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DIRECTIONS OF AIR POLLUTION INFLOWS AS A METHOD FOR EVALUATION OF REPRESENTATIVENESS OF AUTOMATIC AIR MONITORING STATIONS AREA

The use of averaged directional air pollution inflows has been investigated for the area representativeness evaluation of automatic air monitoring stations. Two-year data from chosen monitoring stations were used. The one-hour values of SO_2, NO, NO_2, CO, and PM10 concentrations were ordered with respect to their inflow direction, by dividing them into 36 sectors of 10º range and calculating their arithmetic mean. For the obtained values, the dispersion analysis was carried out. It was concluded that the averaged concentration dispersion of pollutants in the direction sectors can be used as one of the criteria for the automatic air monitoring stations area representativeness evaluation. The changeability coefficients can be used as a measure of the dispersion. They are dimensionless quantities, often expressed as percentages.

1. INTRODUCTION

Air pollutant concentration levels usually vary greatly in time and spatially, particularly in urban areas [1]. The representativeness of air pollutant concentration measurements decreases with the distance from a monitoring station. In various spots around the measuring station the actual level of air pollutant concentrations can show different tendency, e.g. under influence of complicated local wind field, depended on differences in altitude, housing development, or local emission source [2–5].

Legal acts in force give precise guidelines for the location of different types of stations and surface area, to facilitate results representativeness for the specific area [6, 7]. The levels of air pollutant concentrations are usually given for big areas, cities or regions, even though they are measured at a certain location of an air monitoring station [8]. This kind of generalization is usually unfounded. In order to present reliability of measurements, a certain physical feature is usually chosen. It is characterizing the size of the area and for

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this area the results of measurements can be accepted as representative. The, so called, scale of spatial representativeness has been chosen for the purpose [9].

It is possible to determine the representativeness of a measuring point with the use of calculated distributions of averaged pollution concentration in a chosen area. Those distributions can be obtained with mathematical models. It is also possible to obtain the data when performing the periodic measurements in the area with the use of simple techniques, mobile stations, analysis of emission sources location and the dispersion conditions of pollutants in the chosen area [10]. However, so far the methods for the objective evaluation of area representativeness of already existing air monitoring stations with the use of modelling tools were not unambiguously described.

The hypothesis that the information on area representativeness of the particular station is in the measurement data from the air monitoring network was confirmed by preliminary investigation [9]. It has been observed that if several automatic air monitoring stations exist in a small area with the uniform climate, the global and regional factors cause the same changeability of the concentrations in all of those stations. However, the differences in the changeability courses of individual pollutant concentrations are caused by the local factors. Bigger differences between the concentration courses of an individual pollutant observed at particular stations and the courses averaged for the whole area indicate increased influence of the local factors on the levels of those concentrations. It can be directly related to the level of the area representativeness of individual stations. If the local factors have a small impact on the concentration levels of particular pollutants, good agreement between the levels at all stations in the area will be achieved. It was further implied that similar information can be obtained with simple statistical methods and using data only from one station located in the area [9].

The analysis of the direction of the inflow in the region of location of a measuring station can become another important criterion for evaluation of representativeness of the automatic air monitoring stations area. Its most optimum indicator is the uniform distribution of the directional inflows of individual air pollutants.

The aim of the work was to determine possible use of average directional inflows for qualitative determination of automatic air monitoring stations area representativeness. In the present work, the application of the statistical parameters for dispersion of averaged concentration values of particular air pollutants in the sectors of the directional inflows. These results will be used in future for development of the universal, dimensionless parameter, which could be used as an indicator of the level of representativeness of an automatic air monitoring station area by administrative units.

2. METHODS

Calculations were done with the use of data from four automatic measuring stations of Silesian Air Monitoring from 2007–2008. The stations are located in Katowice, Cieszyn, Dąbrowa Górnicza and Częstochowa. In all of them the urban background is measured.

