AIR QUALITY DYNAMICS IN THE RESIDENTIAL AREA NEIGHBORING THE ZOBOR HILL FOREST IN NITRA CITY, SLOVAKIA (CASE STUDY)

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Abstract

Currently, mainly in urbanized environments, air is usually mentioned about air pollution. This case study is to present the results of SO₂ and PM₁₀ air quality measurements, which were carried out in selected locality – Zobor, Nitra (Slovakia) on random days in the year 2013. These data were supplemented by measurements of selected meteorological indicators. The results of statistical analysis in software STATISTICA 9 proved that average quantity of SO₂ and PM₁₀ in air are significantly varied based on monitored season (spring, summer, and winter) and day-time and night-time too. The three-factor analysis of variance ultimately proved that monitored meteorological indicators have statistically significant impact on average concentration of polluting substances in air.

Keywords: air quality, sulphur dioxide (SO₂), particulate matter (PM₁₀), residential area, Nitra – Zobor

Introduction

Quality of air significantly influences not only environment of human in relation to his health, but also all living organisms and individual ecosystems in terms of their existence. Substances which have degrading effect on air quality are called exhalants or polluting compounds. Level of air pollution is given by concentration of individual polluting substances in the air or its deposition on earth surface in given time.

Air pollution is a chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. The harmful chemical compounds (from burning) released into the atmosphere are for example carbon monoxide (CO), nitrogen oxides (NO₂), sulphur dioxide (SO₂) and particulate matter or airborne dust (PM) and carbon dioxide (CO₂) as the most significant greenhouse effect gas. Among many sources of air pollution, one can count factories, industries, domestic heating, transportation and power plants. In urban areas, heating and transportation are the dominant factors (Gümrükçüoğlu, 2011). The causes of air pollution episodes include various factors, e.g., emissions, local and synoptic-scale meteorological conditions, topography and atmospheric chemical processes. The relative importance of such factors is dependent on the geographical region, its surrounding emission source areas and the related climatic characteristics, as well

as the season of the year (Piringer, Kukkonen, 2002). Particulate pollution is currently the focus of air quality management and health protection policies due to its multiple impacts on human health and the environment (Bardouki et al., 2003). The air pollution in urban areas has different characteristics because of the changing meteorological factors depending on the geographical and topographical peculiarities of the urban area. The level of the air pollution concentrations is correlated with the combination of the various meteorological factors. For that reason, air pollution concentrations and meteorological data should be evaluated statistically in order to correlate them (Cuhadaroglu, Demirci, 1997). Pollutant concentrations are known to vary on all temporal scales: diurnal, day-of-week, synoptic, intraseasonal, seasonal, interannual, and short- and long-term trends resulting from imposition of control strategies (Whiteman et al., 2014). Problems of PM₁₀ especially from traffic are evaluated or assessed in many European cities. The air pollution from the traffic in relation to the urbanized environment are subject of many studies e.g. Quitta et al. (2012), Clougherty et al. (2008), etc.

The main objective of our case study was to record seasonal and daily dynamics of SO₂ and PM₁₀ in the residential area of Nitra – Zobor, and relate them to the development of local microclimatic parameters.

Materials and Methods

Our research comes from the execution of the project and from measuring of air quality within the months of the year 2012 in urbanized area of Nitra. This research was conducted only within hourly measurements over the course of each day-time, however in six different locations in the city. We measured several meteorological indicators and air quality indicators and all measured indicators are evaluated in the research publication (Rózová et al., 2013). Within the hourly measurements of pollutant changes throughout the year the most distinctly visible were the changes in concentration of SO₂ and PM₁₀. SO₂ was measured in higher concentrations in winter (in the heating season) than in the summer months and PM₁₀ was measured in lower values from spring to autumn. Simultaneously we were interested whether there would be changes in concentrations of SO₂ and PM₁₀ during the day-time and night-time.

