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TRAFFIC AND THE CITY AIR QUALITY

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Abstract. *The air quality is very important for the quality of living in modern cities. It is known that the traffic is the single largest pollutant in Europe. Therefore, proper treatment of this component of pollution is very important for precise estimation of pollution levels. In this paper, specific approach for measurement of roadside CO₂ concentration, as the tracer gas, is analysed. TESTO 454 gas analyzer has been used for CO₂ concentration measurements. The wind speed and direction have been measured on several locations in the City of Niš, considering that pollution distribution is globally determined by wind characteristics, and for wind measurements cup anemometer was used. For wind data collecting, specific measuring system was developed, as well as the software needed. Traffic intensity has been measured on six major crossroads in the City. The data obtained were used to estimate the traffic generated CO₂ emission on the major streets in Niš. Given methodology shows possibilities for further implementation of other pollutant components measurement, which allows tracking of the main pollution pathways.*

Key words: *traffic intensity, CO₂ concentration, measurement, data analysis*

1. INTRODUCTION

Since the Industrial Revolution, the mankind is dealing with increasing pollution problems. Main pollution sources are the side effects of manufacturing, mining, transportation, and power production. The air pollution is usually explained as the interaction of noxious aerosols, gases and particles emitted into the atmosphere with the surrounding environment.

The impacts of the pollutant emissions on the environment are usually measured by their effects in the human standard of living, the number of people affected and the applied technology [1]. Since 1960, the world population has been doubled due to improvements of standard of living and world economy. At the same time, the global number of pollutant sources like cars emissions have raised by a factor of 10 [2]. The increased air pollution level have led to important impacts on human health and well-being, as well as have caused material damages on economical/technical structures of cultural heritage and large scale

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environmental phenomena as acidification, depletion of the ozone layer and an imminent global warming.

The most direct impacts of air pollution are felt for those who live in cities. The United Nations report from 2006 mentions that already 48.7% of the world's population were living in urban areas in 2005. This development was expected to continue in the subsequent years, and some statistical estimations says that more than the half of the world population is living in urban areas since 2008, thus it marks the first time in history that the world have more urban residents than rural residents [3]. The present EU environmental legislation intents to control high pollutant concentrations and air quality conditions in urban environments.

Considering that the traffic induced emissions are the largest pollution source, proper estimation of the pollutant emission level is of vital importance. As the reference component for the measurements, concentration of CO_2 was chosen. Reasons for such decision were the chemical inertiality and the relatively high concentration of CO_2 in the atmosphere. Although CO_2 is denser than air, it can be assumed that all other components of the flue gasses will be distributed similarly [4], as the area of interest is only a few meters above the ground (zone of influence on the pedestrians). Under such conditions, measuring of CO_2 as a flue gas component can indicate the behaviour of all the other components.

2. SPECIFIC MEASURING TECHNIQUES

In order to make as precise traffic intensity estimation as possible, traffic counting was performed on six major crossroads in the City of Niš. The data were collected from 5AM until 1AM the next day for each location, from the end of October to the beginning of December. For the location Jagodin Mala measurements were performed for about 10 days, for each working day and weekend in this period, as well as for 4 days in the summer [4].

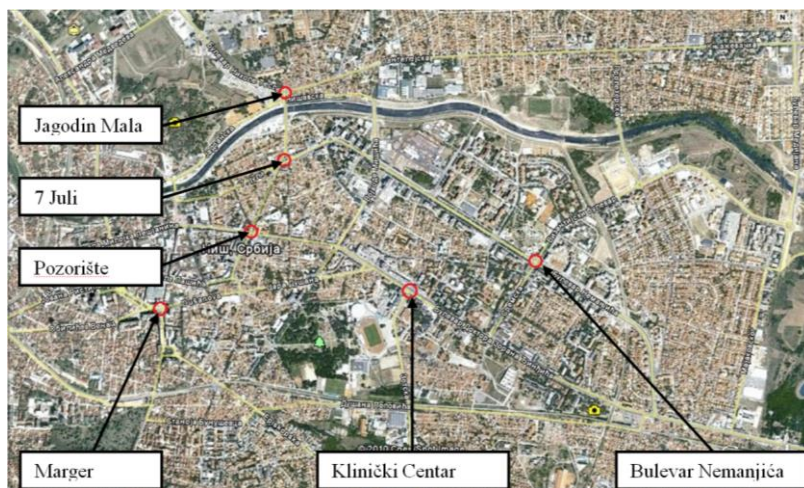


Fig. 1 Disposition of measuring sites

As can be seen in the Figure 1, the measuring locations are carefully chosen and fairly represents the crossroads with highest traffic intensity in the City of Niš. This data were used to estimate the traffic intensity for each direction for all major streets in the City of Niš. It is assumed that traffic intensity for other locations and streets can be estimated on the basis of the data collected.

