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TRENDS OF LEAD IN SUSPENDED PARTICULATE MATTER IN ZAGREB AIR

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ABSTRACT

Monitoring of lead in total suspended particulate matter (TSPM) started in Zagreb, Croatia in 1971 at three measuring sites, located in the city centre and in the northern and western parts. Monitoring of lead concentrations in PM_{10} started in the northern part of the city in 1999. This paper presents the trends of annual mean values for lead concentrations in TSPM and in PM_{10} particles, as well as their comparison with the Croatian limit values and European Union (EU) limit values. The obtained data showed a decreasing trend of lead in TSPM, especially during the last ten years when the consumption of lead-free gasoline increased. Lead in PM_{10} also decreased during the period of measurement. In 1997, the annual mean lead concentration in TSPM was 0.5 $\mu g/m^3$, which is the EU limit value. Since 1999, the concentrations have fallen down and have kept below 0.25 $\mu g/m^3$.

Key Words: Aerosols, Heavy metal, Air quality monitoring, PM_{10}

1. INTRODUCTION

Levels of lead found in the air, food, water and soil vary widely throughout the world, and depend on the degree of industrial development, urbanization and lifestyle factors. Lead is inhaled as fine particles and deposited in the lungs. Since lead uptake by blood is dependent on the deposition pattern and solubility (which is influenced by chemical form and particle size), total lead content is only a surrogate for the biologically effective dose. Furthermore, airborne lead can also reach humans indirectly via deposition on soil and vegetation, and through food chains (Guidelines, 2000).

2. MATERIALS AND METHODS

The monitoring of lead concentrations in total suspended particulate matter started in Zagreb in 1971 at three measuring sites located in the city center, and in the northern and western part of the city. The monitoring of lead concentrations in PM_{10} particles started in the northern part of the city in 1999.

The location of measuring sites is shown in Figure 1.

