Journal of Environmental Protection and Ecology 6, No 3, 505–512 (2005)

AIR QUALITY PARAMETERS IN BELGRADE

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Abstract. The present study discusses the ambient air quality of Belgrade from available data at three permanent locations covering basic (Kosutnjak) and urban (Karadjordjev park and Charlie Chaplin street) monitoring stations examined in the Programme of Air Quality Control over the year 2003. Results of the main common parameters sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and black smoke (BS) as the indicators of air pollution based on a 24-hour average sampling are presented. The concentration of annual averages of SO_2, NO_2, and BS were in the range 47-94 $\mu g\ m^{-3}$, 17-33 $\mu g\ m^{-3}$, and 16-41 $\mu g\ m^{-3}$, respectively. Spatial and temporal distribution of pollutants was established. We found the air quality especially bad in January and February when maximal levels of considered pollutants were recorded. Pollution in the city is exceeding international guidelines in some seasons, which is directly related to fossil fuel burning system and traffic management.

Keywords: urban air quality, sulphur dioxide, nitrogen dioxide, black smoke.

AIMS AND BACKGROUND

Belgrade is the largest urban center in Serbia with 1.6 million inhabitants spreading over the area of 332 km^2 within a circumference of 419 km. The city has a complex relief, with two big rivers (Sava and Danube), many hills and starting from the south the terrain gradually descends to the north, in shapes of wide plateaus, sectioned by stream and valleys situated between 66 and 628 m a.s.l. Belgrade has a moderate continental climate with the average annual temperature of 11°C. The coldest month is February (average temperature –0.3°C) and the hottest is July (average is 22.5 °C). The average amount of precipitation is about 700 mm while the highest monthly precipitation appears in June (110 mm) and the lowest in February (40 mm). The predominate winds from 'Kosava direction' (ESE, SE) blow with average velocity of 3.7 m/s and strokes over 28 m/s while north-western winds prevail during the summer. The transport network in Belgrade is predominantly road.

Air pollution is becoming a major factor in the quality of life of urban dwellers, posing a risk both to human health and to the environment. The Programme of Air Quality Control (PAQC) in Serbia was drawn up in accor-

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dance with the regulations on imission limit values, imission measurement methods, criteria for setting up measurement points and data records and is performed in for two-year periods[1]. The systematic monitoring of air pollution levels in Belgrade was established by the health service in 1953 when the actual measurement and analyses operations were carried out by the City Health Care Institute[2]. The main pollutants in ambient air of interest in current air quality monitoring network are sulphur dioxide (SO_2), nitrogen oxides (NO_x), black smoke (BS), suspended particulates, ozone, carbon monoxide and heavy metals. This group of substances was selected due to their impact on public health.

The objective of this paper is to analyse the ensuing data to current regulations[3], which were drawn up according to the international guidelines[4] and to discuss spatial and temporal distribution of air pollutants in Belgrade. In addition, obtained results were compared with those of the cities worldwide

EXPERIMENTAL

The ambient air quality measurements in Belgrade (44°46′N, 20°25′E) were performed as routine monitoring at three locations covering network of basic (Kosutnjak, KO, 203 m a.s.l.) and urban (Karadjordjev park, KP, 131 m a.s.l. and Charlie Chaplin street, CC, 108 m a.s.l.) meteorological stations (Fig. 1) set up by the Hydrometeorology service of Republic Serbia through the PAQC. The monitoring stations are installed in a sufficient distance from each other and cover the main residential areas for study of air pollution and general public health effects. The monitoring of three principal air pollutants: SO_2 and NO_2 as gas components and BS as a solid phase in the air were conducted on a 24-hour average sampling. Collecting and analysing air quality data were carried out in accordance with the ISO standards for sulphur dioxide[5,6] and nitrogen dioxide[7]. Black smoke was collected on Whatman-41 filters with 12.5-cm diameter and refractometrically evaluated.

Statistical analysis of data was performed with STATISTICA 5 software. Two-way ANOVA analysis was used to test significant differences among sites and different periods. Differences are reported here as significant at $p<0.05$.

