THE COMPARATIVE ANALYSIS OF THE RESULTS OF POLLUTANTS MEASUREMENTS IN AMBIENT AIR MEASURED WITH MEASURING STATIONS „AIRPOINTER"

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Abstract. *Ambient air pollutants are mesasured by various devices and methods. Inter-laboratory comparisons are organized to determine the representativeness of measurement results. This paper presents the results of an inter-laboratory test of NO, NO_2, NO_x, O_3 and PM_{10} concentrations, which are measured by the automated measuring stations "Airpointer" at the measuring point city stadium "Sloboda" in Užice in the period between 11th and 17th February 2014.*

Key words: *pollutants, measuring station "Airpointer", comparative analisys of the results*

1. INTRODUCTION

The problem of today's society, as a consequence of the irresponsible behavior of the man towards the environment, is the deterioration of air quality due to pollutant emissions. For this reason, the recent regulations are forcing the industry to reduce emissions of relevant pollutants. Air quality mostly depends on the presence of sulfur-dioxide, nitrogen-oxides, particulate matter (PM_{10}, $PM_{2.5}$, TSP), carbon-monoxide, as well as ground-level ozone [1]. Air quality control is performed in order to determine the level of air pollution and assessments of the air pollution impact on human health, the environment and climate, in order to take the necessary measures to protect the environment, human health and material goods [4].

In order to collect data on pollutant concentrations in ambient air and to compare limit values for the protection of human health and the concentrations dangerous to human health, monitoring of ambient air should be done. Monitoring has a task to collect information about the state of the environment that forecasts the quality of basic environmental elements and to point out the necessary measures. Monitoring includes

information system for monitoring, evaluating and forecasting changes in the environment. In the urban-industrial areas, the task of air quality monitoring is to collect information for the purpose of air quality management.

To determine the concentration of pollutants in ambient air in the domestic and world practice, we have used different measurement methods. Monitoring of ambient air pollution in Serbia is regulated by the Law on Air Protection ("Official Gazette of RS", N°.36/2009) [1] and the Regulation on Air Quality Requirements and Monitoring Conditions ("Official Gazette of RS", N°.11/2010) [2], where among other things the limit and tolerant values of the concentration of pollutants, period measurement, and the measuring process were defined.

The measurements organized by "City Institute for Public Health" from the town of Užice, which are part of the inter-laboratory research on air quality, were focused on measuring the concentrations of NO, NO2, NOx, PM10, O3 at the measuring point city stadium "Sloboda" in Uzice. The town of Uzice is one of the most polluted cities in Serbia and Serbian black spot. It is located in the Zlatibor region at an altitude of 415 meters, which varies and in different parts exceeds 600 meters. The town of Uzice is surrounded by mountains, and is located in the region of inner Dinarides.

This inter-laboratory study gathered "Air pollution control laboratory", Faculty of Occupational Safety in Niš, and the "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin" in Zrenjanin. The measurements were performed with the same measuring stations, with MLU's, "Airpointer" at the same meteorological conditions, with a distance of 4m, in the period from 11th February to 17th February 2014.

2. METHODS

Monitoring of pollutants in the ambient air basically foresees the monitoring of the concentration for the following pollutants: carbon-monoxide, sulfur-dioxide, oxides of nitrogen, particulate matter and ground-level ozone. Measurements of five out of seven pollutants that fall under the basic pollutants that are monitored in ambient air monitoring were measured with the same automated measuring stations "Airpointer". The automated measuring stations are placed on the floor of the city stadium "Sloboda" in the town of Užice, whose micro-location is shown below (Figure 1), whereas the distance between those two measuring stations was 4 [m] (Figure 2).

The principle of operation of automated measuring stations "Airpointer" is based on standard methods. Measuring of the concentration of pollutant CO was performed by a non-dispersive infrared spectrometry method DIR (EN 14626), NO_2 concentrations by standardized method of chemiluminescence (EN 14211), the concentration of PM10 were measured by a method based on nephelometry, while the concentrations of ground-level ozone O3 we used UV photometry method.