Averaged 1 hour concentrations of SO_2, NO, NO_2, PM10 and CO were ordered in respect to the direction of their inflow. They were divided into 36 directions every 10°. The concentrations were then averaged for each direction sector and each pollutant. In this way, the roses of pollution inflows were obtained. They characterize average concentration levels of individual pollutants in the direction sectors. Next, the dispersion of obtained averaged values in 36 sectors was calculated with the use of descriptive statistic. The following measures of dispersion were used:

- range R – the difference between the maximum and minimum values, average deviation d – the arithmetic mean value of the absolute difference between the individual values of the characterizing parameter and the average value

$$d = \frac{1}{n}\sum_{i=1}^{n}\left|x_i - \overline{x}\right| \tag{1}$$

- variance s^2 as the mean square deviation of individual result from the average

$$s^2 = \frac{1}{n}\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2 \tag{2}$$

- standard deviation s as the square root of the variance.

For the diversification level, comparison between the concentration courses of individual pollutants inflow to the chosen measuring stations, in addition also the per centage changeability coefficient in respect to the standard deviation V_s (Eq. (3)) and the average deviation V_d (Eq. (4)) were calculated,

$$V_s = \frac{s}{\overline{x}} \times 100\% \tag{3}$$

$$V_d = \frac{d}{\overline{x}} \times 100\% \tag{4}$$

Wind roses for the location areas of particular measuring stations were also determined.

3. RESULTS AND DISCUSSION

In Figures 1–4, the pie charts of pollution roses are shown. The average concentration levels of SO_2, NO, NO_2, PM10 and CO inflowing to the particular measuring stations in 36 direction sectors are presented. The bold line in the charts indicates the average concentration values.

The NO_2, PM10 and CO pie charts show similarities for individual measuring stations. This implies that the representativeness of the monitoring station area of those three pollutants will be comparable.