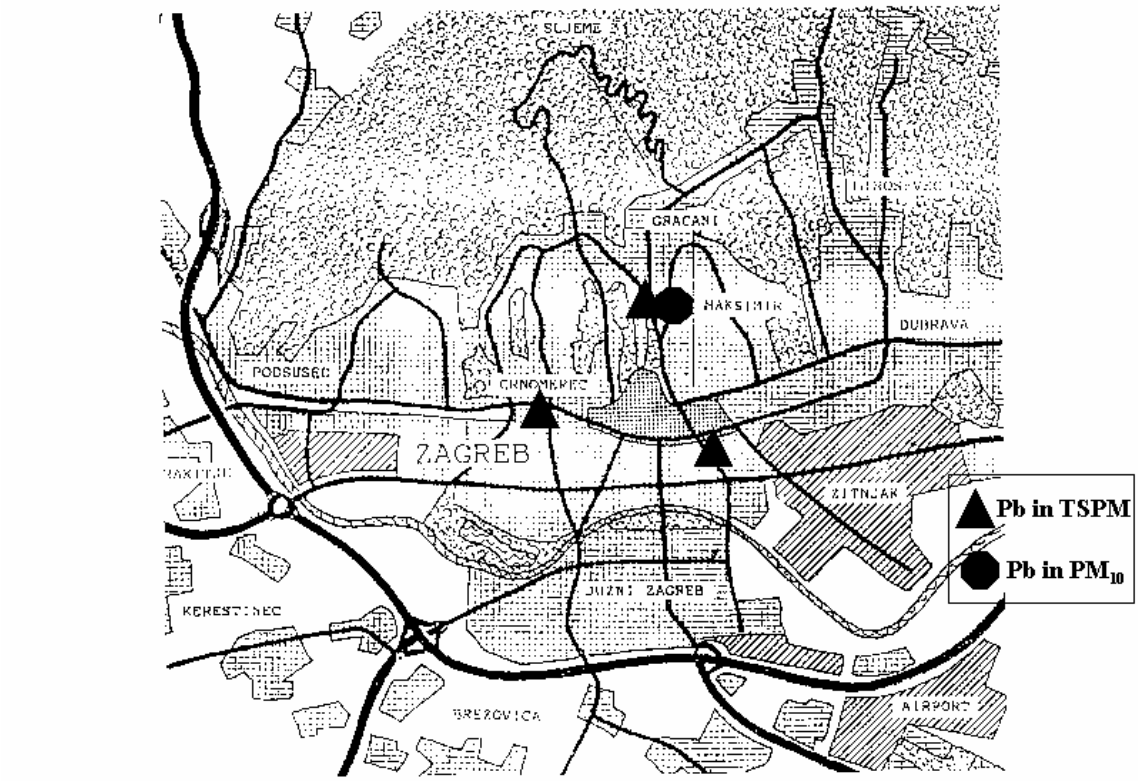

Figure 1 - Location of measuring sites

Twenty-four-hour mass concentration samples of total suspended particulate matter were collected on membrane filters of about 200 m^3 of air, while PM_{10} samples were also collected on membrane filters of about 100 m^3 of air.

Mass concentrations of TSPM and PM_{10} samples were determined gravimetrically. Detection limit values were 2.0 μg m^3 for TSPM and 1.0 μg m^3 for PM_{10} (Bešlić, 2001).

Mass concentration of lead in TSPM and in PM_{10} samples was determined by atomic absorption spectrophotometry (AAS). The detection limit for Pb was 0.0005 μg m^3.

3. CROATIAN AND EUROPEAN AIR QUALITY LIMIT VALUES

The recommended and limit values for lead in TSPM in Croatia are shown in Table 1 (Ordinance, 1996).

Table 1. Recomended (RV) and limit (LV) values for lead in TSPM (μg/m^3) in Croatia

Averaging period	Pollutant	RV	LV	Average over
Calendar year	Lead in TSPM	1	2	24 hour

Table 2 shows Air Quality Guidelines of WHO for lead for Europe (Guidelines, 2000) and Table 3 shows the limit values for lead in TSPM in European countries (Council Directive, 1999).

Table 2.Air Quality Guidelines of WHO for lead

Averaging period	Pollutant	LV (μg/m^3)
Calendar year	Lead	0.5

Table 3.Limit value for lead in the European countries

Averaging period	LV (μg/m^3)	Date by which limit value is to be met
Calendar year	0.5	From 1 January 2001

All three tables show that the Croatian limit values are more tolerant than the European, which in turn suggests that the Croatian regulations should be in agreement with the European standards.

4. RESULTS AND DISCUSSION

Figure 2 shows the trends of annual mean values for lead in TSPM in Zagreb air measured at three sites located in the city center (densely populated area), in the northern part of the city (sparselly populated housing area) and in the western part of the city (industrial area) for the period 1971-2004.

The annual mean concentrations of lead in TSPM ranged between 0.2 and 1.4 μg m^3 in the period 1971-1991, but since 1991, over the past fourteen years, a strong decreasing trend can be observed, resulting from an increased comsumption of unleaded gasoline in Croatia. The annual mean concentrations of lead in TSPM in 1997 were below 0.5 μg m^3, which is in accordance with the EU limit and WHO guideline for Europe. Since 1999, the concentrations have fallen down and they have kept below 0.25 μg m^3, while in 2004 they were below 0.05 μg m^3.