Fig. 1 Exterior and interior design of the measuring station "Airpointer"

The displayed figure (Fig. 1), presents the exterior and the interior design of the measuring stations. Typical feature of this type of device is its compactness and the fact that the system is divided into modules which, when it is necessary for some special purposes of measuring, can be excluded in every moment.

Measuring station "Airpointer" generates minute concentration values of the considered pollutants, and through its software package, these data can be downloaded in excel format. On the basis of these data, statistical analysis can be done, whereby the average daily values and the average value of the entire pollutant concentration are determined as shown in the tables (Table 1 and Table 2). Measurements were made for 7 days, from 11th February to 18th February 2014 and during the measurements there were no interruptions.

Fig. 2 The micro-location for the city stadium "Sloboda" in Užice

Figure 2 shows the micro-location of the city stadium "Sloboda" in the town of Užice, where the measuring point for this inter-laboratory study was. The location of this stadium is distinctive because it is from the north, east and south side surrounded by hill and buildings.
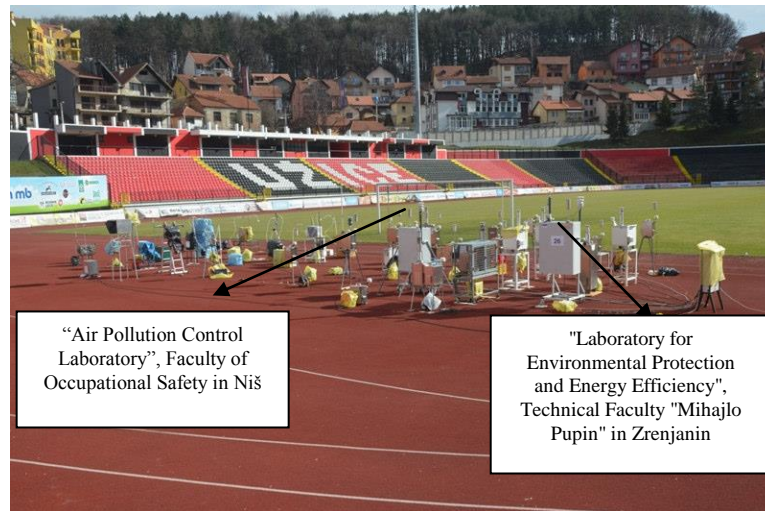

Fig. 3 Measuring stations "Airpointer" at the measuring point city stadium "Sloboda" in Užice

The displayed figure (Figure 3) is presenting the position of the measuring stations at measuring point and the distance between those two measuring stations, which directly affects the relevance of the measured data and the possibility of their comparison. During the seven-day measurement, position and location of measuring stations remained unchanged.

3. RESULTS DISCUSSION

Table 1 and Table 2 show the average daily concentrations of pollutants NO, NO_2, NO_x, O_3, PM_{10} with adjoining unit, the average value of the entire measurement and the standard deviation for each individual pollutants. Table 1 refers to the measuring station "Airpointer" which belongs to the "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin" in Zrenjanin. Table 2 refers to measurements that are conducted with "Airpointer" which is the part of "Air Pollution Control Laboratory", Faculty of Occupational Safety in Niš.

Table 1 Concentration and standard deviation for each of the measured pollutants, measured with measuring station "Airpointer" - "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin"

Time	NO [ppb]	NO$_2$ [ppb]	NO$_x$ [ppb]	O$_3$ [ppb]	PM$_{10}$ [µg/m3]
Day 1	24,89958333	10,00418716	35,00028005	17,50428962	65,70581284
Day 2	2,05489071	4,772595628	6,887622951	25,37854508	21,11980874
Day 3	28,46015027	13,38398224	41,87771858	9,284733607	97,76464481
Day 4	6,718770492	9,917691257	16,64471311	12,85928279	46,9019877
Day 5	18,00032104	10,24827186	28,32724044	9,374993169	88,80525956
Day 6	9,127185792	9,384556011	18,45416667	18,85255464	36,29174863
Day 7	17,73677254	11,5782138	29,35517077	12,17594945	50,75521175
avg x1	15,28538203	9,898499707	25,22098751	15,06147834	58,19206772
s1	8,990023907	2,439055361	11,05361049	5,420388602	25,62465842
RSD$_1$	0,588145189	0,24640657	0,438270329	0,359884234	0,440346243