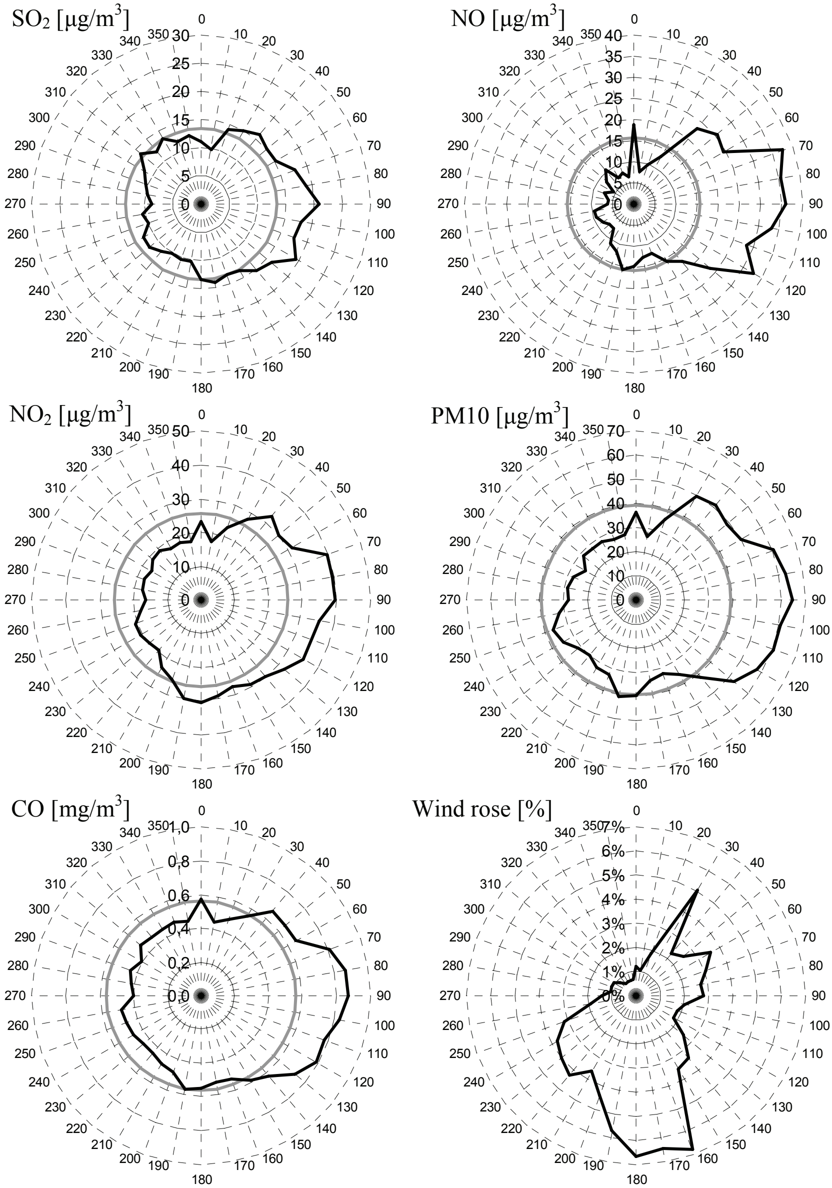

Fig. 1. The pollution rose pie charts illustrating the average concentration levels of SO_2, NO, NO_2, PM10 and CO, inflowing in 10° direction sectors and wind rose for the area at the automatic air monitoring station in Katowice

The directions of SO_2 inflows differ from the other pollutants directional inflows. Especially at the measuring station in Częstochowa, the dominating direction is north-east, and SO_2 concentration values are more than twice higher than the average.

