FACTA UNIVERSITATIS
Series: **Working and Living Environmental Protection** Vol. 11, N^{o} 2, 2014, pp. pp. 97 - 108

COMPARATIVE ANALYSIS OF THE CONCENTRATION OF AMBIENT AIR POLLUTANTS DETERMINED BY MEASURING AND MODELING

UDC 504.3.064:613.15

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Abstract. *This paper presents and analyzes the concentrations of CO (carbon monoxide), NO_2 (nitrogen dioxide) and TSP (total suspended particles), in ambient air, which have been measured in an automated measuring station "Airpointer" and calculated by software package "DISPER 5.2". The measurements were performed during the heating season at the measuring point which was located in the building of the Faculty of Occupational Safety in Niš. The study was aimed to determine the contribution of pollutants emitted from energy sources - district heating plant "Jug" - to the overall pollution of ambient air in the region of the Faculty of Occupational Safety, by direct measurement and modeling, and finally to perform a comparative analysis of the results.*

Key words: *monitoring of ambient air, concentration of pollutants, air quality, measurement, simulation*

1. INTRODUCTION

The problem of air quality is certainly one of the fastest growing problems related to the human impact on the environment. Energy resources are among the most important sources of ambient air pollution [1].

Pollutants emitted from chimney plant are circulated through the ground layer of the atmosphere around the emitter, including the various processes such as diffusion, dispersion, transformation and deposition.

Monitoring of pollutants emitted from these sources in ambient air is performed in order to determine the concentration of: NO_x (nitrogen oxides), SO_2 (sulfur oxides), CO (carbon monoxide) and particulate matters.

Received November 27, 2014 / Accepted December 12, 2014
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For establishing concentration of pollutants in ambient air, different methods of measurement, prediction and evaluation (simulation) are used worldwide. Monitoring of ambient air pollution in Serbia is regulated by the Law of Air Protection ("Official Gazette of RS", No. 36/2009) [2] and Regulation about conditions for monitoring and requirements for air quality ("Official Gazette of RS", No. 11/2010), where among other these documents, prescribe limit and tolerant values of pollutants concentration, the period measurement, measuring procedure, etc. [3]

Based on measurements that were performed in Air Pollution Control Laboratory at the Faculty of Occupational Safety in Niš in 2011, it was observed that especially in winter months, the levels of pollutants in ambient air are very often above the limit values. The Faculty is located near the district heating plant "Jug". In order to determine the contribution of emissions from this plant to total air pollution in the vicinity of the Faculty of Occupational Safety, Air Pollution Control Laboratory has developed an Ambient Air Monitoring Program, which is defines:

- Monitoring concentrations of CO, NO_2 and total suspended matter (TSP) during heating season from October 16th to 28th December 2011;
- Measuring point on terrace on the building of the Faculty;
- Measuring concentrations of CO, NO_2 and TSP by automated monitoring system "Airpointer" with reference methods;
- Simulation field concentration of CO, NO_2 and TSP, with software package "DISPER 5.2".
- The objective of this research is:
- Determining the quality of ambient air at the measuring point "Faculty", based on measured values of the concentrations of CO, NO_2 and TSP;
- Determining field concentrations of CO, NO_2 and TSP in ambient air at the measuring point "Faculty" as a result of operations of the heating plant "Jug" by mathematical modeling;
- Determining contribution concentrations of CO, NO_2 and TSP at the measuring point "Faculty" as a result of the activities of the heating plant "Jug".

2. METHODS

Faculty of Occupational Safety is located on west side from district heating plant "Jug" at 450 m distance (see Fig. 1), so that under certain meteorological conditions, quality of ambient air in the surrounding area is often conditioned by this heating plant. Therefore, the monitoring programme involved monitoring period from October to December, as well as typical pollutants that are monitored from natural gas-fueled energy sources: CO, NO_2 and TSP.

Monitoring of pollutants was preferred by an automated monitoring station "Airpointer", which is part of the Air Pollution Control Laboratory. The measuring point was located on the flat roof at the Faculty, at the high of 10 meters above the ground, outside the zone of the influence of physical barriers (see Fig. 2).