RESULTS AND DUSCUSSON

The daily concentrations of SO_2 (5-349 μg m^{-3}) have been found to be consistently much higher than the permissible limits (150 μg m^{-3}) during the winter months, January and February. The number of these days was 40 that makes 12% of the total number of sampled days (322). During that period the critical air pollution level of 250 μg m^{-3} for warning imission was exceeded and the peak value of 349 μg m^{-3} recorded on February 28 at KP station.

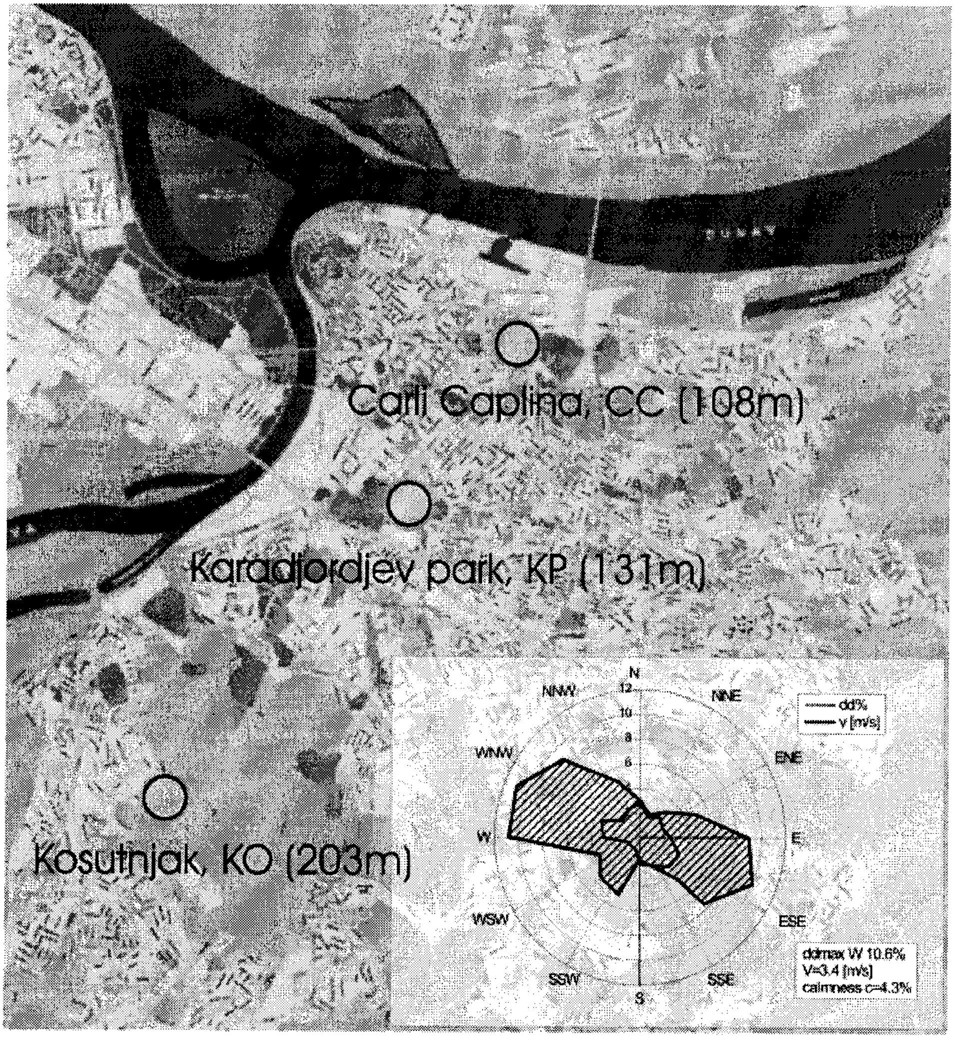

Fig. 1. Map of Belgrade, showing the location of monitoring stations with the rose wind for 2003

The overall daily analysis of BS concentrations fluctuated in a wide range between 1 and 944 μg m^{-3} and in 75 days (23%) out of total sampled days the current limit value (LV) of 50 μg m^{-3} was exceeded. The most serious air pollution took place on January 16 and February 28 with recorded maximum values at CC (944 μg m^{-3}) and KP (559 μg m^{-3}), respectively. During these episodes concentrations were beyond the critical levels (I – of 400 μg m^{-3} and II – of 600 μg m^{-3}) and local authorities should order the application of special measures and give the guidelines for behaviour to population, especially to vulnerable group.