Table 2 Concentration and standard deviation for each of the measured pollutants, measured with measuring station "Airpointer"- "Air Pollution Control Laboratory" Faculty of Occupational Safety in Niš

Time	NO [ppb]	NO$_2$ [ppb]	NO$_x$ [ppb]	O$_3$ [ppb]	PM$_{10}$ [µg/m3]
Day 1	35.73714619	16.88988616	52.68419277	14.65921282	65.17484306
Day 2	3.409931251	8.574648109	12.04389074	23.55151305	25.03315379
Day 3	41.38438523	22.49423656	64.03767237	7.404486479	86.30909329
Day 4	9.909823865	16.78342914	26.77370467	11.62125921	43.04477631
Day 5	26.44606438	17.81386398	44.39400986	7.936763956	79.93209094
Day 6	13.15010035	15.95966441	29.10508357	17.56891327	43.18334119
Day 7	26.24416475	19.32995451	45.62416148	11.03608716	53.95328641
avg x2	22.32594515	16.83509755	39.23753078	13.39689085	11.03608716
s2	12.93712298	3.931833976	16.30401167	5.2991069	25.8821762
RSD$_2$	0.579465859	0.233549818	0.415520838	0.395547516	2.345231224

The values which are given in Table 1 and Table 2 with tags RSD$_1$ and RSD$_2$, represent the relative standard deviation for each measured pollutants, measured by a measuring stations "Airpointer" - where the index 1 refers to the measurement made by a "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin" from Zrenjanin, and index 2 refers to the measurements made by "Air Pollution Control Laboratory", Faculty of Occupational Safety in Niš.

Table 3 Standard deviation and the estimated standard deviations of the two series of measurements for each pollutant

	NO	NO$_2$	NO$_x$	O$_3$	PM$_{10}$
sd	10,9955	16,24	26,06	9,11	4,62
sdproc	11,88	17,5412	28,1482	9,8399	4,99

The following figures contain the diagrams that show the flowchart of concentrations of pollutants for each day. The figures are arranged so that the two figures are related to one day ordered from the first to the seventh day. The first diagram, from those two that are referring to the same day, always shows the flowchart of pollutants concentrations measured by "Airpointer" from "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin" and the second one refers to the measurements by "Airpointer"- "Air Pollution Control Laboratory" Faculty of Occupational Safety in Niš. Each line in the diagram represents a specific pollutant. Comparing the diagrams for the same days for those two measuring stations, we see that the trend of changing concentrations has approximately same shape.
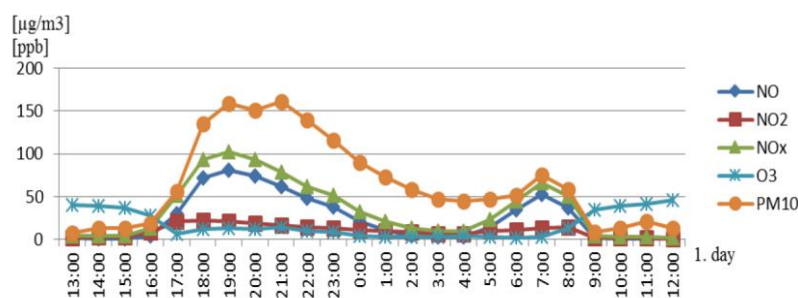
Fig. 4   Diagram of pollutants concentrations on the 1st day of measurements, measured by "Airponter", "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin"
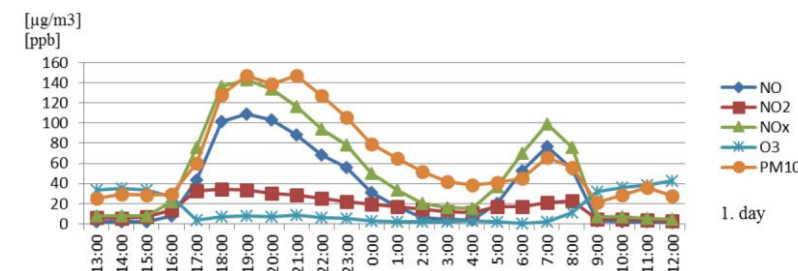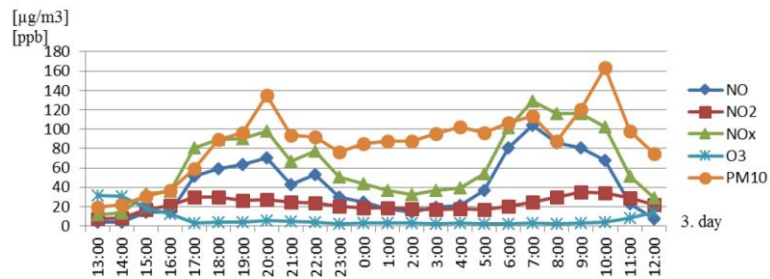