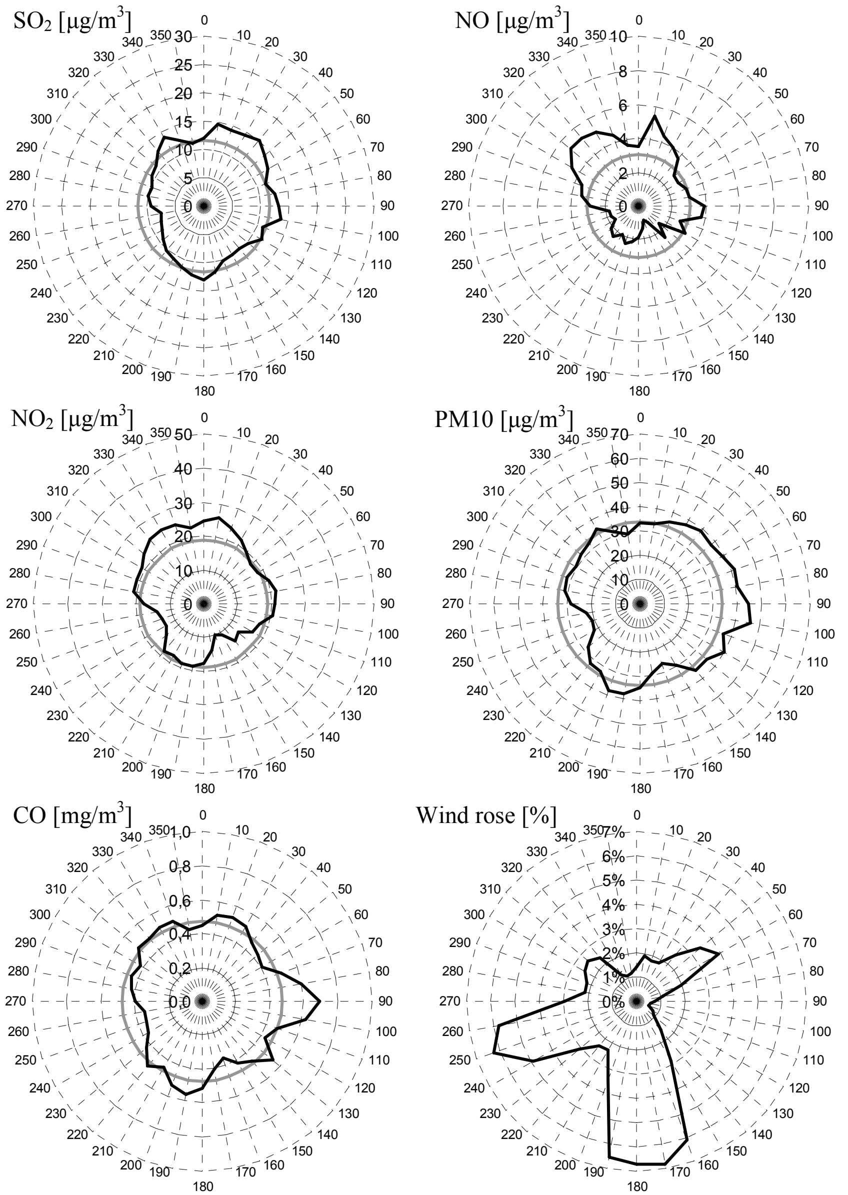

Fig. 2. The pollution rose pie charts illustrating the average concentration levels of SO_2, NO, NO_2, PM10 and CO, inflowing in 10° direction sectors and wind rose for the area at the automatic air monitoring station in Cieszyn