Average daily concentrations of NO_2 at all stations varied between 5 and 200 µg m^{-3} and were generally below 30 µg m^{-3}. Maximum daily values often exceeded 20 µg m^{-3} during most of the season and the maximal values of 87, 129, and 200 µg m^{-3} at KO, CC, and KP, respectively, were recorded on January 16. Moreover, it appears that NO_2 pollution in Belgrade is not considerable in respect to the total number of days 17 (5%) exceeding LV (85 µg m^{-3}) and in general it comes from traffic contributions.

Maximum daily values for measured parameters were lower in 2003 than ever recorded at the monitoring stations since they have been operated[8]. Using statistical analysis of the daily average concentration data, a strong correlation (the Pearson coefficient R=0.73-0.75) exists between monitoring stations regarding only SO_2. From the comparison of histograms in Fig. 2. representing a daily integrated concentrations for considered parameters between monitoring station, it is evident a significant difference in their distribution (peak frequency value and half-width). This is in agreement with geographical and model char-

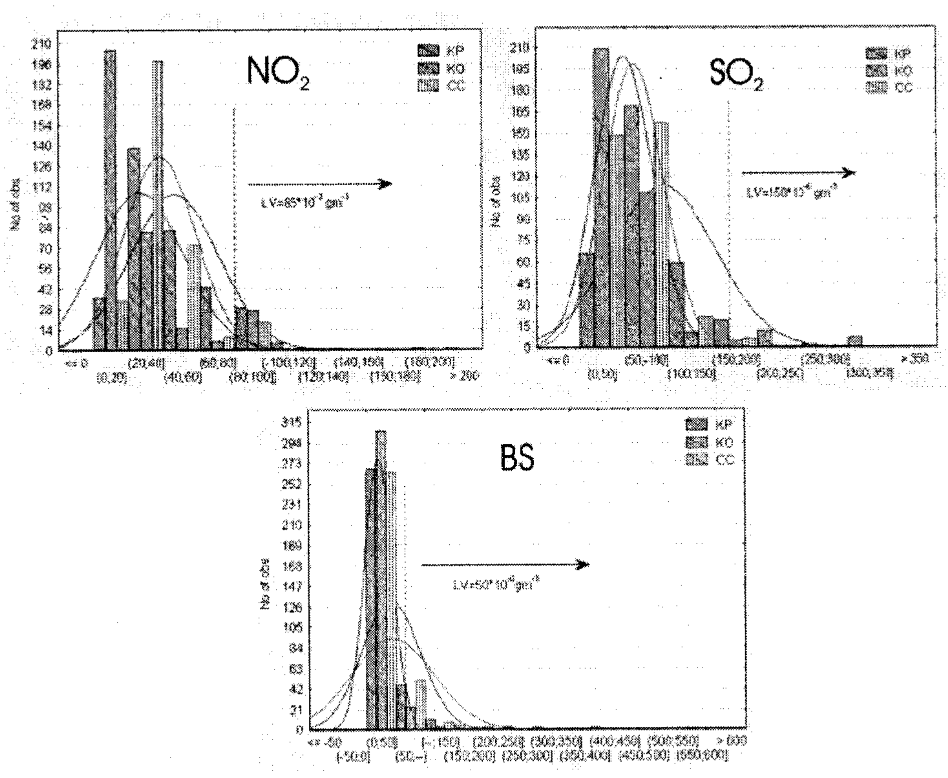

Fig. 2. Histograms of the distribution of the daily SO_2, NO_2, and BS concentrations at monitoring stations. The solid lines represent the envelope of the normal function calculated on the basis of distribution of the samples considered

acteristics of monitoring stations (background pollution, pollution in residential and industrial areas) and exerting meteorological conditions at the sites. The similarity in BS concentration distribution at KP and CC stations could be associated with their location in downtown under direct influence of sources, such as streets.