Fig. 5   Diagram of pollutants concentrations on the 1st day of measurements, measured by "Airponter", "Air Pollution Control Laboratory", Faculty of Occupational Safety in Niš
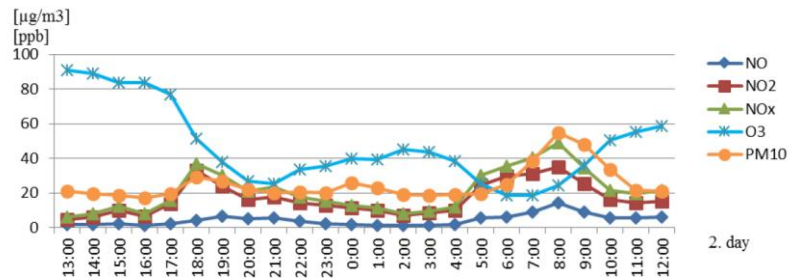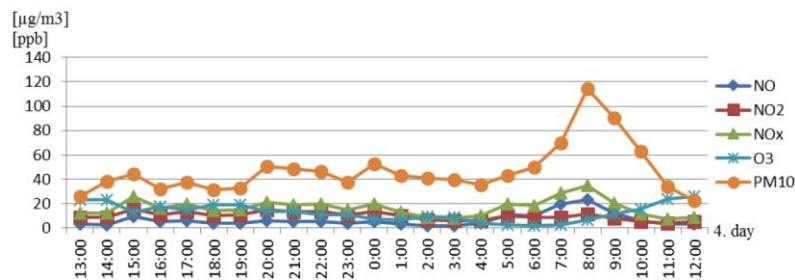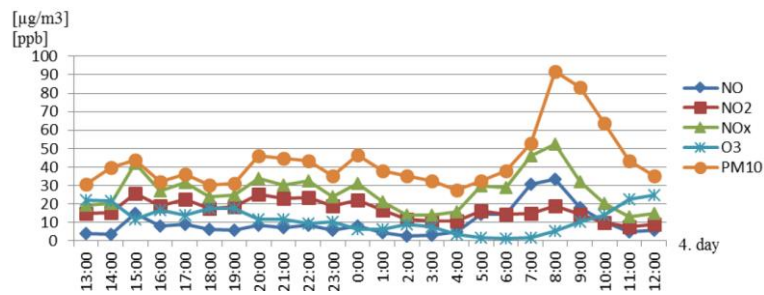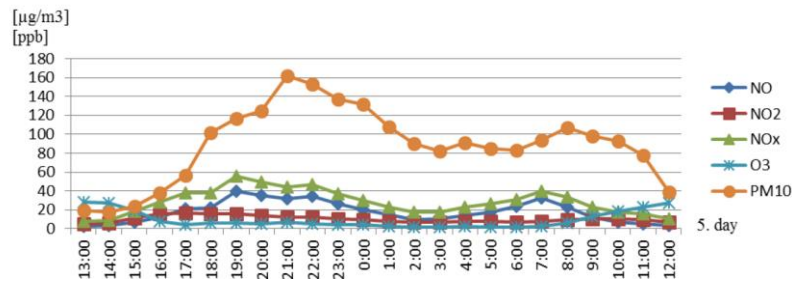
Fig. 6 Diagram of pollutants concentrations on the 2nd day of measurements, measured by "Airponter", "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin"
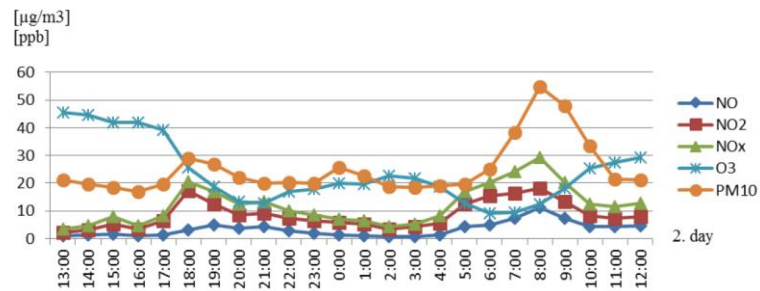