Therefore, during the year 2013 the measurements of these pollutants were recorded only at one selected location, however both day-time and night-time. During spring, summer and winter season 2013 we carried out measurements of air quality in selected location of Nitra, observing concentration of SO₂ and PM₁₀. In our case study, we considered the most important comparison of the summer and winter seasons, but statistically meaningful results also showed in the spring measurement. For this reason, we have included the spring season in the results, but we did not include the autumn 2013. At the same time the meteorological parameters were observed: direction and speed of wind, atmospheric pressure,

temperature and relative humidity of air. Measurements of air quality was carried out in selected location (in individual built-up area) in the town of Nitra (Zobor neighborhood, coordinates: 48.3352778N, 18.0911111E) in three seasons of the year 2013 (spring, summer and winter). Measurements of air quality in the year 2013 were carried out on random days during mentioned seasons. For our statistical analyses we considered the daily part of the day between 06.00-22.00 and the night part of the day from 22.00 to 06.00. The total length of each continuous three-day measurement was 72 hours. For this case study, we randomly selected 3 parts of 2013: 27th - 30th March, 2nd - 4th August and 29th - 31st December. In each season of our measurements, we had most likely experienced extreme weather: temperatures below 0 ° C and snow in March, high temperatures, above 35 ° C in August, and temperatures above 10 ° C in December.

For detecting content of SO₂ in air we used portable multicomponent device Aeroqual AQM60 Environmental Station (Aeroqual Ltd., 109 Valley Road, Mt Eden, Auckland 1024, New Zealand), which measures content of several essential polluting compounds (SO₂, NO_x, CO, CO₂, VOC) and thanks to climate converter (Vaisala Weather Transmitter WXT520, Vaisala Oyj, Helsinki, P. O. Box 26, Finland) certain meteorological indicators as well (direction and speed of wind, atmospheric pressure, temperature and relative humidity – location of the sensor thanks to a pedestal and a metal rod at a height of 2.5 m above the ground). The content of polluting compounds was measured in ppm (parts per million). Gas module for sulphur dioxide performs measurements with accuracy $\leq \pm 0.5$ ppm and precision 0.2 ppm. Portable device DustTrak DRX model 8535 (TSI Incorporated, 500 Cardigan Road, Shoreview, MN55126-3996 USA) was used for measuring airborne dust particles (PM₁, PM_{2.5}, RESP – Respirable, PM₁₀ and TPM – Total Particulate Matters). This device measures and records concentration of dust particles in air (mg/m³). DustTrak DRX measures particle sizes of polluting compounds in the range of 0.1–15 µm and by weight concentration between 0.001–150 mg/m³ with separation $\pm 0.1\%$ of the scan or 0.001 mg/m³ and with flow 3 l/min¹. Since we did not compare the pollutants with each other, we keep the measured values in the original units.

The results of measurements were evaluated by methods of mathematical statistics; the calculations themselves were executed in software STATISTICA 9. We have decided to statistically evaluate the results of the measurements by the two-phase and three-factor analysis of scattering (Anděl, 2003). During statistical analysis of results, we used the two-factor analysis of variance with interactions. Factor *A* was the season of the year, during which the measurements were carried out and factor *B* was the time of the day-time of the monitoring. Factor *A* had 3 levels (spring, summer, winter) and factor *B* had 2 levels (day-time, night-time). In a standard way, all observed values (SO₂, PM₁₀) have been denoted by *X*. In the following step, we were interested, which levels of factor *A* are statistically significantly distinct in observed index. For testing distinction, we used the Tukey

test multi-comparison of averages. The result of the evaluation is that the correlation matrices are between the two observed signs and we did not combine them.

Another problem we faced in our research with method ANOVA was the question, whether speed and direction of wind have an effect on the value of polluting compounds in the air. For solving this problem, we used two-factor analysis of variance without interaction. We verified the impact of two factors *C*, *D* on values of the observed variable *X*, while the factor *C* was the speed of wind and factor *D* was the direction of wind. The observed variable *X* was the amount of polluting compound in the air (SO₂ and PM₁₀). The factor *C* (the speed of wind) had 5 levels - intervals A to E in m/s¹ (A: 0.120–3.896; B: 3.897–7.673; C: 7.674–11.450; D: 11.451–15.227; E: 15.228–19.004) and the factor *D* (the direction of wind) had 8 levels in degrees (N: 0–22.5; NE: 22.6–67.5; E: 67.6–112.5; SE: 112.6–157.5; S: 157.6–202.5; SW: 202.6–247.5; W: 247.6–292.5; NW: 292.6–337.5; N: 337.6–360). We divided the wind rose into 8 regular intervals - each of them presenting 44.9 degrees of the wind direction (for N wind direction there are two intervals with joint value of 44.9 degrees).