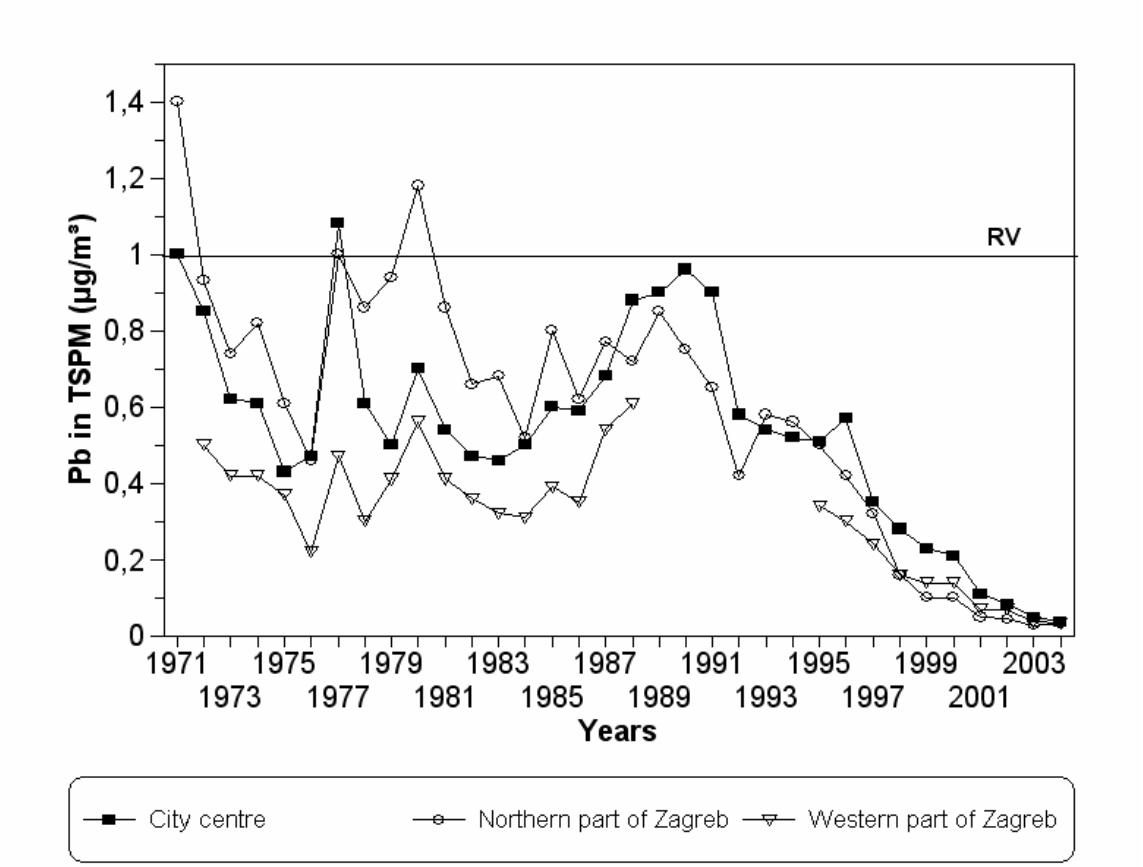

Figure 2. Trends of annual mean values for lead in TSPM in Zagreb for the period 1971-2004.

Figure 3 shows daily concentrations of lead in TSPM in 1981 and 2004, measured in the northern part of the city. These data show a significant decrease in 24-hour mass concentrations of lead in TSPM in 2004 in comparison to 1981 measurements.

Figure 4 shows the trend of annual mean values of lead in PM_{10} in the northern part of the city for the period 1999-2004.

Lead concentrations in PM_{10} particles were very low throughout the measuring period, and showed a strong decreasing trend.

Air quality in Croatia is currently assessed by comparing annual means with recommended (RV) and limit (LV) values stipulated by the Law on Air Quality Protection in Croatia and the Ordinance on Recommended and Limit Air Quality Values. The Law on Air Quality Protection in Croatia gives three categories of air quality:

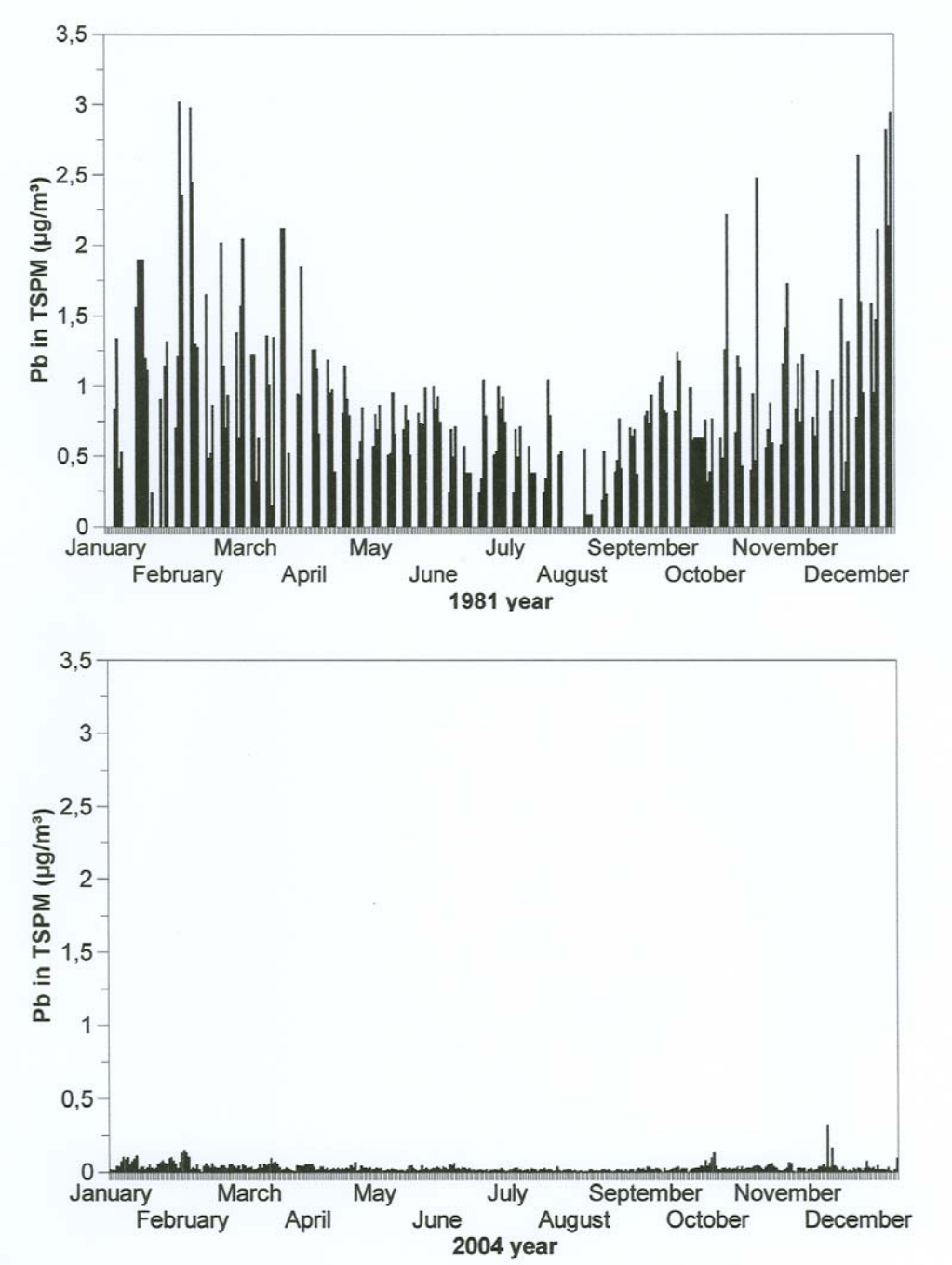

Figure 3. Daily concentrations of lead in TSPM in 1981 and 2004 measured in the northern part of the city