Fig. 7 Diagram of pollutants concentrations on the 2nd day of measurements, measured by "Airponter", "Air Pollution Control Laboratory", Faculty of Occupational Safety in Niš
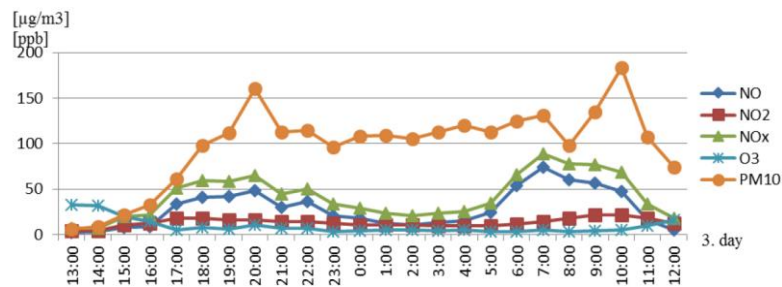
Fig. 8 Diagram of pollutants concentrations on the 3rd day of measurements, measured by "Airponter", "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin"
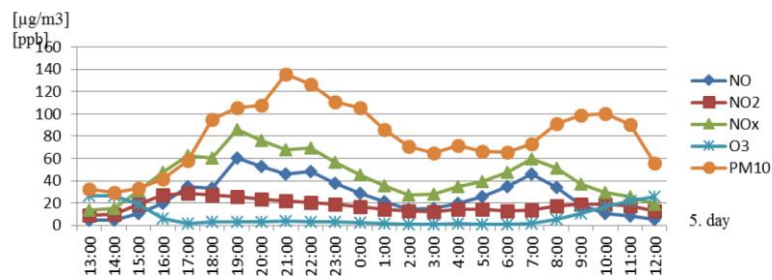
Fig. 9 Diagram of pollutants concentrations on the 3rd day of measurements, measured by "Airponter", "Air Pollution Control Laboratory", Faculty of Occupational Safety in Niš
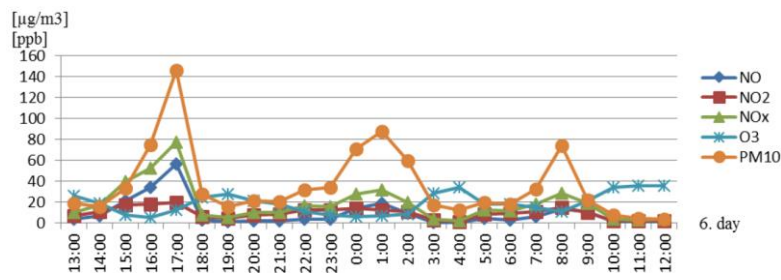