Monitoring station "Airpointer" measures the concentration of CO by a standardized method of non-dispersive infrared (EN 14626 standard), the concentration of NO_2 by a standardized method of chemiluminescence (EN 14211 standard) whereas for measuring TSP concentration it uses a method based on the principle of nephelometry.

Fig. 1 Location view of measuring point Faculty of Occupational Safety and heating plant "Jug"

Fig. 2 The position of measuring point

The considered measurement covered the period from October 1st to December 28th 2011. Measurements lasted 89 days. During the measurement there was no break.

The station is configured to generate minute concentration values of the considered pollutants. Based on these values monthly average concentration have been determined (see Table 1).

Table 1 Monthly average values of measured concentrations of pollutants in ambient air

Month	Monthly average values of NO_2 concentration ($\mu g/m^3$)	Monthly average values of CO concentration (mg/m^3)	Monthly average values of TSP concentration ($\mu g/m^3$)
October	25,628	1,884	83,214
November	36,1950	5,312	186,1315
December	38,726	12,332	160,7529

At the measuring station "Airpointer", the following meteorological parameters have been performed and measured: wind speed and direction, temperature of air, relative humidity. Based on measured values average hourly values for these parameters have been determined (see Table 2).

Table 2 Monthly average values of measured values of meteorological parameters

Month	Average wind direction NW, (^{0})	Average wind speed (m/s)	Average relative humidity (%)	Average temperature (^oC)
October	275	0,484	70,37	11,14
November	281	0,259	73,93	4,37
December	303	0,360	84,11	4,41

Calculation of the concentration of CO, NO_2 and TSP in ambient air at the measuring point "Faculty", as a result of the operation of the heating plant "JUG", was performed by software package "DISPER 5.2" owned by the Air Pollution Control Laboratory. The package was developed by the company „Canarina Algoritmos Numericos", Spain, on account of a numerical algorithm that is based on equation for dispersion of the Gaussian model. The input data required by the software are: meteorological data, data about energy sources and fuels.

Relying on calculated concentration of pollutants in the considered territory, the software generates field concentration.

The characteristics of the heating plant "Jug", which were used in the modeling process are shown in Table 3.

Table 3 The characteristics of heating plant "Jug"

Energy source	Physical stack height: h (m)	Stack inside diameter: D (m)	Stack gas exit temperature: t (^oC)	Stack gas exit velocity: (m/s)	Source power: (MW)
Heating plant „Jug"	60	2	61	8	67

Simulation software “DISPER 5.2” measured individual concentrations of CO, NO_2 and TSP for each day when wind when wind direction was from NE, E, SE from 16th October (beginning of heating season) until 28th December. The smoke plume is expected to spread towards the Faculty at this wind direction. Daily values of meteorological parameters measured by “Airpointer” were used in calculations.

Table 4 shows the average concentrations of CO, NO_2 and TSP obtained by simulation software "DISPER 5.2", at the measuring point ”Faculty“, at NE, E and SE wind directions.

Table 4 Concentration of pollutants calculated by "DISPER 5.2"

Month	Number of days with winds blowing from NE, E, SE	CO (mg/m^3)	NO_2 ($\mu g/m^3$)	TSP ($\mu g/m^3$)
October	13	$0,05 \cdot 10^{-3}$	0,27	0,01
November	25	$0,13 \cdot 10^{-3}$	0,78	0,02
December	11	$0,10 \cdot 10^{-3}$	0,59	0,02

3. Results and Discussion

Determination of air quality at the measuring point "Faculty", involved a comparison of the average monthly values of the concentration of CO, NO_2 and TSP, with concentration limit values on a monthly basis, which according to the “Regulation on Air Quality Requirements and Monitoring Conditions” ("Official Gazette of RS, No. 11/2010) amount to: CO = 5 mg/m^3; NO_2 = 85 $\mu g/m^3$. Limit value for TSP concentration is 120 $\mu g/m^3$ in accordance with the “Regulation on the limit values, methods of measuring the emissions, establishing criteria for measuring places and data records“ ("Official Gazette of RS", No. 54/92, 30/99 and 19/2006), because of the fact that the limited value of this pollutant has not been defined in the new regulations.

