

## SHORT COMMUNICATION

## LEVELS OF NITROGEN DIOXIDE IN THE ZAGREB AIR

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Surveillance of NO<sub>2</sub> in Zagreb started in 1994 at five measuring sites. This paper presents the levels and trends of NO<sub>2</sub> annual mean values for the period between 1994 and 1998. The obtained data are compared with the recommended and limit values according to the Law on Air Quality Protection in Croatia and the Ordinance on Recommended and Limit Air Quality Values. For the past five years, ever since the measurement commenced, the concentration levels of NO<sub>2</sub> in Zagreb have kept between the national recommended and limit values at all measuring sites, indicating that the air has been moderately polluted. This paper also shows the variations of monthly mean values through 1998 at all sites. The levels of NO<sub>2</sub> in the northern part of Zagreb were measured at two distances from traffic. Daily variations in the levels were measured near the road and presented as hourly averages for workdays and weekends in winter and in summer reflecting the activity pattern of emission sources.

*Key words:*  
air quality, limit values, recommended values, surveillance

Sources of nitrogen oxide in the environment are natural or man-made. Considerable amounts of nitrogen oxide are emitted into the atmosphere from natural sources. The principal man-made source of nitrogen oxide is fuel combustion. Initially, NO is emitted into the ambient air and converted by oxidation into NO<sub>2</sub>. The speed of conversion and the formation of secondary pollutants depends on concentrations of ozone, OH-radicals, hydrocarbons, other air pollutants, and especially on insolation.

Nitrogen oxides play a significant role in various chemical and photochemical reactions in the ambient air and the products of these reactions reduce the visibility

and adversely affect human health, materials, and vegetation. The investigation of effects of nitrogen oxides on human health (1) shows that NO<sub>2</sub> is four to five times more toxic than NO.

The Croatian Ordinance on Recommended and Limited Air Quality Values (2), and the Law on Air Quality Protection (3) provide a good basis for the categorisation of air quality concerning NO<sub>2</sub> in different urban areas.

The levels and trends of NO<sub>2</sub> concentrations presented in this paper refer to the period since 1994, that is, ever since the beginning of constant monitoring of NO<sub>2</sub> in Zagreb.

## MATERIALS AND METHODS

Surveillance of NO<sub>2</sub> in Zagreb started in 1994 at five measuring sites. The measurements were performed with passive samplers which collected 24-hour samples of NO<sub>2</sub> by molecular diffusion on a filter Whatman No. 1 impregnated with triethanolamine (4). The samples were extracted from filters with triethanolamine solution and analysed using a colorimetric method based on the Griess-Ilosway reaction (4). In the northern part of the town samples were collected close to traffic and at a 50 m distance in a backyard. Daily variations of NO and NO<sub>2</sub> concentrations were monitored at the site close to traffic using an automatic chemiluminescence instrument AC 30M ANSYCO, Germany.

## RESULTS AND DISCUSSION

Concentrations of air pollutants fluctuated over a day, week, or a year, depending on human activities and meteorological conditions. There is a regular daily, weekly, and a yearly fluctuation in the concentration levels depending on levels of emission and weather conditions (5).

Figure 1 shows daily variations of NO and NO<sub>2</sub> concentrations measured with an automatic chemiluminescence analyser, by workdays and weekends for winter and summer 1998. Regardless of the season, NO reached highest concentrations between 6 and 10 a.m. and fell in the afternoon hours on workdays, yet it corresponded to changes in the traffic intensity that is, rush hours. On Sundays, concentrations of NO were significantly higher in the late afternoon or over night due to higher traffic intensity at that time. The obtained data agree with the investigation of some other authors (6).

Figure 2 shows the differences in monthly NO<sub>2</sub> averages measured close to traffic and 50 m away in 1998. During summer, when traffic is the dominant source of NO<sub>2</sub>, its levels were significantly higher on the measuring site close to traffic. In winter, during the heating season, the difference in NO<sub>2</sub> was less significant.