Fig. 10 Diagram of pollutants concentrations on the 4th day of measurements, measured by "Airponter", "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin"
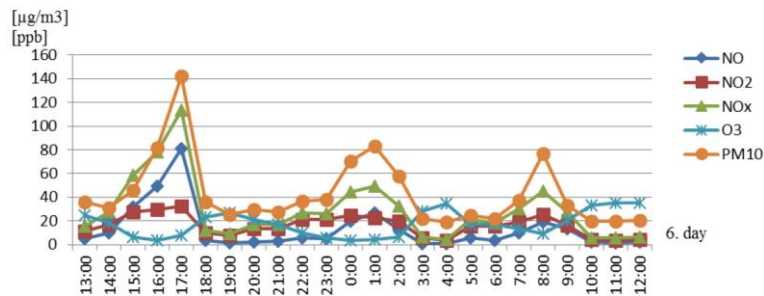

Fig. 11 Diagram of pollutants concentrations on the 4th day of measurements, measured by "Airponter", "Air Pollution Control Laboratory", Faculty of Occupational Safety in Niš

Fig. 12 Diagram of pollutant concentrations on the 5th day of measurements, measured by "Airponter", "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin"

Fig. 13 Diagram of pollutants concentrations on the 5th day of measurements, measured by "Airponter", "Air Pollution Control Laboratory", Faculty of Occupational Safety in Niš
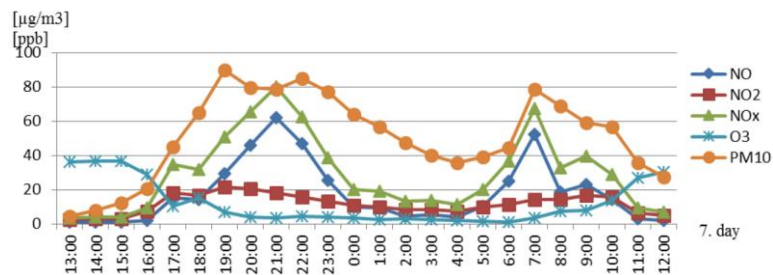

Fig. 14 Diagram of pollutants concentrations the 6th day of measurements, measured by "Airponter", "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin"
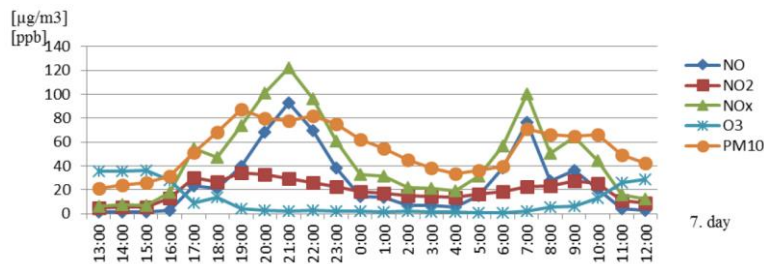
Fig. 15 Diagram of pollutants concentrations on the 6th day of measurements, measured by "Airponter", "Air Pollution Control Laboratory", Faculty of Occupational Safety in Niš

Fig. 16 Diagram of pollutants concentrations on the 7th day of measurements, measured by "Airponter", "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin"

Fig. 17 Diagram of pollutants concentrations on the 7th day of measurements, measured by "Airponter", "Air Pollution Control Laboratory", Faculty of Occupational Safety in Niš

Table 4 and Table 5 show the average daily values for meteorological parameters, including temperature of the ambient air, the relative humidity of ambient air, the speed and direction of the wind flow. By comparing the values of meteorological parameters, which are the elements of these two tables, where the first table refers to the measuring station "Airpointer"- "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin" in Zrenjanin, and Table 5 relates to the measuring station "Airpointer"-"Air Pollution Control Laboratory", Faculty of Occupational Safety

in Niš, it is evident that there is a large deviation of angle that defines the direction of wind flow. This deviation is due to poor adjustment of the zero point for the sensor for meteorological parameters, i.e. poor determining of the north at the measuring point, which is taken as a reference direction and the zero point of the circle for direction of the wind, for each measuring station "Aipointer".