Measured and average daily values of CO concentration for the months of October, November and December are shown in diagrams (see Fig. 3). From this screen, we can see that the concentration of CO in October were still below the limit, with an upward trend from 16th October (the period when heating plant, "Jug" started operating). In November, the concentrations were below the limit, until the 16th of November, when rapidly, concentrations were above the limit in period between 17th and 19th November, and between 22nd and 30th November. In the first period, the increase was between 22% and 37%, while in the second period the increase was between 22% and 161%. The highest concentration measured during November was 13,029 mg/m^3, measured on 30th November and the increase was 160,6% from the limit value. It may be noted that during the month of December, there is a trend of increasing concentrations compared to the limit values for this pollutant. The highest concentration was measured on 3rd December and it was 17,6024 mg/m^3 whereas the increase was 252%.

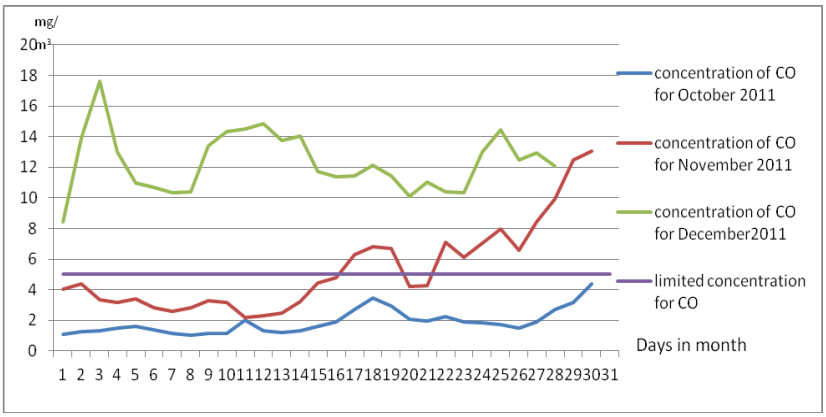

Fig. 3 Viewing daily CO concentration for months October, November, and December 2011.

Limit value for NO_2 concentration observed on any day through three-month period of the heating season, was not exceeded, as indicated on Figure 4.

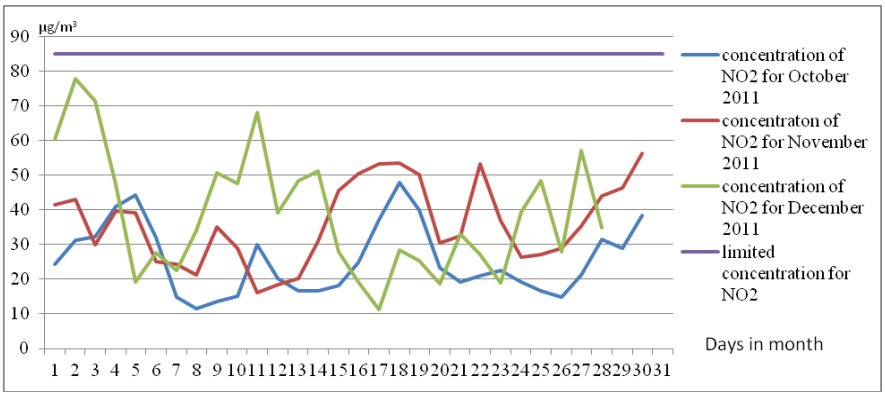

Fig. 4 Viewing daily NO_2 concentration for months October, November, and December 2011.

Graphic display of averaged daily TSP concentrations for the months October, November and December were shown on Figure 5. During the month of October there were exceeded concentrations of TSP, on 18th and 19th October and after 29th of October an increasing trend of TSP concentration was noticed, with a few exceptions, through November and December. In November, there were the periods when the limit concentration of TSP was not exceeded, and those periods were from 6th to 8th November, and from 11th to 13th November, while the highest measured value of TSP concentration, was recorded on 22nd of November, and it was 353,35 µg/m^3, which was an increase of 194,45%. The highest concentration of TSP during the month of December was measured on December 3th and it was 352 µg/m^3, with the increase of 193,3%. The

diagram shows that in periods from 5th to 8th, from 15th until 23rd December, and 26th December, the measured concentration of TSP did not exceed the limited concentration.

