

THE AIR QUALITY ASSESSMENT FROM THE STATIONARY SOURCE AIR POLLUTION

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Abstract

Air quality significantly affects the state of the environment, human health, as well as individual ecosystems. This contribution deals with the assessment of air quality from big stationary source located in Eastern Slovakia. Our additional aim was to define the final order of the air pollution in selected monitored areas based on the level of air polluted by surveyed contamination substances. To analyze the state of air pollution in the area of the selected source pollution, we used basic statistical methods and methods of multidimensional comparison.

Keywords: pollutants; air pollution; air quality state; emissions; statistical methods



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1. Introduction

Air pollution is a phenomenon that increased both in geographical and temporal measure since the start of the civilisation. It is therefore a complex problem that covers many subjects. Air pollution impacts various scales ranging from pure local over regional to global. Cities are by nature concentrations of humans, materials and activities. Today nitrogen oxides, hydrocarbons and small particles attract the attention. Most important are health impacts and impacts on vegetation, on natural and agricultural ecosystems in the form of acidification and eutrophication and impacts of ozone. The depletion of the ozone layer and the increasing greenhouse effect are two most important environmental problems [1].

At present several hundreds of air contamination substances are known and identifiable. The most frequently monitored contamination substances are represented by the substances resulting from combustion of solid, liquid and gaseous fuels as the: carbon oxide, sulphur dioxide, oxides of nitrogen including nitrogen dioxide and nitrogen oxide, the dust components and the secondary pollution substances like the ozone, carbon dioxide and other [2, 3, 4]. The particulate matter (PM) represent the most important health risk involved in air contamination within EU [3, 5, 6]. According to World Health Organization (WHO) reference values, more severe than EU legislative limits, 81 % resp. 95 % of the cities inhabitants were exposed to PM concentrations exceeding the reference values specified with regard to the human health prevention. The ozone may evoke the respiratory problems and may cause the premature death. 17 % of the inhabitants were exposed to the concentrations exceeding the EU target value of the ozone [5, 7, 8]. The formation of both the solid substances and the ozone is contributed by the nitrogen oxide (NO₂) mainly reasoning the eutrophication – the overgrowth of the water plants and sea-grass and the acidification. In many countries of the Union the inland nitrogen oxides emissions remain over the upper levels specified in EU legal enactments and in the international agreements. A big success was reached regarding the sulphur dioxide (SO₂) – its emissions markedly decreased during the foregoing years. The EU legal enactments demand the application of the exhaust gas filtration technologies and the fuel of the lower sulphur volume. In EU the air concentrations of the carbon monoxide, benzene and of the heavy metals (arsenic, cadmium, nickel and plumbum) are generally low, local and sporadic. The cases of both the exceeded limits and the target values specified by EU legal enactments are rare.

In Slovakia, several years of observations result in the investigation that the emissions of both the solid substances and the sulphur dioxide are continuously decreasing from 1990 and that it is caused also by the changed fuel basis in favour of the generous fuels, through the implementation of the separators technique and by improving its efficiency, through the application of the heating oils with low volume of the sulphur and by installation of the desulphurating equipment in big energetic sources. CO emissions are of the decreasing tendencies too. The nitrogen oxides emissions show slight decrease from 1990 [3, 5, 9]. The air prevention is one of the most monitored environmental components evidenced through a considerable progress of the development of the legislation. Now, in Slovakia the allowed level of air pollution is determined by Law No. 318/2012 Coll. of Laws on the Air [10] and by Ministry of Environment Regulation No. 442/2013 Coll. of Laws on the Air Quality Limit Values, tolerance limits, numbers of exceeded limit values [11]. Long term, within several spheres, Slovakia does not follow the limit values of dust particles (PM₁₀) specified through the European Parliament and Board Directive 2008/50/ES on Environment Air Quality and on Clean Air transposed to Ministry of Environment Regulation No. 442/2013 Coll. of Laws on Air Quality [12].

2. Object and methods of research

In east Slovakia the air quality is to a great degree influenced by the activities of big stationary industrial sources within both the metallurgical and the chemical industries and through the production of heat and electric energy. The considerable pollution of the emissions negatively impacting the air quality is the consequence of the mentioned activities [13].

Monitoring area	Distance from contamination source (km)
MA1	8
MA2	5.6
MA3	15.8
MA4	10.3
MA5	1

Table 1. Monitoring areas – characteristics

In East Slovakia is located an important steel plant which, on one hand, is one of the biggest and the most important companies of decisive relevance regarding entire Slovakia, but on the other hand it is one of big air polluters. With more than 10 % share of SO₂ production it is one of four dominant SO₂ production sources within Slovakia.