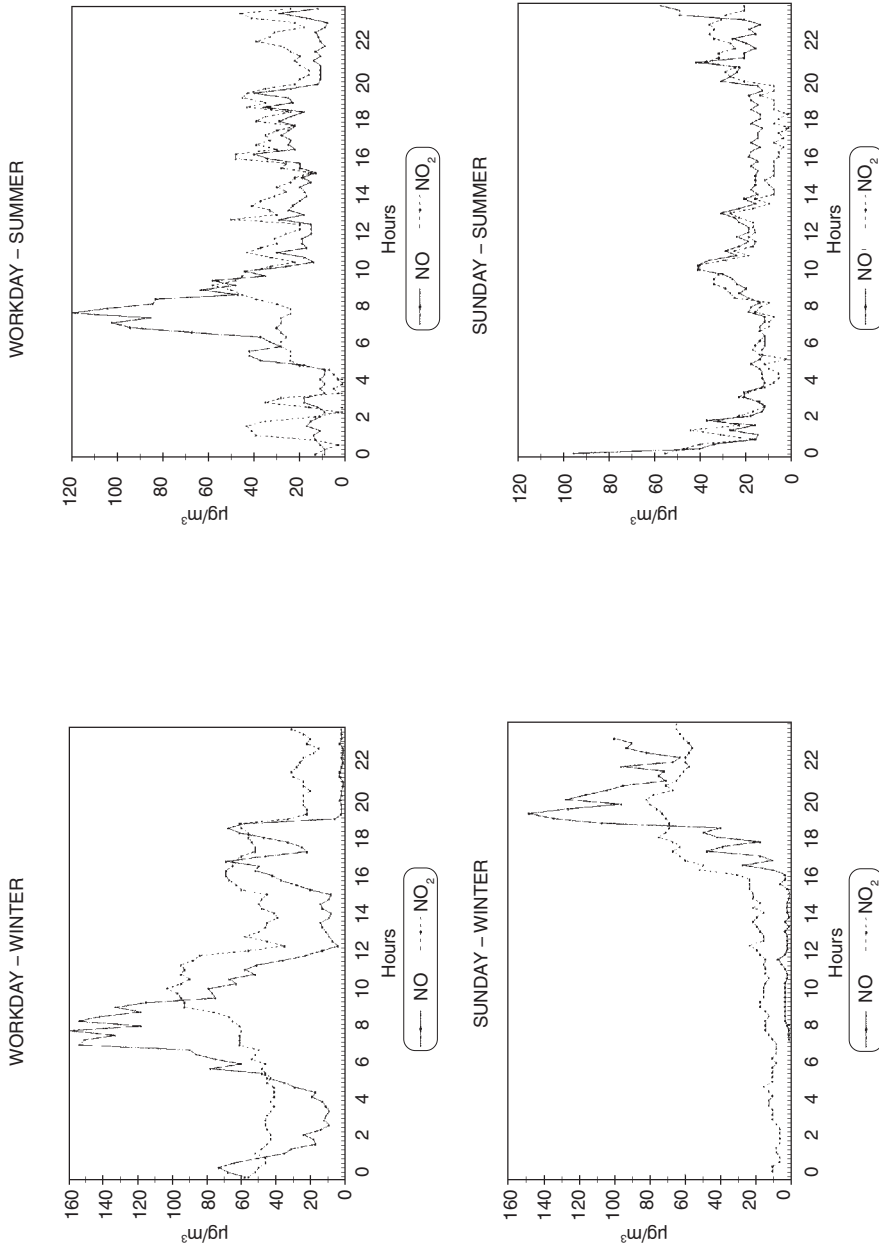


Figure 1 Daily variations of NO and NO<sub>2</sub> concentrations for 1998

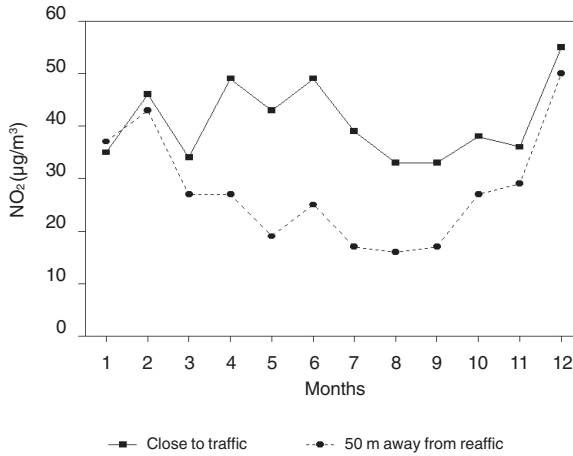


Figure 2 Differences in the levels of NO<sub>2</sub> concentrations close to traffic and at about 50-m distance in the backyard in 1998

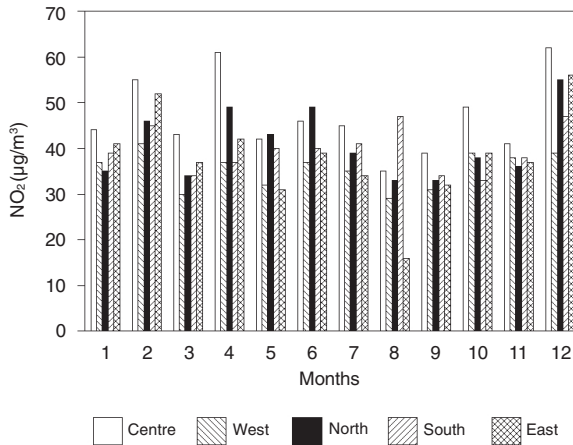


Figure 3 Annual trend of average monthly NO<sub>2</sub> concentrations in 1998

Figure 3 shows the 1998 variations of monthly NO<sub>2</sub> averages. The differences between the summer and winter levels of NO<sub>2</sub> concentrations were not significant. The highest monthly averages of NO<sub>2</sub> were recorded in the city centre.

Figure 4 shows the trend of annual mean values and Figure 5 the trend of the 98<sup>th</sup> percentile values for years 1994–1998. Figure 4 shows that the annual mean values on the measuring site in the city centre kept above the recommended value of 40 µg/m<sup>3</sup>.