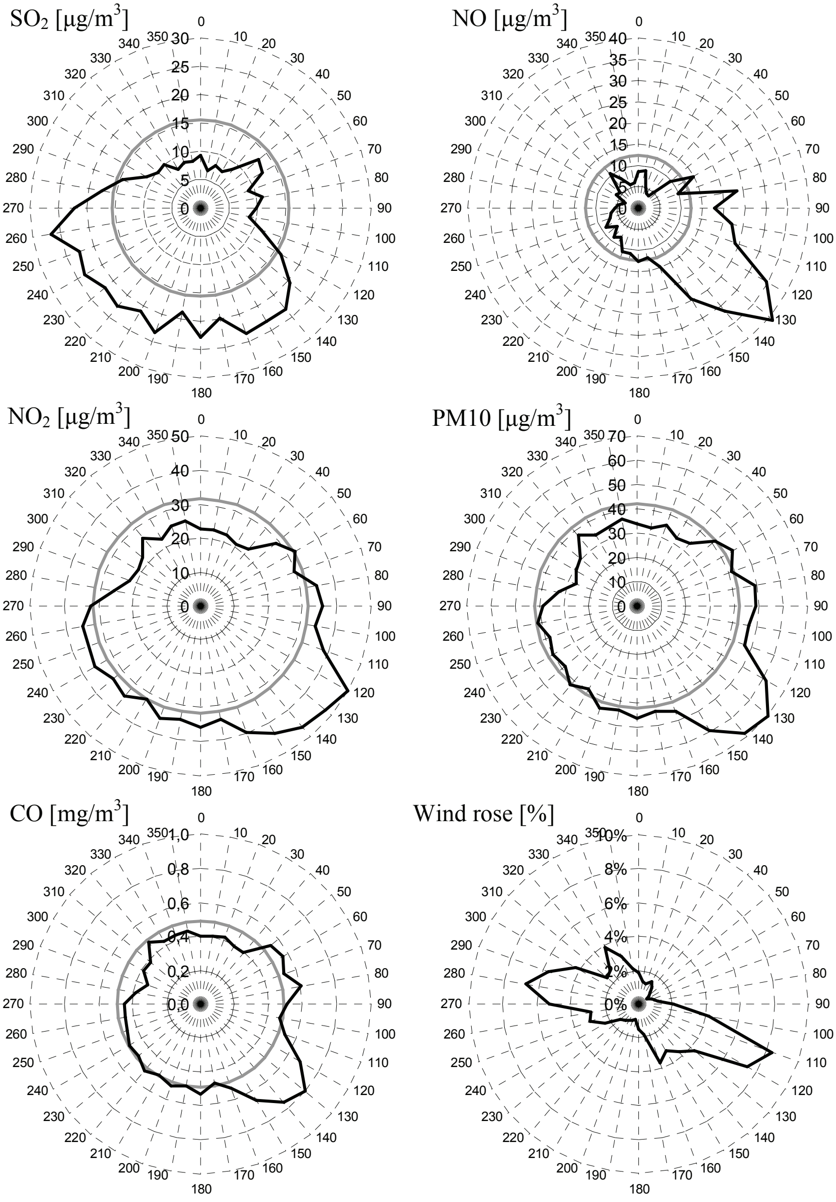

Fig. 3. The pollution rose pie charts illustrating the average concentration levels of SO_2, NO, NO_2, PM10 and CO, inflowing in 10° direction sectors and wind rose for the area at the automatic air monitoring station in Dąbrowa Górnicza

The NO concentration pie charts also differ significantly from the charts for the other pollutants. The dominating inflow directions of this pollutant can be indicated, especially at the measuring stations in Dąbrowa Górnicza and Częstochowa. NO is unstable emission and it reacts further to NO_2 in air.