One of many obligations of the air pollution sources operators is their responsibility to perform the regular monitoring of the particular polluting substances discharged from these sources. The purpose is to recognize the

compliance with the specified emission limits. The steel plant performs also the regular air monitoring by the measuring vehicle in surrounding villages. In recent time period the most frequently monitored areas were the five villages: MA1, MA2, MA3, MA4 and MA5 (Table 1). Every month is realized the distribution and the collection of the dust fall sample-cases within the localities near the company namely due to the long-term control of the spread and the evaluation of the soil dustiness intensity.

To analyze the state of air pollution in the area of the selected source pollution, we used basic statistical methods and methods of multidimensional comparison.

3. Result

The level of the air quality of selected areas within the strategic plant environment was described by five contamination substances: carbon oxide CO, sulphur dioxide SO₂, nitrogen oxide NO₂, ozone O₃ and the particulate matter PM₁₀. The air quality assurance was based on the previous year data measured by the company.

3.1 Basic characteristic

The Table 2 shows the basic features of selected air quality indicators within the respective locations. The values of CO and O₃ represent the maximum 8-hour day average. The values of SO₂ and PM₁₀ show the 24-hour average and the values of NO₂ represent the maximum 1 hour average.

Monitoring area	Max. daily average	CO (mg/m ³)	SO ₂ (µg/m ³)	NO ₂ (µg/m ³)	O ₃ (µg/m ³)	PM ₁₀ (µg/m ³)
		8-hours	24-hours	1-hour	8-hours	24-hours
MA1	Average	0.935	32.955	18.227	88.750	21.909
	Stand.deviation	0.388	16.102	16.142	5.560	10.034
	Max-min	1.4-0.1	55-1	59-1	94-83	39-5
MA2	Average	1.217	39.087	38.130	63.625	33.529
	Stand.deviation	0.402	15.719	18.013	21.974	14.803
	Max-min	1.9-0.1	65-14	72-7	94-41	60-6
MA3	Average	1.184	33.429	31.611	60.222	32.273
	Stand.deviation	0.456	13.815	21.219	5.674	9.328
	Max-min	2.3-0.6	48-4	85-3	69-50	45-13
MA4	Average	1.263	52.745	33.340	75.333	22.042
	Stand.deviation	0.539	33.966	21.379	24.055	7.850
	Max-min	2.5-0.3	230-8	85-5	91-27	43-12
MA5	Average	0.981	27.714	30.434	28.250	27.375
	Stand.deviation	0.389	10.199	15.496	7.365	17.378
	Max-min	1.7-0.4	48-4	55-6	37-19	51-11
limit		10 mg/m ³	125 µg/m ³	200 µg/m ³	120 µg/m ³	50 µg/m ³

Table 2. Descriptive characteristics of air quality indicators

CO concentrations found within the respective measuring locations result in the knowledge that the monitoring area MA4 is the most contaminated locality. The order of the locations of the highest average CO concentration is as follows: MA4 > MA2 > MA3 > MA5 > MA1.

The maximum daily 1-hour SO₂ value was measured in the monitoring locality MA4 (230 µm/m³). The order of the locations of the highest average of SO₂ concentrations is as follows: MA4 > MA2 > MA3 > MA1 > MA5.

During the existing time period the highest average NO₂ value was measured in the monitoring location MA4. The order of the locations of the highest average NO₂ concentration is as follows: MA2 > MA4 > MA3 > MA5 > MA1.

In the monitoring location MA1 the highest average value of ozone O₃, of allowed limit 120 µm/m³, was measured during the time period of the monitoring. The order of the locations of the highest O₃ concentration is as follows: MA1 > MA4 > MA2 > MA3 > MA5.

The highest PM₁₀ value was measured in the monitoring location MA2 representing 1.2 multiple of allowed 50 µm/m³ limit value. The order of the locations air pollution is as follows: MA2 > MA3 > MA5 > MA4 > MA1. Air Quality Index (AQI) was applied in air quality assessmen (Table 3) [14]. The measured data analysis most frequently shows the low level of air polluted by surveyed indicators in respective monitoring locations (Table 4).