Table 4 Overview of the meteorological parameters for the measurements that were made by "Laboratory for Environmental Protection and Energy Efficiency", Technical Faculty "Mihajlo Pupin" in Zrenjanin

Time	Air temperature	Relative humidity	Wind direction	Wind speed
Day 1	9,410867486	58,57381148	-1314,458005	0,650942623
Day 2	7,100286885	70,59624317	-6,26159153	0,661782787
Day 3	4,60454918	78,60812842	-1204,626387	0,434733607
Day 4	3,17988388	85,55724044	-1375,1261	0,503387978
Day 5	4,597889344	79,16204918	-3290,822596	0,36022541
Day 6	12,84616803	55,62739071	-183,2050546	0,726844262
Day 7	9,683903689	66,78282787	-2926,415605	0,423702186

Table 5 Overview of the meteorological parameters for the measurements that were made by "Airponter", "Air Pollution Control Laboratory", Faculty of Occupational Safety in Niš

| Time	Air temperature	Relative humidity	Wind direction	Wind speed
Day 1	9,426186193	57,71807952	165,7900635	0,669118484
Day 2	7,187988895	69,71143861	151,9704246	0,705387111
Day 3	4,655177883	78,07255803	136,8042925	0,456736424
Day 4	3,290145037	84,59651251	142,3425134	0,527543025
Day 5	4,700408218	78,20464289	136,9152797	0,375709904
Day 6	12,90898978	54,6253811	163,0434595	0,750038568
Day 7	9,713450724	65,99780653	136,8393663	0,415525979
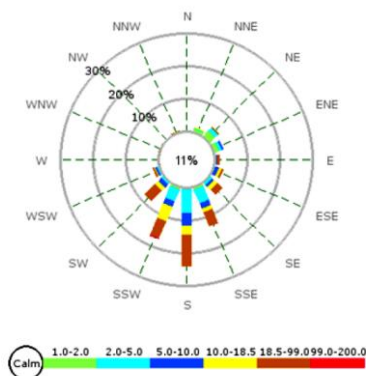
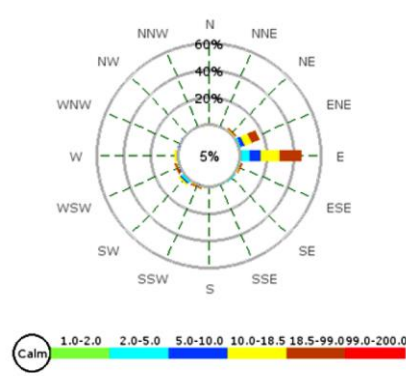**Fig. 18** Windrose diagram for pollutant NO -Zrenjanin

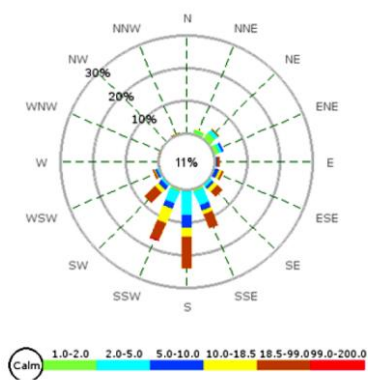**Fig. 19** Windrose diagram for pollutant NO -Niš
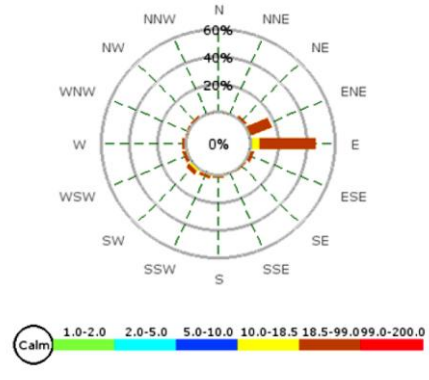
Fig. 20 Windrose diagram for pollutant
NO$_2$ -Zrenjanin
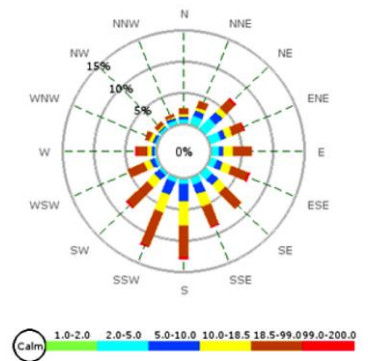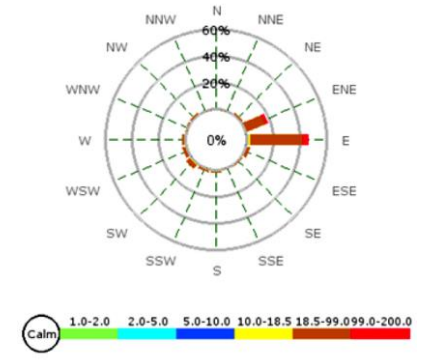