The average monthly of the SO_2, NO_2, and BS concentrations calculated from the daily integrated monitoring data at considered stations are presented in Fig. 3. A clear difference in SO_2 and BS distribution during the season occurred as in the previous 2002 year with pronounced winter-time maximum (November–March) and summer-time minimum (June–September). The SO_2 concentrations at KP station are higher than at the other sites and can be related to the presence of hospital campus located in its vicinity with individual oil-fired heating system. The heavy fuel oils used for heating power plants contains up to 1% of sulphur content. The higher air pollution level during winter month creates 'winter syndrome' characterised by the neutral and stable stratifi-

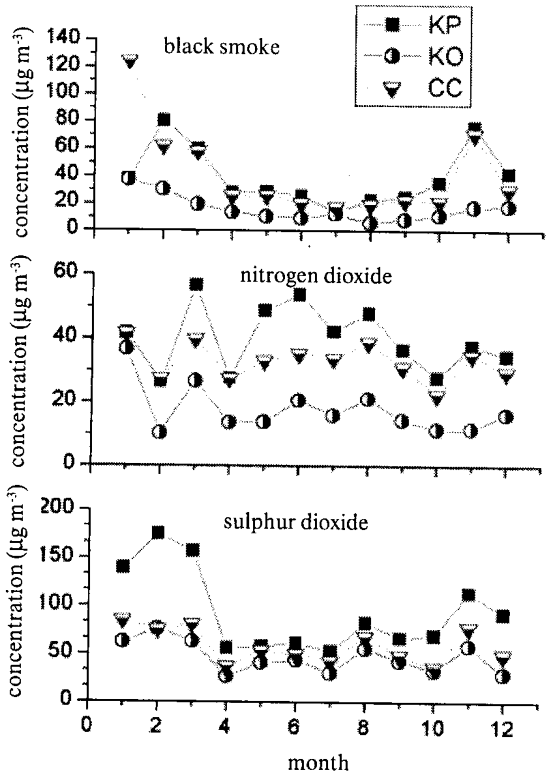

Fig. 3. Monthly average concentrations of the SO_2, NO_2, and BS at three monitoring stations in the year 2003

cation of the atmosphere with low temperature, low mixing depth, pollution inversion combined with combustion processes. The daily pollution emission is less variable than the weather that implies that the weather determines air quality[9] as in the case of 'Kosava wind' that significantly participates in pollutants transport.

Nitrogen dioxide concentrations at KP and CC were similar and significantly higher than concentrations recorded at KO. Relationship between SO_2 and NO_2 species was found at the CC station (Fig. 4). A linear regression of the plotted data reveals statistically significant correlation $[SO_2] = (2.1 \pm 0.7)\ [NO_2] - (12.24 \pm 23)$ with correlation coefficient of R=0.69. Higher SO_2/NO_x ratio is typically characterised for point sources emission[10].

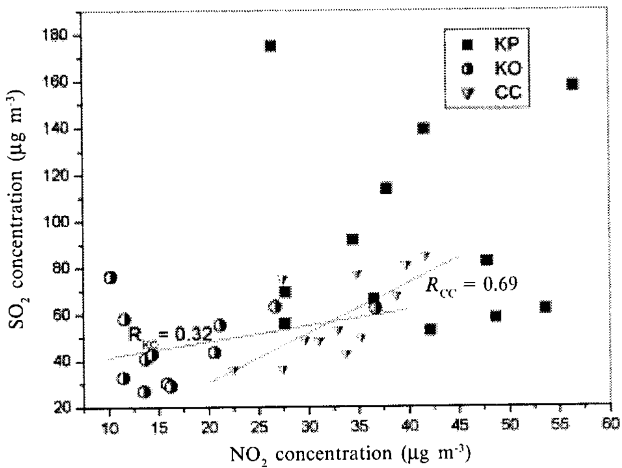

Fig. 4. Variations of SO_2/NO_2 concentrations at monitoring stations in Belgrade