Simultaneously with the traffic counting, CO₂ imission measurement was performed using the TESTO 454 gas analyzer with ambient CO₂ probe 0632 1240. Measurements were performed on distances 1, 3 or 5m from the street, on height of 1m.

Wind measurements were performed on 3 locations in the city, in the period two years. In those locations, wind speed and direction, temperature and CO₂ concentration were measured on the height of 10m. Wind measurements were performed with second generation cup anemometer produced by the firm Vetrotipalnik – Ljubljana, CO₂ concentration with probe TGS4161 produced by company Figaro Engineering INC., Japan, and temperature measurements by PT100 element with precision of 0.5°C.

3. CHARACTERISTICS OF THE SENSORS USED

For the performed measurements, available instruments were used. Used sensors were chosen by the specific temperature, humidity and concentration levels in the free atmosphere. The measuring period was until the end of the year.

3.1 Cup anemometer technical data

The anemometer used is Vetrotipalnik Ljubljana. It is second generation cup anemometer, with direction sensor mounted on the same shaft with the speed sensor. During the measurement period, considering the city of Niš climate, there was no frosting of the sensor (during the winter period, when the calibration was done).

Table 1 Cup anemometer technical data

Wind speed measurement		Wind direction measurement	
Measuring range	0.5÷50m/s	Measuring range	0÷360°
Accuracy	±0.1m/s	Accuracy	±0.1°
Temperature range	-40÷80°C	Temperature range	-40÷80°C
Rel. humidity range	0÷100%RH	Rel. humidity range	0÷100%RH
Acquisition speed	2samples/sec	Acquisition speed	2samples/sec

The measuring range of the anemometer is 0.5÷50m/s, with precision of 0.1m/s. Wind speed lower than 0.5m/s is measurable, but with lower accuracy. Wind direction is being measured with precision of 22.5°, which should be improved in the following period, by applying new sensor, mounted on another shaft.

Sampling rate is 0.5sec, while the measuring results are being shown as average over the 10sec period. This should reduce the turbulent influences to the measurements.

All sensors are mounted on the 10m high mast.

3.2 CO₂ sensor technical data

The main goal of this measurement technique was developed following the need to understand the CO₂ distribution in the atmosphere, mostly performed by the wind. For this purpose, the specific measuring device was developed by the firm IMD-Niš. The sensor used as the heart of the device is TGS4161, CO₂ measurement sensor, product of the Figaro Engineering INC., Japan. The characteristics of the sensor used are shown in the following table. From this data one can notice that the sensor can operate normally in the entire measuring range, since the lower measured value of CO₂ concentration was about 400ppm, and the higher about 800ppm.

Table 2 CO₂ sensor technical data

Model number			TGS 4161	
Sensing element type			Solid electrolyte	
Target gases			Carbon dioxide	
Typical detection range			350 ~ 10,000 ppm	
Electrical characteristics	Heater resistance	RH	70 ± 7Ω at room temp.	
	Heater current	IH	approx. 50mA	
	Heater power consumption	PH	approx. 250mW	
	Electromotive force	EMF	220~490mV in 350ppm CO2	
	Sensitivity	ΔEMF	44~72mV	EMF(350ppm CO2)- EMF(3500ppm CO2)
	Heater voltage	VH	5.0 ± 0.2V (DC)	
Sensor characteristics	Response time		approx. 1.5 min. (to 90% of final ΔEMF value)	
	Measurement accuracy		approx. ±20% at 1,000ppm CO2	
Operating conditions			-10~50°C, 5~95%RH	
Storage conditions			-20~60°C, 5~90%RH (store in moisture proof bag with silica gel)	
Standard test conditions	Test gas condition		CO2 in air at 20±2°C, 65±5%RH	
	Circuit condition		VH = 5.0±0.05V DC	
	Conditioning period before test		12 hours or longer	

3.3 Temperature sensor technical data

The temperature sensor used is PT100 element, with precision of 0.2°C. This measurement was added in order to ensure the comparison of the measured data with standard ones.

4. RESULTS AND DISCUSSION

From the data obtained by the IT Sector of MUP R. Serbia, there are 60880 vehicles registered in the City of Niš. According to the composition of this fleet of vehicles, using Copert [5] software, CO₂ emission estimation was performed. In the Figure 2, comparison between estimated CO₂ emission and measured CO₂ concentration for one of the measured locations is presented. It is obvious that there is direct relation of measured CO₂ concentration and traffic frequency, i.e. CO₂ emission.