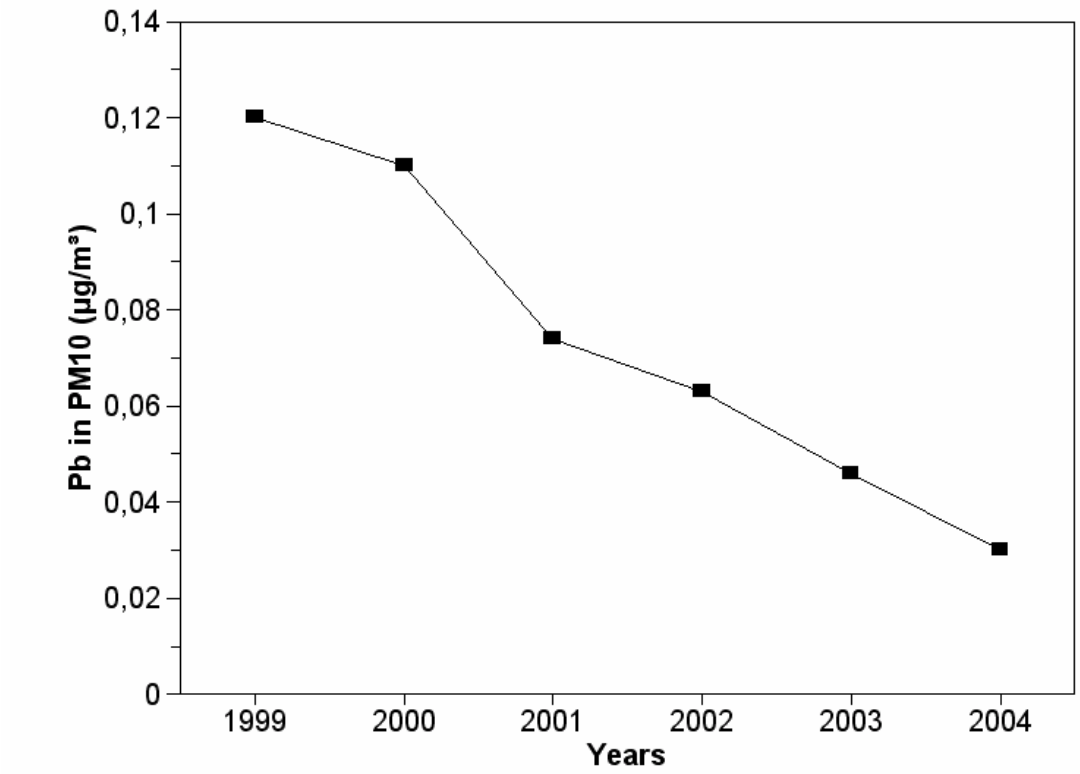

Figure 4.Trend of annual mean values of lead in PM_{10} in the northern part of the city for the period 1999-2004

1st category - clean air (the concentration levels of air pollution are below RV)
2nd category -moderately polluted air (the concentration levels of air pollution are over RV and below LV)
3rd category - polluted air (the concentration levels of air pollution are over LV).

Table 4 shows the categorisation of Zagreb air with the respect to the levels of lead in TSPM. The levels of lead in TSPM were very low and the air was of the 1st category throughout the monitoring period, except in the city centre in 1977 and in the northern part of the city in 1980.

Table 4. Categorization of Zagreb with respect to levels of Pb in TSPM

Years	1st category C<RV	2nd category RV<C<LV	3rd category C>LV
1971.	□ Λ	F	
1972.	□ F Λ		
1973.	□ F Λ		
1974.	□ F Λ		
1975.	□ F Λ		
1976.	□ F Λ		
1977.	F Λ	□	
1978.	□ F Λ		
1979.	□ F Λ		
1980.	□ Λ	F	
1981.	□ F Λ		
1982.	□ F Λ		
1983.	□ F Λ		
1984.	□ F Λ		
1985.	□ F Λ		
1986.	□ F Λ		
1987.	□ F Λ		
1988.	□ F Λ		
1989.	□ F Λ		
1990.	□ F Λ		
1991.	□ F Λ		
1992.	□ F Λ		
1993.	□ F Λ		
1994.	□ F Λ		
1995.	□ F Λ		
1996.	□ F Λ		
1997.	□ F Λ		
1998.	□ F Λ		
1999.	□ F Λ		
2000.	□ F Λ		
2001.	□ F Λ		
2002.	□ F Λ		
2003.	□ F Λ		
2004.	□ F Λ		

□ - City centre F- Northern part of Zagreb Λ- Western part of Zagreb

5. CONCLUSION

The results of monitoring lead in TSPM in Zagreb, the capital of Croatia, show that its concentrations were not high. Since 1991, a strong decreasing trend of lead in TSPM has been observed due to increased consumption of unleaded gasoline. Lead concentrations in PM_{10} particles also showed a strong decreasing trend over the entire measuring period. During the last fourteen years, concentrations were below the Croatian recommended limit value, limit values in EU, and WHO guideline for Europe.

The Croatian limit values are more tolerant than the European and need to be adjusted to the European standards.

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