Pollution category	CO (8h) (mg/m ³)	SO ₂ (24 h) (µg/m ³)	NO ₂ (1 h) (µg/m ³)	O ₃ (8 h) (µg/m ³)	PM ₁₀ (24 h) (µg/m ³)
Unhealthy	15.5-30	500-1000	950-1900	223-500	238-500
Unhealthy for sensitive groups	11.6-15.5	250-500	400-950	180-223	144-238
Moderate pollution	10-11.6	125-500	200-400	120-180	50-144
Low pollution	4-10	20-125	40-200	65-120	20-50
Good quality	0-4	0-20	0-40	0-65	0-20

Table 3. Breakpoints for the AQI, according to [14]

Monitoring area	CO (8h) (mg/m ³)	SO ₂ (24 h) (µg/m ³)	NO ₂ (1 h) (µg/m ³)	O ₃ (8 h) (µg/m ³)	PM ₁₀ (24 h) (µg/m ³)
MA1	Good quality	Low pollution	Low pollution	Low pollution	Low pollution
MA2	Good quality	Low pollution	Low pollution	Low pollution	Moderate pollution
MA3	Good quality	Low pollution	Low pollution	Low pollution	Low pollution
MA4	Good quality	Low pollution	Low pollution	Low pollution	Low pollution
MA5	Good quality	Low pollution	Low pollution	Good quality	Low pollution

Table 4. AQI of surveyed indicators in respective monitoring locations.

3.2 Multidimensional comparison methods

Our additional aim is to define the final order of the air pollution in selected monitoring localities based on the level of air polluted by surveyed contamination substances. In comparison of monitoring areas were chosen the methods: simple ordering method, the scoring method, the standardized variable method and the fictitious point distance method [15, 16, 17, 18]. All variables are deemed as de-stimulating variables (its decrease is the positive effect).

Through the *ordering method* the location of the lowest average value of surveyed parameter was assigned with the highest value equal to 1. In case of the equal values the respective monitoring locations were assigned with average order. The final order of surveyed locations was determined based on the sum of the respective orders. The location of the lowest sum of orders is assigned with the lowest order. The analysis indicates that locality MA2 is the monitoring location of the highest concentration of air pollution substances and locality MA5 is the location of the lowest concentration (Table 5). The final order is as follows: MA2 > MA4 > MA3 > MA1 > MA5.

Monitoring area	CO (8h) (mg/m ³)	SO ₂ (24 h) (µg/m ³)	NO ₂ (1 h) (µg/m ³)	O ₃ (8 h) (µg/m ³)	PM ₁₀ (24 h) (µg/m ³)	d _i	Order
MA1	1	2	1	5	1	10	2.
MA2	4	4	5	3	5	21	5.
MA3	3	3	3	2	4	15	3.
MA4	5	5	4	4	2	20	4.
MA5	2	1	2	1	3	9	1.

Table 5. The resulting values and average order - Ordering method

With the scoring method the determined values of variables were replaced with the number of points. Maximum number of 100 points was assigned to the location of the lowest value of given parameter. Remaining monitoring locations were assigned with the number of points according to formula:

$$z_{ij} = \frac{x_{\min,j}}{x_{ij}} \cdot 100\% , i = 1,2,\dots,5 , j = 1,2,\dots,5 \tag{1}$$

where *i* is the number of monitoring locations, *j* is the number of variables, *b_{ij}* is the number of points of *j* variable in *i* measuring location, *x_{ij}* is the value of assigned variable *d_i* appertaining to *i* location and *x_{min,j}* is the minimum value of the respective variable.

Based on the total score is defined the order of the respective monitoring locations. The final order of the monitoring locations is as follows (Table 6): MA2 > MA4 > MA3 > MA1 > MA5.

Monitoring area	CO (8h) (mg/m ³)	SO ₂ (24 h) (µg/m ³)	NO ₂ (1 h) (µg/m ³)	O ₃ (8 h) (µg/m ³)	PM ₁₀ (24 h) (µg/m ³)	d _i	Order
MA1	100.000	84.099	100.000	31.831	100.000	83.186	2.
MA2	76.804	70.904	47.802	44.401	65.343	61.051	5.
MA3	78.956	82.906	57.661	46.910	67.887	66.864	3.
MA4	74.038	52.544	54.671	37.500	99.399	63.630	4.
MA5	95.316	100.000	59.884	100.000	80.033	87.047	1.

Table 6. The resulting values and average order - Scoring method

In the standardized variable method are the values of de-stimulating variables standardized according to the relation:

$$z_{ij} = \frac{\bar{x}_j - x_{ij}}{s_j}, \quad i = 1, 2, \dots, 5, \quad j = 1, 2, \dots, 5 \quad (2)$$

where \bar{x}_j is arithmetic mean and s_j is standard deviation of j variable.

Based on the arithmetic mean of \bar{z}_i standardized values was determined the order of the monitoring locations depending on the air pollution. The final order of the monitoring locations is as follows (Table 7): MA2 > MA4 > MA3 > MA1 > MA5.