The recommended values were also exceeded in the northern part of the town in the years 1994, 1996, and 1998, and in southern part in 1996. In the eastern and

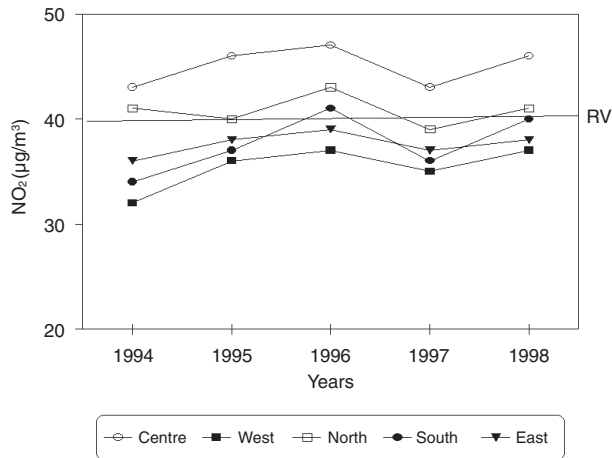


Figure 4 Trend of annual mean of  $\text{NO}_2$  concentrations in Zagreb from 1994 to 1998

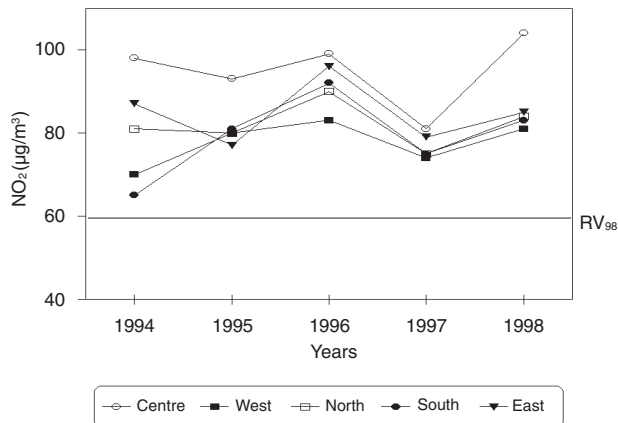


Figure 5 Trend of the 98<sup>th</sup> percentile values of  $\text{NO}_2$  concentrations in Zagreb from 1994 to 1998

the western part of the town the mean annual concentrations of  $\text{NO}_2$  kept below the recommended value. However, the 98<sup>th</sup> percentile values (Figure 5) were over the prescribed 98<sup>th</sup> percentile value at all measuring sites throughout the measuring period indicating occasional occurrence of relatively high values, which, however, did not significantly affect the annual means.

According to the recommended and limit values taken from the Ordinance on Recommended and Limited Air Quality Values and the Law on Air Quality Protection, the ambient air in Zagreb concerning  $\text{NO}_2$  levels is moderately polluted for all measuring sites and for the whole measuring period.

## CONCLUSION

Surveillance of air quality in Zagreb which started with measurement of SO<sub>2</sub> and smoke in 1963 showed that the levels of SO<sub>2</sub> fell substantially with the introduction of natural gas as the main source of energy in the city, and then NO<sub>2</sub> became one of the dominant air pollutants.

The mean annual concentration levels of NO<sub>2</sub> in Zagreb measured since 1994 kept above the recommended value (40 µg/m<sup>3</sup>) yet also below the limit value (60 µg/m<sup>3</sup>) at all measuring sites, indicating that the air was moderately polluted. Traffic and fuel control and the abatement of industrial emissions may play a key role in decreasing NO<sub>2</sub> levels in Zagreb.

An analysis performed by Schwela for the World Health Organization (7) showed that the levels and trends of NO<sub>2</sub> concentrations in Zagreb were very similar or lower than in other Western European cities with a comparable number of inhabitants.

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### *Sažetak*

## RAZINE NO<sub>2</sub> U ZRAKU ZAGREBA

Mjerenje NO<sub>2</sub> počelo je u Zagrebu 1994. godine na 5 mjernih postaja. U ovom radu prikazane su razine i trendovi srednjih godišnjih koncentracija NO<sub>2</sub> za sve mjerne postaje u razdoblju od 5 godina (1994.-1998.). Dobiveni rezultati uspoređeni su s PV i GV prema Zakonu o zaštiti zraka i Uredbi o preporučenim i graničnim vrijednostima kakvoće zraka. Zrak je u Zagrebu glede NO<sub>2</sub> umjereno onečišćen na svim mjernim postajama, jer je tijekom svih 5 godina mjerenja na svim postajama dolazilo do prelaska PV, ali su izmjerene koncentracije bile ispod GV. U radu je također prikazan tijek srednjih mjesečnih koncentracija u 1998. godini za sve mjerne postaje. Na mjernoj postaji u sjevernom dijelu grada mjerene su razine koncentracija NO<sub>2</sub> na dvije različite udaljenosti od prometnice. Na istoj postaji mjerene su i dnevne varijacije u razinama koncentracija koje su prikazane kao satni prosjeci, a upozoravaju na varijacije u intenzitetu izvora emisije.

*Cljučne riječi:*  
granične vrijednosti, kakvoća zraka, praćenje, preporučene vrijednosti

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