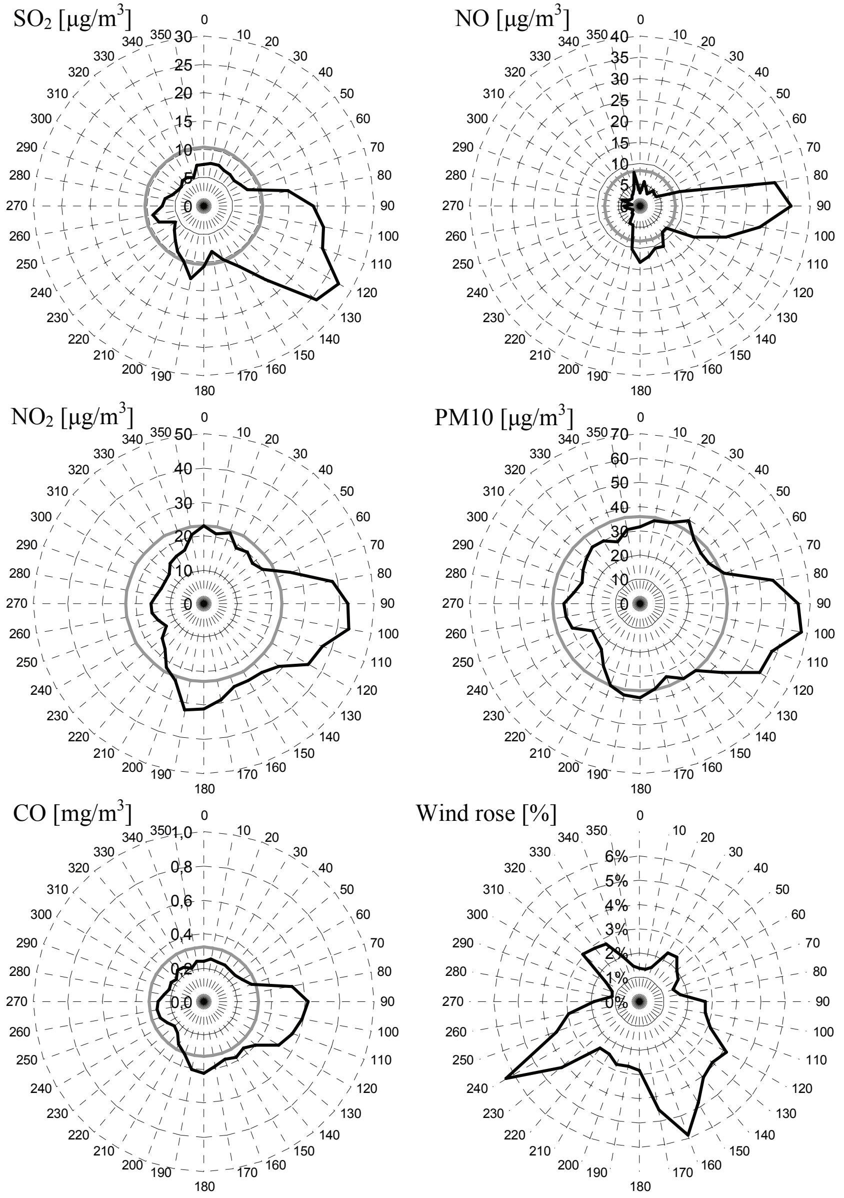

Fig. 4. The pollution rose pie charts illustrating the average concentration levels of SO_2, NO, NO_2, PM10 and CO, inflowing in 10° direction sectors and wind rose for the area at the automatic air monitoring station in Częstochowa

Low concentration levels of NO indicate that in the close neighbourhood no intensive sources of emission of NO exist. Significantly the lowest NO concentrations were measured at the measuring station in Cieszyn, the average of 3.0 μg/m^3, while, in Katowice the NO average inflow concentration was 15.8 μg/m^3. At the station in Cieszyn also the most uniform distribution of the average inflow concentrations were observed for all analyzed pollutants in the direction sectors.

The pollution pie charts are not similar with the shape of wind roses determined for particular stations. It would imply that pollution roses in the 10° direction sectors can be the objective indicators of the concentration levels dispersion. Not only for the concentrations inflowing from the directions with the highest wind occurrence frequency but inflowing from all of the direction sectors.

Table 1

Analysis of statistical dispersion of concentrations
of SO_2, NO, NO_2, PM10 and CO in 36 direction sectors

Pollutant	Statistical parameter	Unit	Katowice	Cieszyn	Dąbrowa Górnicza	Częstochowa
1	2	3	4	5	6	7
SO_2	Arithmetic mean value $\bar{x}$	μg/m^3	13.5	11.5	15.5	10.4
	Range *R*		12.2	7.6	19.8	22.1
	Average deviation *d*		2.6	1.6	6.0	4.5
	Variance s^2		9.8	3.8	41.8	35.4
	Standard deviation *s*	μg/m^3	3.1	2.0	6.5	6.0
	Changeability coefficinet V_s	%	23.3	16.9	41.8	57.3
	Changeability coefficinet V_d		19.0	13.9	38.6	43.0
NO	Arithmetic mean value $\bar{x}$	μg/m^3	15.8	3.0	12.4	8.4
	Range *R*		32.2	4.5	37.7	33.4
	Average deviation *d*		8.2	1.0	6.9	6.0
	Variance s^2	–	98.4	1.5	85.6	71.3
	Standard deviation *s*	μg/m^3	9.9	1.2	9.3	8.4
	Changeability coefficinet V_s	%	62.8	41.2	74.6	100.7
	Changeability coefficinet V_d		51.8	34.0	56.1	71.0
NO_2	Arithmetic mean value $\bar{x}$	μg/m^3	25.5	18.7	31.5	22.9
	Range *R*		23.0	15.6	28.8	30.3
	Average deviation *d*		6.4	3.5	6.4	6.9
	Variance s^2	–	53.5	17.9	61.9	73.0
	Standard deviation *s*	μg/m^3	7.3	4.2	7.9	8.5
	Changeability coefficinet V_s	%	28.6	22.6	24.9	37.3
	Changeability coefficinet V_d		25.1	18.4	20.2	30.1