Fig. 21 Windrose diagram for pollutant
NO$_2$ -Niš

Fig. 22 Windrose diagram for pollutant
NO$_x$ -Zrenjanin
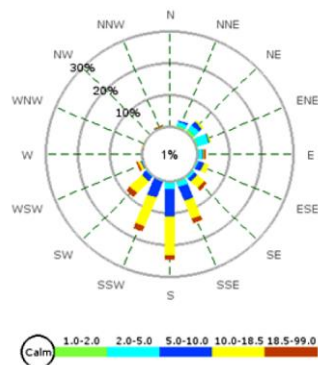

Fig. 23 Windrose diagram for pollutant
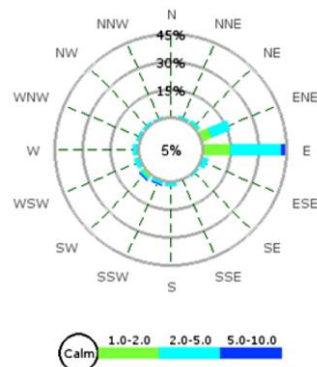NO$_x$ -Niš

Fig. 24 Windrose diagram for pollutant O₃ -Zrenjanin
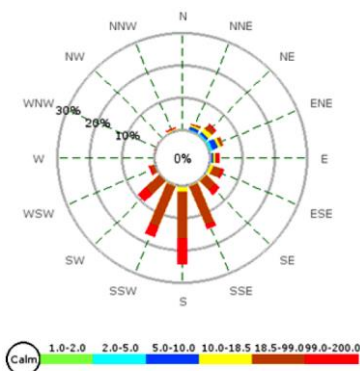

Fig. 25 Windrose diagram for pollutant O₃ -Niš

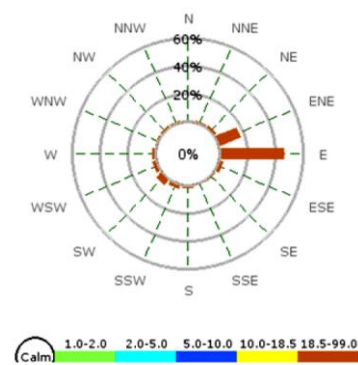**Fig. 26** Windrose diagram for pollutant PM₁₀ -Zrenjanin

Fig. 27 Windrose diagram for pollutant PM₁₀ -Niš

4. CONCLUSION

On the basis of tabular and graphic presentation of results we can conclude the following:

- that the differences in the measured concentrations of pollutants, measured by two measuring stations "Airpointer" are in the range of measurement uncertainty, which is 6,51% for this type of device;
- the diagrams that represent flowchart of pollutant concentrations per day, for each measuring station, show the similarity of the flowchart for pollutant concentrations in both measuring stations;
- deviation of the angle that defines direction of wind flow for one measuring station, which is best seen through ten Windrose figures displayed in a final section, appeared as a result of poor adjustment of the zero point for the sensor for meteorological parameters.

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UPOREDNA ANALIZA REZULTATA MERENJA ZAGAĐUJUĆIH SUPSTANCI U AMBIJENTALNOM VAZDUHU MERENIH MERNIM STANICAMA "AIRPOINTER"

Merenja zagaćujućih supstanci u ambijentalnom vazduhu vrše se različitim uređajima i primenom različitih metoda. Radi određivanja reprezentativnosti rezultata merenja vrše se međulaboratorijska poređenja. U ovom radu su prikazani rezultati međulaboratorijskog ispitivanja koncentracija CO, NO, NO_2, NO_x, O_3 i PM_{10} koje su merene sa automatizovanim mernim stanicama Airpointer, na mernom mestu "Gradski stadion Sloboda" u Užicu u period od 11. do 17. Februara 2014. godine.

Ključne reči: *zagađujuće supstance, merna stanica "Airpointer", uporedna analiza rezultata*