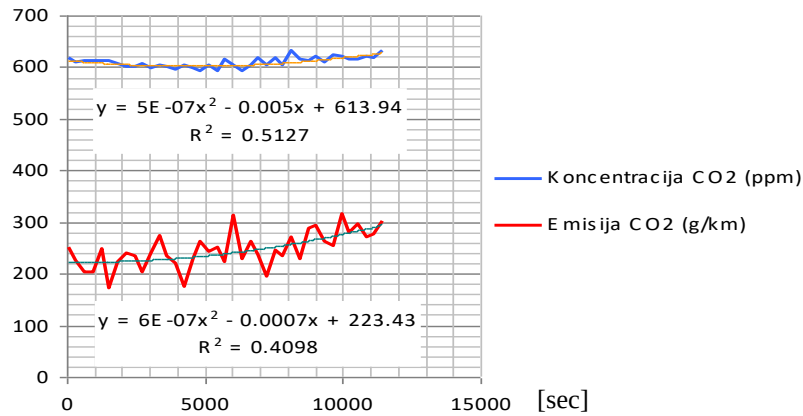


Fig. 2 Comparison of estimated CO₂ emission and measured CO₂ concentration

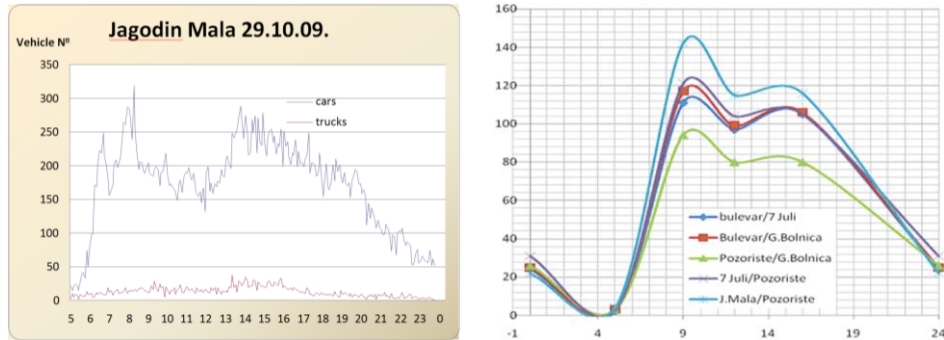


Fig. 3 (a) Measured frequency of vehicles on a measuring location and
(b) distribution approximation for all measured locations used for Copert

In the Figure 3.a. measured traffic frequency for the chosen location and date is presented. Data have been averaged over 5 min intervals. Two extremes can be noticed, one in the morning, between 9 and 10 AM (morning rush-hour) and between 3 and 4 PM (afternoon rush-hour). Number of vehicles in the period from 1 to 5 AM is <50 per hour, which is negligible, comparing to ~3000 per hour during rush hours.

Similar distributions were obtained for all measuring locations during work days. During weekend, distribution was normal statistical distribution.

4.1 Wind measurement

Wind measurements were performed on 3 different locations – near the street (to measure the influence of traffic), in the City Fortress (to indicate the influence of green and forested areas) and in the suburbia (to indicate the influence of single households on outdoor air quality).

The results from all measuring sites shows the dominant wind direction same as the Nišava river (sector 60°), which flows through the chosen domain and the influence of the larger Morava river (sector 330°), which is about 7km to the west from Niš. The results are very similar to the ones from the main meteorological station Niš.

These results show that the Measuring site 1 have the dominant wind direction same as the Nišava river (sector 60°), and the Measuring site 2 experiences the influence of the larger Morava river (sector 330°), which is about 7km to the west of Niš.