Table 1 continued

1	2	3	4	5	6	7
PM10	Arithmetic mean value $\bar{x}$	µg/m^3	39.3	33.7	42.1	36.0
	Range R		40.5	25.5	43.8	44.6
	Average deviation d		10.5	4.7	7.4	7.7
	Variance s^2	–	153.7	34.9	103.3	123.0
	Standard deviation s	µg/m^3	12.4	5.9	10.2	11.1
	Changeability coefficinet V_s	%	31.5	17.6	24.2	30.8
	Changeability coefficinet V_d		26.8	13.8	17.7	21.5
CO	Arithmetic mean value $\bar{x}$	mg/m^3	0.56	0.47	0.49	0.32
	Range R		0.47	0.35	0.47	0.41
	Average deviation d		0.12	0.06	0.07	0.09
	Variance s^2	–	0.02	0.01	0.01	0.01
	Standard deviation s	mg/m^3	0.14	0.08	0.10	0.12
	Changeability coefficinet V_s	%	25.2	16.1	20.8	36.1
	Changeability coefficinet V_d		20.7	12.5	14.9	29.3

In Table 1, the results of the statistical dispersion analysis of the obtained average directional inflow values in 36 sectors are shown. The measures of the dispersion characterize the batch in respect to the changeability of the observed values and are always non-negative. The values that are close to zero designate only small variations within the batch. According to previously introduced assumption, the dispersion measures are numerical indicators of the uniformity of individual pollutant concentration inflows in the direction sectors. Higher values of the dispersion measures indicate significant differentiations of the concentrations inflowing from the direction sectors and worse conditions of area representativeness at the particular station. The dispersion measures have the same units as the input data (variance is the exception). The dispersion measures do not give objective results when comparing the stations with different average concentration levels. It is due to the fact that the higher the average concentration of a pollutant, the higher values of the dispersion measures are.

The changeability coefficients V_s and V_d are dimensionless values, and can be used for the objective evaluation of uniformity of pollution directional inflow to a particular station when comparing stations with different average concentration levels of a pollutant.

When using the changeability coefficient V_d as an indicator of the concentration dispersion in direction sectors, the most uniform concentration inflows of SO_2, NO, NO_2, PM10 and CO were observed at the measuring station in Cieszyn out of four presented stations. The worst conditions, in respect to the uniformity of directional inflows of SO_2, NO, NO_2 and CO concentrations, are at the measuring station in Częstochowa, whereas, in respect to PM10 concentrations the worst conditions are at the measuring station in Katowice.

4. CONCLUSIONS

The dispersion of the average pollution concentrations in the direction sectors can be one of the criteria in the determination of representativeness of automatic air monitoring stations area.

The statistical measures of dispersion like: range, average deviation, variance, and standard deviation cannot be used for the objective evaluation of pollution directional inflows uniformity in the region of measuring station, due to theirs dependence on the average concentration levels.

The preferable statistical indicator which in objective manner can describe level of pollution directional inflow uniformity in the region of measuring station is the changeability coefficient, V_s or V_d.

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REFERENCES

[1] JASIŃSKI R., Environ. Prot. Eng., 2006, 32 (4), 85.
[2] KIMBROUGH S., VALLERO D., SHORES R., VETTE A., BLACK K., MARTINEZ V., Transport. Res. Part, 2008, D 13, 505.
[3] MOFARRAH A., HUSAIN T., Atmos. Environ., 2010, 44 (3), 432.
[4] VENEGAS L.E., MAZZEO N.A., Int. J. Environ. Pollut., 2004, 20 (1–2), 185 .
[5] VENEGAS L.E., MAZZEO N.A., Environ. Modell. Softw., 2006, 21, 577.
[6] *On the evaluation of the substances in air levels*, The Ministry of the Environment Ordinance, December 17, 2008, (Dz.U. 2008 Nr 5, poz. 31) (in Polish).
[7] Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulfur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air: Official Journal L 163, 29/06/1999 p. 41–60.
[8] JUDA-REZLER K., REIZER M., TRAPP W., Environ. Prot. Eng., 2011, 37 (2), 109.
[9] JASIŃSKI R., Pol. J. Environ. Stud., 2009, 18 (2B), 170.
[10] JASIŃSKI R., Pol. J. Environ. Stud., 2011, 20 (4A), 104.