Lastly, we verified the effect of temperature, relative humidity and air pressure on the value of polluting compounds in the air (SO₂ and PM₁₀). Three-factor analysis of variance without interactions was used to test the statistical significance of the effect of these three factors. The factor *E* was the temperature, the factor *F* was the relative humidity and the factor *G* was the air pressure. The measured values of each considered factor were divided into 5 levels. The temperature (°C) had these 5 levels: A: -1.9–5.78; B: 5.781–13.461; C: 13.462–21.142; D: 21.143–28.823; E: 28.824–36.504, the relative humidity (%) had these 5 levels: A: 21.8–36.0; B: 36.01–50.21; C: 50.22–64.42; D: 64.43–78.63; E: 78.64–92.84 and the pressure (kPa) had 5 levels too: A: 976.9–981.2; B: 981.21–985.51; C: 985.52–989.82; D: 989.83–994.13; E: 994.14–998.44. We didn't take into account of frequency distribution in the divided 5 or 8 intervals in the statistical analysis.

The subject of further analysis is the testing of differences. In the following step, we were interested in which levels of factor *C* – *G* are significantly different in the observed variable (SO₂ and PM₁₀). We used the Tukey test of multi-comparison of averages to test the differences.

Results

We verified whether the effect of mentioned factors is statistically significant in relation to the value of polluting compounds in air. The observed variable *X* was the amount of SO₂ or PM₁₀ in air. Analysis of variance was gradually carried out for individual polluting compounds SO₂ and PM₁₀. Results of the two-factor analysis of variance are given in the Table 1. As in all cases the

value of probability is $p = 0.000000$, we reject the null hypothesis at arbitrarily small significance level. Probability of error which we commit this way is close to zero. That means that the average value of polluting compounds (SO_2 and PM_{10}) in the air during the observed seasons is different and the average value of polluting (SO_2 and PM_{10}) in the air is not the same during day-time and night-time. The mutual interaction of factors A , B in relation to amount of SO_2 and PM_{10} in air is statistically significant. The results which we obtained using the Tukey test, were evaluated based on calculated p -values, which are distinctly given in Table 2. Based on the results in this table we can conclude that the measured average values of SO_2 and PM_{10} are statistically significantly different during all observed seasons. The results are graphically illustrated in Graph 1 and 2 (Vertical bars denote 0.95 confidence intervals).

Table 1: The final table of double classification analysis of variance with interactions for the measured value of SO_2 and PM_{10} in the air

Effect	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>
Season SO_2	0.07	2	0.04	47.38***
Time during day SO_2	0.04	1	0.04	50.63***
Season* Time during day SO_2	0.14	2	0.07	93.91***
Season PM_{10}	6.74	2	3.37	4102.65***
Time during day PM_{10}	0.26	1	0.26	320.08***
Season * Time during day PM_{10}	0.18	2	0.09	109.02***

(*SS* - sums of squares deviations, *Df* - degrees of freedom, *MS* - dispersions, *F* - values of the test criteria, p - values of probability, *** $p < 0.001$)

Table 2: The results of Tukey's test of contrasts effects of factor A on SO_2 and factor A on PM_{10} content in the air in different seasons in 2013

Season	Spring monitoring	SM	WM
Average SO_2	0.01377	0.01015	0.01899
SM SO_2	0.00006***		
WM SO_2	0.00002***	0.00002***	
Average PM_{10}	0.07973	0.02156	0.09909
SM PM_{10}	0.00002***		
WMPM ₁₀	0.00002***	0.00002***	

(SM – summer monitoring, WM – winter monitoring, p - values of probability, *** $p < 0.001$)

By testing it was proved that the amount of measured values of polluting compounds SO_2 and PM_{10} during particular seasons is significantly different. This matter of fact can be caused by transforming meteorological indicators, mainly temperature, pressure, humidity and speed and direction of wind. The average

values of amount of SO_2 and PM_{10} in the air during day-time and night-time are illustrated in Graph 3 and 4 (Vertical bars denote 0.95 confidence intervals).

Graph 1: The average values of SO_2 (ppm) in the air in different seasons of measurements in 2013

Graph 2: The average values of PM_{10} (mg/m^3) in the air in different seasons of measurements in 2013

Graph 3: The average values of SO_2 (ppm) in the air during day-time and night-time in different seasons of measurements in 2013

Graph 4: The average values of PM_{10} (mg/m^3) in the air during day-time and night-time in different seasons of measurements in 2013

With method ANOVA, we verified whether the effect of the presented factors on the value of polluting compounds in the air is statistically significant. The results which we obtained using the two-factor analysis of variance with repetition for each observed attribute (amount of SO_2 and amount of PM_{10}), are distinctly noted in Table 3.

In this case, we also evaluated the results based on the calculated values of probability p . As in all cases the value of probability p is low enough, we can reject the tested hypotheses on the relevant level of significance. This proved that the speed of wind and direction of wind statistically significantly influence the amount of SO_2 and PM_{10} in the air.