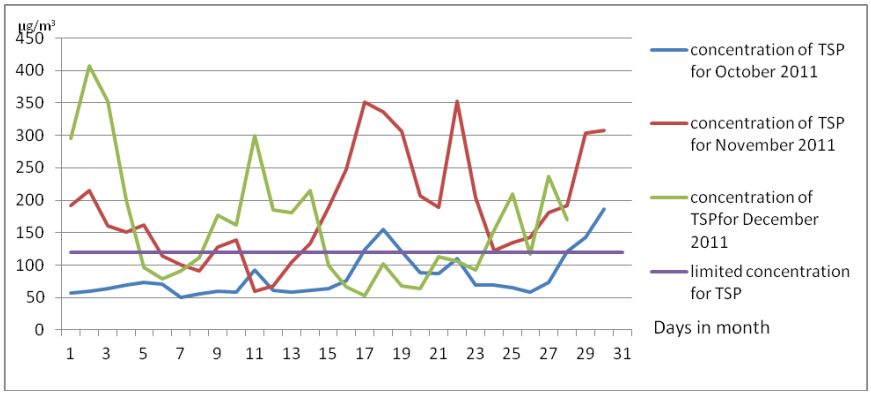

Fig. 5 Viewing daily TSP concentration for months October, November, December 2011.

In order to determine the concentration of CO, NO_2 and TSP at the measuring point "Faculty" under the influence of emissions from the heating plant "Jug", we separated from the total set of measurements the days when the wind blew from the direction of NE, E, SE.

Averaged values of the concentration of CO, NO_2 and TSP at the measuring point "Faculty" when it was under the influence of emissions from the heating plant "Jug", are shown in Table 5.

Table 5 Average values of the measured concentration of CO, NO_2 and TSP at the measuring point "Faculty" when the wind blew from the direction of NE, E, SE.

Month	Average values of NO_2 concentration (µg/m^3)	Average values of CO concentration (mg/m^3)	Average values of TSP concentration (µg/m^3)
October	20,50	1,79	70,70
November	26,70	3,48	118,85
December	32,94	12,09	122,55

The values of CO, NO_2 and TSP concentration at the measuring point "Faculty", calculated by using a mathematical model, are shown in a set of isolines of wind direction from NE, E, SE, and its speed, averaged on a daily basis. For the wind speed and the daily insolation based on Pasquill categorization we determined the category of atmospheric stability for three months - "A" (stable).

Graphical interpretation of the calculated field concentration of CO, NO_2 and TSP for considered wind directions from NE, E, SE in October, November and December, has been shown with isolines on Figures 6, 7, 8, 9, 10, 11, 12, 13 and 14.

Maximum values of the calculated concentrations for the days in October, when the wind direction was from NE, E, SE were: CO = 14,35 µg/m^3, NO_2 = 84,08 µg/m^3 and TSP = 2,40 µg/m^3, and achieved at a distance from the heating plant "Jug" at 2150 m. At the measuring point „Faculty“, the calculated concentrations in October were: CO = 0,05µg/m^3, NO_2 = 0,27µg/m^3 and TSP = 0,01µg/m^3.