The ambient air quality data indicate high values of SO_2 – 47-94 µg m^{-3} on annual average basis against the proposed standard of 50 µ gm^{-3}. On the other hand, the annual mean values of BS – 16-41 µg m^{-3} and NO_2 – 17-33 µg m^{-3} are within the permissible national limits of 50 and 60 µg m^{-3}, respectively. The geographical variations for annual average concentrations of SO_2, NO_2, and BS at considered monitoring stations are illustrated in Fig. 5.

In order to compare air quality in Belgrade with the data published for cities worldwide, the annual averages for considered pollutants were summarised in Table 1. The obtained results reflect an actual situation in Belgrade area with a lack of district heating systems for an urban town and relatively low traffic intensity. However, NO_2 concentrations are less than those in the cities of developed countries. A relative composition of ambient air pollutants on an annual average basis in Belgrade was found to be pretty steady towards 2000.

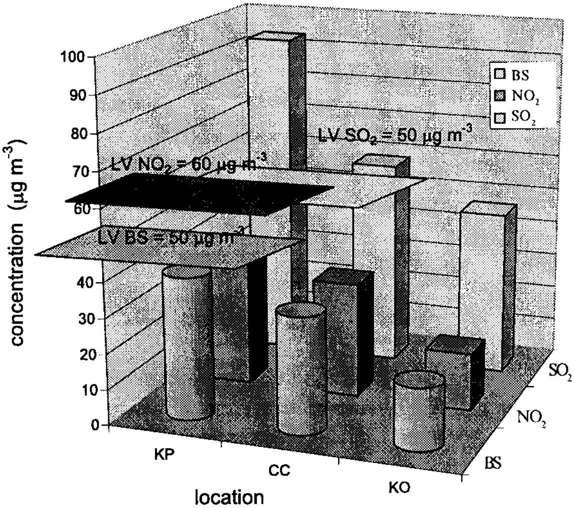

Fig. 5. Geographical variation of annual average concentrations (μg m^{-3}) of SO_2, NO_2, and BS in Belgrade in 2003

Table 1. Annual averages for main pollutants in cities worldwide and Belgrade

Location	Period of observation	SO_2	NO_2	SPM	BS
		(μg m^{-3})			
Cities in West Europe[11]	1993	18-22	35-48		
Cities in USA[11]	1993	20-40	40-42		
Cities in Japan[11]	1993	18-22	35-50		
Athens[12]	1995	16-45	34-98		22-99
Thessaloniki[13]	1989-2000	10-120	25-100	40-110	
Cities in Turkey[14]	1996	46-86		62-68	
San Paolo[15]	1991-93	20	163	65	
Delhi[10]	2001	14-15		311-476	
Belgrade	2000	52-77	13-31		14-96
	2002	33-50	19-35		17-51
	2003	47-94	17-33		16-41

CONCLUSIONS

Levels of air pollution evaluated from the available ambient national monitoring data at two (KP and CC) out of three considered sites indicate that concentrations of SO_2 and BS contribute constituently to air pollution of the city emitted directly from various sources. Number of daily concentrations exceeding LV was for BS and SO_2 above 10% and only for NO_2 it was below it. Annual level for measured SO_2 failed to meet air quality standards set by WHO in winter season, which is directly related to fossil fuel burning system (institutional and residential combustion) and traffic management.

Acknowledgements. The authors express their appreciation to Ms. Ana Popovic, the Regional Environmental Center for Central and Eastern Europe, Belgrade, for available data. This research was supported by the grant funded by the Ministry for Science and Environmental Protection, No 1995.

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Received 14 June 2004
Revised 8 July 2004