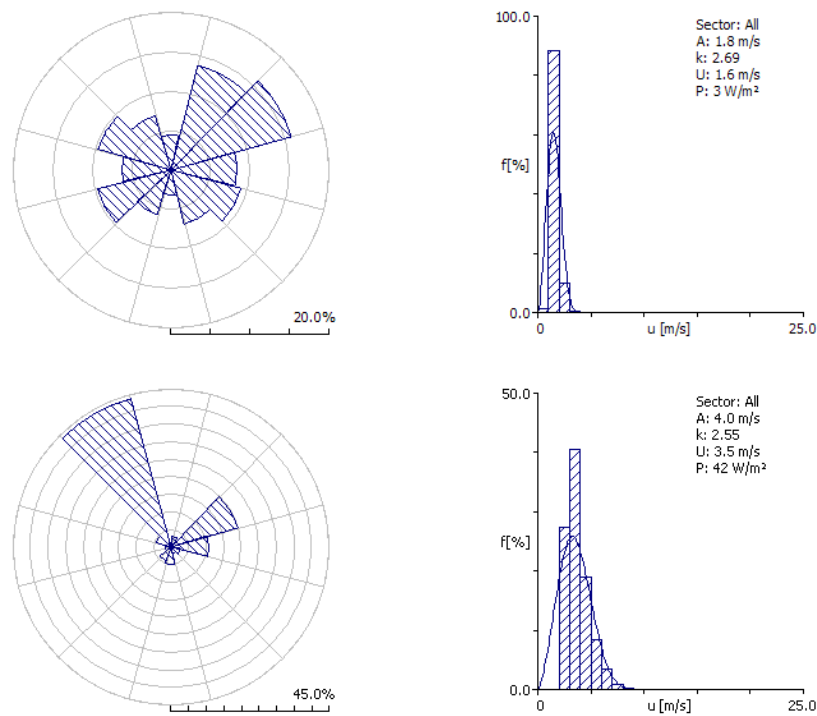


Fig. 4 Wind roses and Weibull distribution histogram on the measuring site 1 (up) and the Main meteorological station Niš (down)

4.2 CO₂ measurement

As there is large number of measurements on all measuring sites, the data comparison for the first half of April is presented. This measurements on both measuring locations shows the significant decrease of CO₂ concentration on the end of the heating season (marked with circle on both diagrams). This shows that the start predictions are correct, and that these measurements, after thorough analysis, can take us closer to understanding of the CO₂ distribution into the atmosphere.

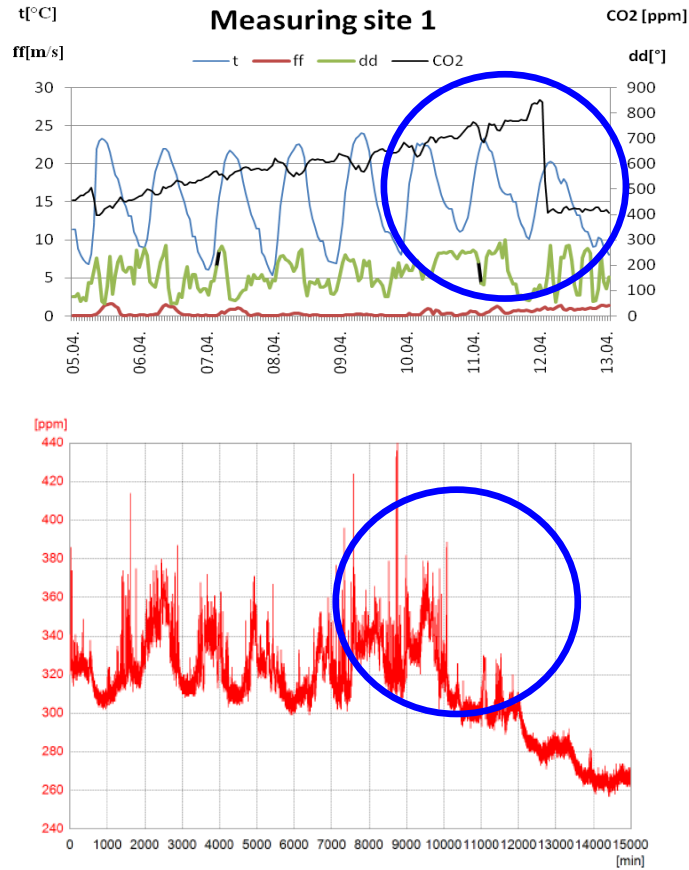


Fig. 5 Data collected on the Measuring site 1 (suburban) and CO₂ concentration measurement on the Measuring site 3 (green area)

5. CONCLUSION

In this paper a specific methodology for traffic intensity distribution measurement in the City of Niš is presented. Measuring locations were chosen in order to make as precise traffic induced pollutant emissions as possible. Simultaneously, the CO₂ concentration levels on the 1, 3 and 5m distance from the street, on 1m height were performed.

Results of the estimated traffic induced CO₂ emission shows good agreement with the measured CO₂ concentrations near the street (Figure 2). One can notice that traffic frequency increase leads to an adequate CO₂ concentration level increase on the measuring location.

Such measuring results were compared with the long-term wind, temperature and CO₂ concentration measurements on 3 different measuring locations in the City of Niš. Locations of these measuring sites were chosen in order to allow the proper estimation of street with high-frequency traffic, green and forest area and suburban area.

The results obtained show the potential of this measuring technique for proper estimation of traffic influence on air quality in different urban areas, using available, precise and relatively cheap instruments. Such methodology can be easily applied on air quality estimation in different locations. Knowing the exhaust gasses composition, other pollutant concentrations can be easily estimated.

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