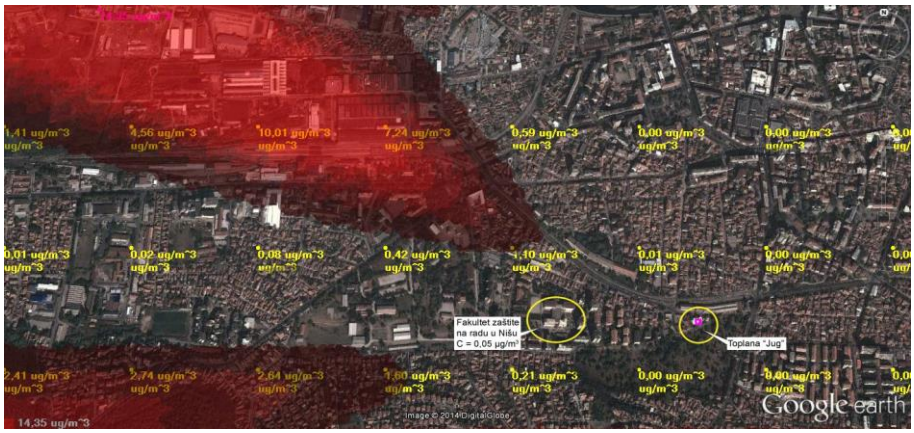

Fig. 6 Field concentration of CO in October

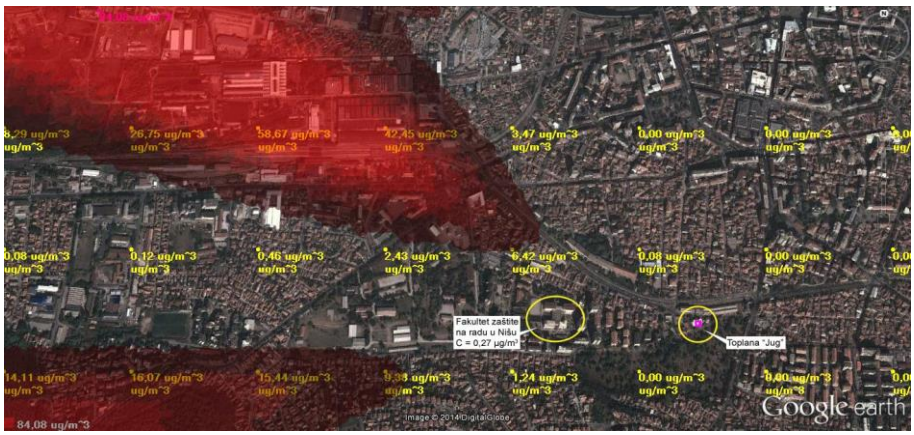

Fig. 7 Field concentration of NO_2 in October

Fig. 8 Field concentration of TSP in October

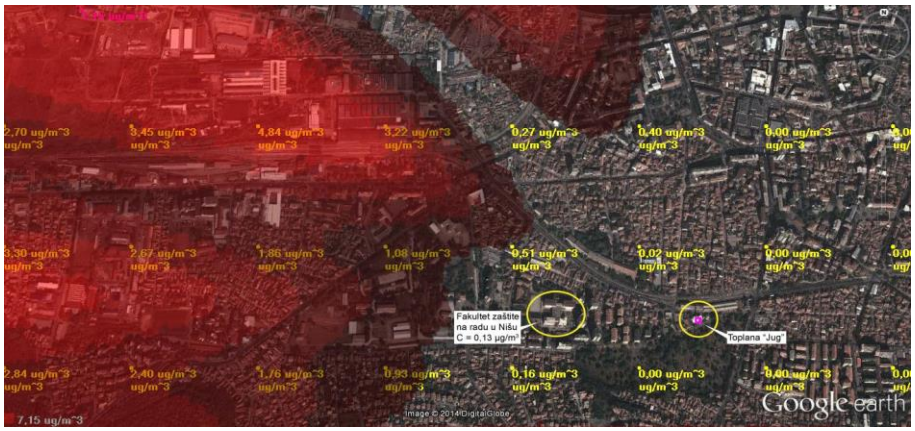

Fig. 9 Field concentration of CO in November

Fig. 10 Field concentration of NO_2 in November

Fig. 11 Field concentration of TSP in November

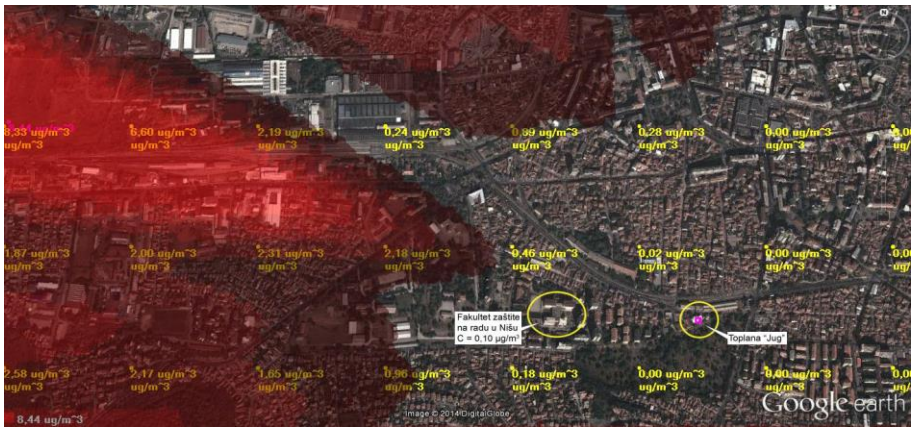

Fig. 12 Field concentration of CO in December

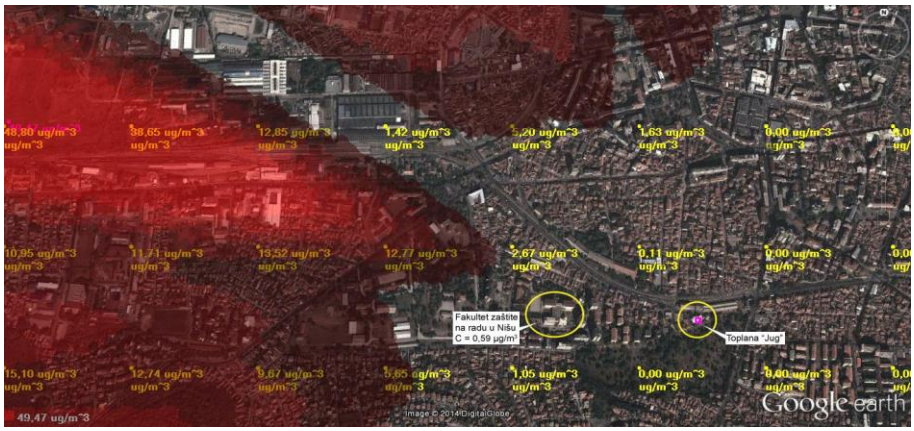

Fig. 13 Field concentration of NO_2 in December

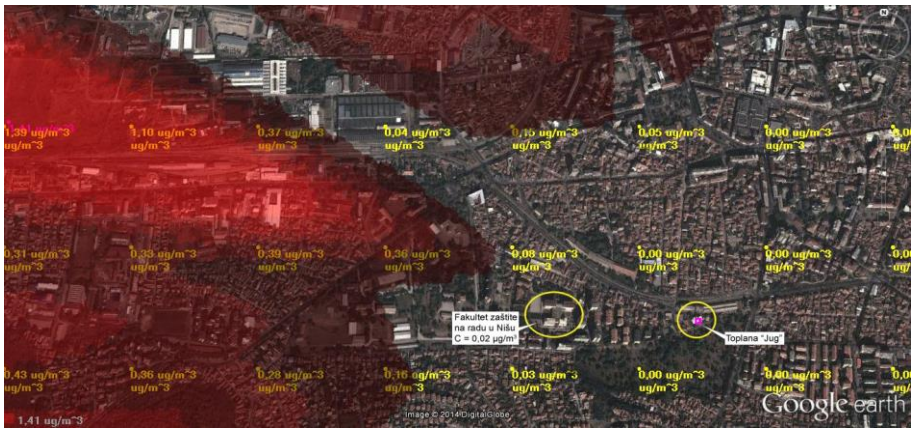

Fig. 14 Field concentration of TSP in December

Maximum values of the calculated concentrations for certain days in November, when the wind direction was from NE, E, SE were: CO = 7,15 μg/m^3, NO_2 = 41,93 μg/m^3 and TSP = 1,20 μg/m^3, at 2209 m distance from heating plant "Jug". At the measuring point "Faculty" for certain days in November, the calculated concentrations were: CO = 0,13 μg/m^3, NO_2 = 0,78 μg/m^3 and TSP = 0,02 μg/m^3.

Maximum values of the calculated concentrations for certain days in December, when the wind direction was from NE, E, SE were: CO = 8,44 μg/m^3, NO_2 = 49,47 μg/m^3 and TSP = 1,41 μg/m^3 at 2209 m distance from the heating plant "Jug". At the measuring point "Faculty" for days in December, the calculated concentrations were: CO = 0,10 μg/m^3, NO_2 = 0,50 μg/m^3 and TSP = 0,02 μg/m^3.