Table 3: The final table of double classification analysis of variance for measured value of SO₂ and PM₁₀ in the air

SO ₂ / PM ₁₀	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>
Wind speed SO ₂	0.01	4	0.003	3.32*
Wind speed PM ₁₀	0.05	4	0.012	6.43***
Wind direction SO ₂	0.16	7	0.023	29.69***
Wind direction PM ₁₀	0.79	7	0.113	61.16***

(*SS* - sums of squares deviations, *Df* - degrees of freedom, *MS* - dispersions, *F* - values of the test criteria, *p* - values of probability, **p* < 0.05; ****p* < 0.001)

The Tukey test was evaluated based on calculated *p*-values. Based on the results in these tables we can conclude that the average values of SO₂ and PM₁₀ in the air are statistically significantly different in relation to speed of wind in the interval A (0,120–3,896 m/s¹) and in the interval B (3,897–7,673 m/s¹). A statistically significant difference of the amount of SO₂ and PM₁₀ in the air was not proved in other intervals of the speed of wind. The above results are graphically illustrated in the Graph 5 and 6 (Vertical bars denote 0.95 confidence intervals).

Graph 5: The average values of SO₂ (ppm) in the air in each category wind speed (factor C) Graph 6: The average values of PM₁₀ (mg/m³) in the air in each category wind speed (factor C)

Next, we were interested to find out which levels of factor *D* (direction of wind) are statistically significantly different in terms of the observed attribute. Calculated *p*-values for individual polluting compounds (SO₂ and PM₁₀) are given in the Graph 7 and 8 (Vertical bars denote 0.95 confidence intervals). We proceeded analogically in determining the effect of factor *D* (direction of wind) on the amount of polluting compounds in the air, i.e. SO₂ and PM₁₀. The average values of SO₂ in air are statistically different in the case of the direction of wind from North to Northeast, East, Southeast, also equally statistically different

directions of wind from Northeast and East to South, Southwest, West, Northwest, also from Southeast to South, West, Southwest, and finally from Southwest to West and Northwest. In other directions of wind there was no statistically proven significant difference of the amount of SO_2 in the air.

The average values of PM_{10} in air are statistically different in the case of the direction of wind from North to Northeast, Southeast, South, Southwest, next from Northeast to Southeast, South, Southwest, West, also from East to Southeast, South, Southwest, also from Southeast to South, Southwest, West, Northwest, and equally statistically different directions of wind from South and Southwest to West and Northwest. In other directions of wind there was no statistically proven significant difference of the amount of PM_{10} in the air.

Graph 7: The average values of SO_2 (ppm) in the air at different wind directions

Graph 8: The average values of PM_{10} (mg/m^3) in the air at different wind directions

We tested three hypotheses, where the first is the hypothesis that the average temperature does not have an effect on the amount of polluting compounds in the air (SO_2 and PM_{10}), the second is the hypothesis that the relative humidity does not have an effect on the amount of polluting compounds in the air (SO_2 and PM_{10}) and the third is the hypothesis that the air pressure does not have an effect on the amount of polluting compounds in the air (SO_2 and PM_{10}). After entering the initial data, we obtained the following output table (Table 4) of the three-factor analysis of variance. As in all cases the value of probability p is low enough, these three tested hypotheses can be rejected on the relevant level of significance. By testing it was proved that the pressure, temperature and also air humidity statistically significantly influence the value of polluting compounds SO_2 and PM_{10} in the air.

With the help of Tukey's test of differences of effect of the factor E it was proved that there is no statistically significant difference in the average value of SO_2 in air in two cases; between temperatures in the intervals A (-1.90 – 5.78 °C)

and C (13.460–21.142 °C) and in intervals E (28.824–36.504 °C) and D (21.143–28.823 °C). In other cases, differences in concentration of SO₂ are statistically significant. A statistically significant difference in the average value of SO₂ in air was proved in every category of the relative humidity (factor *F*) and air pressure also (factor *G*). The results are graphically illustrated in Graphs 9–11 (Vertical bars denote 0.95 confidence intervals).