Monitoring area	CO (8h) (mg/m ³)	SO ₂ (24 h) (µg/m ³)	NO ₂ (1 h) (µg/m ³)	O ₃ (8 h) (µg/m ³)	PM ₁₀ (24 h) (µg/m ³)	d _i	Order
MA1	1.224	0.441	1.642	-1.132	1.006	0.636	2.
MA2	-0.685	-0.198	-1.054	-0.017	-1.114	-0.614	5.
MA3	-0.461	0.392	-0.171	0.134	-0.884	-0.198	3.
MA4	-0.992	-1.623	-0.405	-0.537	0.982	-0.515	4.
MA5	0.914	0.988	-0.012	1.553	0.009	0.690	1.

Table 7. The resulting values and average order - Standardized variable method

In the fictitious point distance method was defined the fictitious point with the co-ordinates depending on the type of the variable. For de-stimulating variable is formula:

$$z_{oj} = \min_i \{z_{ij}\}, \quad i = 1, 2, \dots, 5, \quad (3)$$

where z_{ij} are the standardized values of the variables. The order of the locations was specified through the average Euclidian fictitious point distance d_i according to formula:

$$d_i = \sqrt{\frac{1}{k} \sum_{j=1}^k (z_{ij} - z_{oj})^2}, \quad i = 1, 2, \dots, 5, \quad (4)$$

The final order of the monitoring locations is as follows (Table 8): MA2 > MA4 > MA3 > MA5 > MA1.

Monitoring area	CO (8h) (mg/m ³)	SO ₂ (24 h) (µg/m ³)	NO ₂ (1 h) (µg/m ³)	O ₃ (8 h) (µg/m ³)	PM ₁₀ (24 h) (µg/m ³)	d _i	Order
MA1	4.914	4.264	7.267	0.000	4.495	4.188	1.
MA2	0.094	2.031	0.000	1.244	0.000	0.674	5.
MA3	0.283	4.062	0.780	1.603	0.053	1.356	3.
MA4	0.000	0.000	0.421	0.355	4.393	1.034	4.
MA5	3.633	6.821	1.086	7.210	1.261	4.002	2.

Table 8. The resulting values and average order - Fictitious point distance method

Overall analysis of the air pollution assessment indicates the order of the monitoring locations as follows in Table 9.

Ordering method	Scoring method	Standardized variable	Fictitious point distance method	Final order
MA2	MA2	MA2	MA2	5.
MA4	MA4	MA4	MA4	4.
MA3	MA3	MA3	MA3	3.
MA1	MA1	MA1	MA5	2.
MA5	MA5	MA5	MA1	1.

Table 9. Final order of monitoring locations- from locality of the highest level of pollution

Any applied method indicates that the locality MA2 is the location of the highest air pollution. Next are the localities MA4, MA3 and MA1. The monitoring area MA5 seems to be the location of the lowest level of the air pollution. The final order of the monitoring locations is as follows: MA2 > MA4 > MA3 > MA1 > MA5.

Equal orders were verified by *Kendall coefficient of concordance W*. Regarding the concerned case the coefficient of concordance value is $W = 0.963$ and indicates a good concordance of the respective methods results. The statistical significance of Kendall coefficient of concordance was confirmed through the table of critical values of real distribution of w parameter.

4. Conclusion

High priority recommendations are made in the following six strategic areas: observations, data, understanding, modelling, tools and education. These include the need for more operational urban measurement stations and networks; for an international data archive to aid translation of research findings into design tools, along with guidelines for different climate zones and land uses; to develop methods to analyse atmospheric data measured above complex urban surfaces; to improve short-range, high-resolution numerical prediction of weather, air quality and chemical dispersion through improved modelling of the biogeophysical features of the urban land surface; to improve education about urban meteorology; and to encourage communication across scientific disciplines at a range of spatial and temporal scales. There need reviews with attention to sustainability of cities, applications that use climate information, and scientific understanding in relation to measurements and modelling [16, 19].

These are reviewed here with attention to sustainability of cities, applications that use climate information, and scientific understanding in relation to measurements and modelling. Based on the comparison of the measuring locations within the plant environment we found that the highest pollution was in the monitoring locality MA2 and the lowest pollution was in the locality MA5. Surprising is that the pollution source nearest locality MA5 is the locality of the best air quality state. The reason may be the appropriate meteorological conditions and especially the speed and the direction of the wind.

As the Eurobarometer enquiry shows the European citizens see the air pollution very serious. The air pollution across the continent shortens the age of life and lot of people suffer from chronic respiratory diseases. European Commission was interested in the most effective methods of problems solving according to the citizens opinion. The most frequent answer in Slovakia (43%) and in EU average (38 %) represented the application of more strict air pollution control of industrial technologies and the energy production.

This work is devoted to a statistical analysis of air pollution emissions and air quality assessment from the stationary source. From these results we can deduce the necessity of the research and studies addressing to implementation and development cleaner technologies and techniques (BAT) and integrated control of pollution, because the issue of environmental protection will always be a priority problem.

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6. References

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