. Experimental and Molecular Medicine, vol. 52, pp. 318-328, Mar. 2020. https://doi.org/10.1038/s12276-020-0405-1

[3] Kremier, M. et al.: Report on Air Quality in Slovak Republic in 2020. Slovak Hydrometeorological Institute, Air Quality Department, Oct. 2021. Available: <https://www.shmu.sk/File/oko/rocenky/2020_Sprava_o_KO_v_SR_v2.pdf>. (In Slovak).

[4] Mühlfeld, C., Rothen-Rutishauser, B., Blank, F., Vanhecke, D., Ochs, M., Gehr, P.: Interactions of nanoparticles with pulmonary structures and cellular responses. The American Journal of Physiology-Lung Cellular and Molecular Physiology, vol. 294, no. 5, L817-L829, May 2008. DOI: 10.1152/ajplung.00442.2007

[5] Kampa, M., Castanas, E.: Human health effects of air pollution. Environmental Pollution, vol. 151, no. 2, pp. 362-367, Jan. 2008. DOI: 10.1016/j.envpol.2007.06.012

[6] Schraufnagel, D. E.: The health effects of ultrafine particles. Experimental & Molecular Medicine, vol. 52, pp. 311-317, Mar. 2020. https://doi.org/10.1038/s12276-020-0403-3
[7] Kyung, S. Y., Jeong, S. H.: Particulate-Matter Related Respiratory Diseases. Tuberculosis and Respiratory Diseases, vol. 83, no. 2, pp. 116-121, Mar. 2020. doi: 10.4046/trd.2019.0025
[8] Jo. E. J. et al.: Effects of particulate matter on respiratory disease and the impact of meteorologival factors in Busan, Korea. Respiratory Medicine, vol. 124, pp. 79-87, Feb. 2017. DOI: 10.1016/j.rmed.2017.02.010
[9] Götschi, T.; Heinrich, J.; Sunyer, J.; Künzli, N. Long-Term Effects of Ambient Air Pollution on Lung Function: A Review. Epidemiology 2008, 19 (5). https://doi.org/10.1097/EDE.0b013e318181650f.
[10] Brook, R. D. Cardiovascular Effects of Air Pollution. Clin. Sci. 2008, 115 (5–6). https://doi.org/10.1042/CS20070444.
[11] Pope, C. A., Ezzati, M., Dockery, D. W.: Fine-Particulate Air Pollution and Life Expectancy in the United States. New England Journal of Medicine, vol. 360, no. 4, pp. 376–386, Jan. 2009. DOI: 10.1056/NEJMsa0805646
[12] Gehring, U. et al: Air Pollution Exposure and Lung Function in Children: The ESCAPE Project. Environmental Health Perspectives, vol. 121, no. 11-12, pp. 1357-1364, Jan. 2013. DOI: 10.1289/ehp.1306770
[13] Zhang, Y., He, M., Wu, S., Zhu, Y., Wang, S., Shima, M., Tamura, K., Ma, L.: Short-Term Effects of Fine Particulate Matter and Temperature on Lung Function among Healthy College Students in Wuhan, China. International Journal of Environmental Research and Public Health, vol. 12, no. 7, pp. 7777–7793, Jul. 2015. DOI: 10.3390/ijerph120707777
[14] Omori, T., Fujimoto, G., Yoshimura, I., Nitta, H., Ono, M.: Effects of Particulate Matter on Daily Mortality in 13 Japanese Cities. Journal of Epidemiology, vol. 13, no. 6, pp. 314-322, Nov. 2007. DOI: 10.2188/jea.13.314
[15] Chafe, Z. et al., "Residential heating with wood and coal: health impacts and policy options in Europe and North America", World Health Organization, 2015. Available: <https://www.euro.who.int/en/publications/abstracts/residential-heating-with-wood-and-coal-health-impacts-and-policy-options-in-europe-and-north-america>.
[16] Suleiman, A., Tight, M. R., Quinn, A. D.: Assessment and prediction of the impact of road transport on ambient concentrations of particulate matter PM10, Transportation Research Part D: Transport and Environment, vol. 49, pp. 301-312, Dec. 2016. https://doi.org/10.1016/j.trd.2016.10.010
[17] World Health Organization: "Health Effects of Particulate Matter", WHO Regional Office for Europe, Copenhagen, Denmark, 2013, ISBN: 978-92-890-0001-7.
[18] Kirešová, S.; Guzan, M.; Galajda, P.: Measuring Particulate Matter (PM) Using SPS30. In 32nd International Conference Radioelektronika; IEEE: Košice, 2022; pp 160–165. DOI: 10.1109/RADIOELEKTRONIKA54537.2022.9764925
[19] Kirešová, S.; Guzan, M., "Koncentrácia pevných častí v ovzduší: porovnanie meraní,", Electrical Engineering and Informatics 13, pp 301-306, Košice, 2022, ISBN: 978-80-553-4120-0. (In Slovak).
[20] Kirešová, S.; Guzan, M., "Analyzing the Sample Period of Particle Mass Concentration Measurements," Proceeding of scientific and student's works in the field of Industrial Electrical Engineering, Volume 11, pp 210-214: Košice 2022, ISBN 978-80-553-4112-5.
[21] Kirešová, S.; Guzan, M. Determining the Correlation between Particulate Matter PM10 and Meteorological Factors. Eng 2022, 3, 343-363. https://doi.org/10.3390/eng3030025
[22] Sensirion. Particulate Matter Sensor for Air Quality Monitoring and Control. Datasheet SPS30. https://cdn.sos.sk/product-449 data/98/89/92718144/sps30-2.pdf. (Accessed 2022-05-30).
[23] Shihab, A. S. Assessment of Ambient Air Quality of Mosul City/Iraq Via Air Quality Index. J. Ecol. Eng. 2021, 22 (10). https://doi.org/10.12911/22998993/142448.
[24] United States Environmental Protection Agency. Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI). Environ. Prot. 2018.