The analysis of field concentration of CO, NO_2 and TSP shows that the smoke plume flue of the gases emitted from the chimney heating plant "Jug" in terms of the height of the chimney in the observed meteorological conditions has no significant impact on air quality at the measuring point "Faculty".

Monthly averaged values of concentration of CO, NO_2 and TSP at the measuring point "Faculty" at the wind direction from NE, E, SE obtained by measurements and mathematical modeling are shown in Table 6, and they are not significantly correlated.

Table 6 Comparative review of the concentration of pollutants obtained by measuring with measuring station "Airpointer" and with simulation software "DISPER 5.2".

Month/Pollutant	CO, mg/m^3		NO_2, μg/m^3		TSP, μg/m^3	
	Airpointer	DISPER	Airpointer	DISPER	Airpointer	DISPER
October	1,79	$0,05 \cdot 10^{-3}$	20,50	0,27	70,70	0,01
November	3,48	$0,13 \cdot 10^{-3}$	26,70	0,78	118,85	0,02
December	12,09	$0,10 \cdot 10^{-3}$	32,94	0,59	122,55	0,02

The analysis of measured and calculated averaged concentrations of pollutants shows that the measured concentrations are greater than calculated in the entire research period.

4. CONCLUSION

Quality of ambient air around of the Faculty of Occupational Safety, conditioned by the heating plant "Jug" was assessed in relation to the concentrations of CO, NO_2 and TSP, by direct measurement and simulation with software package "DISPER 5.2".

Based on the results of measurements and simulations it can be concluded that:

- The trend of the measured values of CO, NO_2 and TSP increased from October to December, in line with the general trend of the temperature of the ambient air.
- The measured concentrations of CO and NO_2 are always less than the limit value which is interpreted as the fact that heating plant "Jug" has no significant impact in this regard to the quality of ambient air in the vicinity of the Faculty.
- The measured concentrations of TSP in October were below the limit values and in November and December were above, which suggests that during the period of low temperature heating plant „Jug" contributes to ambient air pollution in the vicinity of the Faculty.

- Model “DISPER 5.2” in an analyzed period shows much less concentration of NO_2, CO and TSP and, therefore, so the correlation has not been performed.
- This suggests that in measured concentrations of NO_2, CO and TSP there is the contribution of other sources of pollution that are in the wind direction from NE, E, SE to the Faculty, except for heating plant "Jug", which were not considered in the simulation.

REFERENCES

1. Živković, N., Đorđević, A. (2001). Zaštita vazduha - teorijske osnove predviđanja zagađenosti vazduha. Fakultet zaštite na radu, Niš.
2. Zakon o zaštiti vazduha ("Sl. glasnik RS, br.36/2009).
3. Uredba o uslovima za monitoring i zahtevima kvaliteta vazduha ("Sl. glasnik RS" br.11/2010).
4. Đorđević, A., Živković, N., Todorović, B., Anđelković, B. (2006). Kartografski prikaz polja kvaliteta vazduha. Prva Naučno-stručna konferencija sa međunarodnim učešćem. Banja Luka, 339-347.

UPOREDNA ANALIZA KONCENTRACIJA ZAGAĐUJUĆIH SUPSTANCI U AMBIJENTALNOM VAZDUHU ODREĐENIH MERENJEM I MODELIRANJEM

U radu su prikazani i analizirani nivoi koncentracija CO (ugljen-monoksid), NO_2 (azot-dioksid) i TSP (ukupne suspendovane čestice), u ambijentalnom vazduhu, koje su određene merenjem, automatizovanom mernom stanicom “Airpointer”, kao i izračunavanjem softverskim paketom „DISPER 5.2”. Merenja su izvedena u grejnoj sezoni na mernom mestu koje je locirano na zgradi Fakulteta zaštite na radu u Nišu. Istraživanje je imalo za cilj da se odredi doprinos emitovanih zagađujućih supstanci iz energetskog izvora – gradske toplane “Jug” ukupnom zagađenju ambijentalnog vazduha u okruženju Fakulteta zaštite na radu, direktnim merenjima i modeliranjem i izvrši uporedna analiza dobijenih rezultata.

Ključne reči: *monitoring ambijentalnog vazduha, koncentracija zagađujućih supstanci, kvalitet vazduha, merenje, simulacija*