Table 4: The final table of triple classification analysis of variance for measured value of SO₂ and PM₁₀ in the air

SO ₂ /PM ₁₀	<i>SS</i>	<i>Df</i>	<i>MS</i>	<i>F</i>
Pressure SO ₂	0.38	4	0.094	132.84***
Temperature SO ₂	0.01	4	0.004	5.11***
Humidity SO ₂	0.04	4	0.010	14.31***
Pressure PM ₁₀	1.62	4	0.405	761.71***
Temperature PM ₁₀	2.42	4	0.606	1140.02***
Humidity PM ₁₀	0.60	4	0.150	283.01***

(*SS* - sums of squares deviations, *Df* - degrees of freedom, *MS* - dispersions, *F* - values of the test criteria, *p* - values of probability, ****p* < 0.001)

Graph 9: The average values of SO₂ (ppm) in the air in each category of air temperature (factor *E*)

Graph 10: The average values of SO₂ (ppm) in the air in each category of relative humidity (factor *F*)

Based on the results in the Graph 12, in the case of factor *E* we can conclude that the average value of PM₁₀ in air is statistically significantly different almost in every category. A statistically significant difference in the average value of PM₁₀ in air was not proved only in one case; between temperatures in the intervals E (28.824–36.504 °C) and C (13.46–21.142 °C). A statistically significant difference in the average value of PM₁₀ in air was proved in all cases of relative humidity (Graph 13). Results of Tukey's test (Graph 14) proved the differences in average value of PM₁₀ in the air almost in every category of pressure to be

statistically significant. A statistically significant difference in the average value of PM_{10} in air was not proved only in one case, that being between the categories of pressure D (989.83–994.13 kPa) and E (994.14–998.44 kPa) (In graphs 12-14 are vertical bars denote 0.95 confidence intervals).

Graph 11: The average values of SO_2 (ppm) in the air in each category of atmospheric pressure (factor G)

Graph 12: The average values of PM_{10} (mg/m^3) in the air in each category of air temperature (factor E)

Graph 13: The average values of PM_{10} (mg/m^3) in the air in each category of relative humidity (factor F)

Graph 14: The average values of PM_{10} (mg/m^3) in the air in each category of atmospheric pressure (factor G)

Discussion

Urbanization has a myriad of implications for the environment. More recently, the multifariousness of human effects has created various types of urban environments (De La Barrera et al., 2016). According to Nowak (1994) air pollution from transportation, industry, domestic heating, and solid urban waste incineration is a major problem for environmental quality and human health in the urban environment; it leads to increases in respiratory and cardiovascular diseases.

Vegetation in urban systems can improve air quality by removing pollutants from the atmosphere, including ozone (O_3), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matter, which size is less than $10\ \mu m$ (PM_{10}). Limit values for individual pollutants for the protection of human health and the protection of vegetation are set out in the public notice of the Ministry of Environment SR no. 244/2016 Coll. about air quality. The hourly value for human health limit is $350\ \mu g/m^3$ for SO_2 and may not be exceeded more than 24 times per calendar year and the daily value of $25\ \mu g/m^3$ may not be exceeded more than 3 times per calendar year. The annual limit value for the protection of vegetation is $20\ \mu g/m^3$ without possible overrun during the year. PM_{10} have an hourly limit value for the protection of human health of $50\ \mu g/m^3$, which cannot be exceeded more than 35 times a calendar year and an annual value of $40\ \mu g/m^3$ without possible overrun in the year. For SO_2 , a threshold of $500\ \mu g/m^3$ (average hourly value over 3 hours) and for PM_{10} is a valid threshold of $100\ \mu g/m^3$ and a warning threshold of $150\ \mu g/m^3$ (average of 12 hours).

Polluting compounds SO_2 and PM_{10} in the air are among the key components of scoring in the ambient air situation in certain area. Both pollutants belong to the most significant pollutants of the recent decades. In our study the average daily SO_2 concentration during the day-time measured was 0.016 ppm and at night-time the average SO_2 value was 0.011 ppm. Average daily SO_2 values ranged from 0.008 ppm (summer) to 0.020 ppm (spring, winter). From our measurements, the highest average SO_2 night-time value was 0.017 ppm in the winter period, and the lowest average night-time values of SO_2 were measured in spring (0.002 ppm). The highest measured value of SO_2 was on 31 December 2013 at 23:02 (0.490 ppm) and the lowest measured value was on 2 August 2013 at 20:00 (0.001 ppm).

Similar results of measured SO_2 values in the seasons (spring, summer and winter) were obtained in several studies e.g. Durran et al. (1979), Luhana et al. (2007) etc. Measured SO_2 concentrations in the vicinity of point sources are highest for winter and spring conditions and lowest for summer. The major factors are among influencing the SO_2 oxidation reactions in the clouds, in particular the chemical composition of air, changes in light intensity between day-time and night-time and the influence of meteorological parameters such as humidity, wind speed and atmospheric stability.

The average PM_{10} values in our measurements were also diverse during the year 2013. The average day-time PM_{10} value was $0.062\ mg/m^3$ and the average night-time value was $0.076\ mg/m^3$. The average daily value of PM_{10} was $0.070\ mg/m^3$ in spring, $0.021\ mg/m^3$ in summer and with maximum $0.095\ mg/m^3$ in winter. The concentrations of night-time values of PM_{10} were shown likewise. The average night-time value of PM_{10} was $0.098\ mg/m^3$ in spring, $0.022\ mg/m^3$ (almost identical to the average day-time value in the same season) and highest again in winter with $0.107\ mg/m^3$. The highest measured value of PM_{10} was on 31

December 2013 at 20:24 (0.427 mg/m³) and the lowest measured value was on 4 August 2013 at 22:18 (0.007 mg/m³).

The influence of atmospheric exchange conditions on near-surface PM₁₀ concentrations are evaluated in four cities in the South-West of Germany in the period from 2001 to 2005 (Roste et al., 2009). The results of their research point to relatively high PM₁₀ values, especially in winter, due to the absence of precipitation during this period. The results of this statistical analysis indicate that the height of several meteorological variables (for example solar radiation, air temperature and wind speed) affects the nearest PM₁₀ concentrations in cities. Similarly, higher PM₁₀ values were measured in the winter months in a study that analysed and evaluated PM₁₀ in seven selected regions within the European Union. Climatic differences and long-range transport contributed to the increase of PM₁₀ (Querol et al., 2004). The ambient PM₁₀ aerosol samples from Taiwan's Taichung metropolitan basin were collected between October 1997 and January 1998, and were studied their chemical characteristics (Tsai, Cheng, 2004). This research results relate to the average wind speed and relative humidity, which is likely to cause stagnation of PM₁₀ as pollutants.

The relationship between air quality, vegetation and microclimatic factors has also been addressed by several authors. In order to mitigate air pollutant problems, the use of urban vegetation is often promoted as an effective measure to reduce concentrations. This measure is based on the underlying argument that trees (and vegetation in general) have the capability of cleaning the air by filtering out the pollutants. Vegetation leaves absorb gaseous pollutants through their stomata, while particles are removed from the air by deposition onto the leaves and the branches (Vos et al., 2013). The urban trees influence local air quality in various ways. Trees can reduce or increase building energy use by shading buildings, altering air flows and lowering air temperatures through transpiration (Heisler, 1986). Urban green spaces can provide a significant cooling service, which extends beyond the green space boundaries (Vaz Monteiro et al., 2016).

Conclusion

The results of the measurements of the SO₂ and PM₁₀ in our case study showed the differences between 3 randomly selected periods in the year and the differences between day-time and night-time. The results of the measurements prove that the amounts of polluting compounds are varied during different periods of the year. Concentrations of SO₂ were highest during the winter measurement, which is probably due to heating season (winter measurement). Concentration of SO₂ can get to air from sources of pollution. In urbanized areas, specifically in the area we monitored in – residential area, the source is mainly energetic burning processes in residential houses and buildings (local furnaces). The amount of measured concentration of SO₂ can be also influenced by meteorological indicators, mainly changing temperature during the year. Higher levels of

concentration of SO₂ in the air were measured during the colder periods of the year. On the contrary during the warmer periods of the year, the concentration of SO₂ was lower. Also thanks to relation between speed and direction of wind, it is possible for SO₂ to be spread from even remote areas into relatively clean areas.

We measured in our case study lower concentration of PM₁₀ during the summer measurement. We presume, that is due to retaining of the dust particles with assimilatory organs. In case of PM₁₀, tree vegetation in the monitored area can be an important factor – lower concentration of dust particles was measured during the phase of foliage in the summer season. In the winter, with the microclimatic conditions, with the use of spreading bulk material in the streets and with local heating, higher PM₁₀ values were measured.

In the statistical analysis of the results of measurements of pollutants in the atmosphere in selected location in Nitra we used selected methods of mathematical statistics – specifically two-factor and three-factor analysis of variance with interactions. As already stated, the results of statistical analysis proved that average quantity of SO₂ and PM₁₀ in the air significantly varies based on monitored season (spring, summer and winter). It has been shown that the seasons have a statistically significant impact on the concentration of pollutants in the air. At the same time, the statistical analysis revealed that the differences between day-time and night-time were statistically significant.

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