SEASONAL AND SPATIAL DISTRIBUTION OF PM 2.5 PARTICLE FRACTION IN ZAGREB AIR DURING 2005

Ivan Bešlić and Krešimir Šega
Institute for Medical Research and Occupational Health,
Ksaverska cesta 2, 10000 Zagreb, Croatia, ibeslic@imi.hr, ksega@imi.hr

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ABSTRACT

Pilot investigations of seasonal and spatial differences of PM2.5 particle fraction concentrations in Zagreb were performed at four sampling sites, for a month period in summer and again in winter period during the year 2002. Based on these data, together with the conclusions of several recent WHO projects and WHO meetings, Zagreb PM2.5 monitoring network was established in year 2005. New monitoring network contain five measuring sites located in different parts of Zagreb. The results show much higher annual concentration averages compared to the recommended values at all measuring sites. Significant seasonal and spatial differences in PM2.5 concentration levels were observed.

INTRODUCTION

The air quality surveillance in Croatia started in Zagreb in 1962 with the measurement of deposited matter. Investigation of particulate air pollution in Zagreb started in 1972 by collecting total suspended particulate matter (TSP) at four different measuring sites. Determination of their heavy metal content was also performed. Because of better relation to the health outcomes, parallel PM10 and PM2.5 monitoring started in 1999 at one measuring site in northern residential part of Zagreb. Monitoring included determination of heavy metal content, as well as anion content [Čačković, 2004] and PAHs [Šišović, 2004] in both particle fractions. Daily concentration levels of PM2.5 fraction were related to TSP and PM10 fraction concentration levels. In order to get first insight in seasonal and spatial distributions of PM10 and PM2.5 concentrations in Zagreb area an investigation as a part of SILAQ project (Sofia Initiative for Local Air Quality, initiated in 1995) was performed in 2002. This pilot project was performed at four measuring sites located at different parts of Zagreb, for a month period during summer and again during winter season. Samples were collected on daily basis and investigation included determination of heavy metal, anion and PAHs content.

Fine particles (PM2.5) are more hazardous than large ones in terms of mortality and morbidity (cardiovascular and respiratory health endpoints) [CAFÉ program Second Position Paper on Particulate Matter, 2004]. WHO paper [WHO, 2005] recommends a range of values (12 to 20 $\mu g/m^3$) for the integrated assessment procedure to identify an appropriate PM2.5 annual average limit value. The PM2.5concentration value of 35 $\mu g/m^3$ is recommended as the level not to be exceeded more than 10% of the days in the year.

In scope of these conclusions, daily PM2.5 concentrations levels obtained during previous investigations (1999-2004) were higher compared to the proposed values. These facts resulted in PM2.5 Zagreb network implementation.

In this paper, the results of PM2.5 concentration levels monitoring at new Zagreb monitoring network are presented and assessed.

MATERIALS AND METHODS

PM2.5 monitoring network has five measuring sites located at different parts of Zagreb. Measuring site located in northern part of the town is characterized by residential surroundings and medium traffic density. Measuring site located in the town centre is characterized by high traffic density and street canyons. Western and eastern measuring sites are located at residential-industrial parts and characterized by dense traffic during rush-hours, while southern measuring sites is located in residential area characterized by dense traffic during rush-hours and district heating.
Samples from northern measuring site were collected daily, while samples collected at other measuring sites were collected daily during weekdays and a cumulative samples were taken during weekends. All samples were collected on 47 mm diameter Whatman Quartz filters from 55 m^3 of ambient air per day by means of low volume samplers LVS3. Samples were preconditioned for 48 hour under ~50% relative humidity and temperature of 20°C.
Particle mass was determined by weighing using microbalance Mettler Toledo MX-5.

RESULTS AND DISCUSSION

For all measuring sites annual average concentration values exceed proposed concentration range (12 to 20 μg/m³). Further, more than 25% of daily concentrations exceed the value of 35 μg/m³ (Table 1) which is much higher compared to the proposed value of 10%,. These results justify the importance of PM2.5 Zagreb network implementation.

Table 1. Statistical parameters of PM2.5 particle fraction concentrations during 2005 [μg/m^3]

Measuring site	West	Center	East	South	North
N	248	245	246	248	363
C_{avg}	**35,3**	**37,7**	**35,9**	**40,7**	**29,7**
Median	26,6	29,9	27,0	29,3	22,7
C_{25}	16,9	19,2	16,3	19,6	14,5
C_{75}	44,3	48,4	45,8	49,3	35,9
C_{98}	119,6	114,8	125,7	140,3	104,1
%	25	28	26	28	28

% - percentage of the days with PM2.5 concentrations values higher than the proposed concentration value of 35 μg/m^3.

Further, results show significant spatial distribution of the fine particles. The highest annual average concentration values are observed at southern part of town and in the centre of town. Reasons for that are street canyons in centre of the town and probably large, open-wide crossroad in the vicinity of the southern measuring site. The results, as it was expected, show the lowest annual average concentration value at northern, residential, part of the town.

Table 2 shows the same concentration spatial distribution for all seasons. Also, elevated fine particle concentration values were observed during the cold part of the year (autumn and winter). These results are expected because of the space heating and higher traffic density during this part of the year.

Table 2. Statistical parameters of PM2.5 particle fraction concentrations per seasons and per measuring sites during 2005 [μg/m^3]

Measuring site	West	Center	East	South	North
WINTER					
N	58	58	60	58	90
C_{avg}	**59,2**	**61,3**	**61,3**	**72,4**	**44,5**
Median	50,2	50,8	50,1	59,2	33,9
C_{25}	33,3	36,3	35,1	40,2	24,8
C_{75}	71,3	70,4	73,0	92,3	53,5
C_{98}	173,9	189,1	200,1	224,2	132,8
SPRING					
N	64	60	62	64	91
C_{avg}	**20,3**	**23,3**	**20,0**	**22,5**	**18,3**
Median	16,5	19,3	15,9	19,9	15,0
C_{25}	12,8	14,6	11,8	14,2	10,3
C_{75}	23,0	25,8	20,5	23,8	21,2
C_{98}	50,6	52,9	57,1	58,8	40,9
SUMMER					
N	64	65	63	65	93
C_{avg}	**19,5**	**22,3**	**18,8**	**22,4**	**18,4**
Median	18,5	21,3	18,0	21,2	16,4
C_{25}	13,6	15,9	12,8	16,1	11,7
C_{75}	24,1	27,5	25,7	27,4	22,7
C_{98}	34,7	41,7	34,2	42,6	43,2
AUTUMN					
N	62	62	61	61	89
C_{avg}	**44,7**	**45,9**	**44,9**	**49,3**	**38,4**
Median	41,9	43,6	43,2	46,0	33,6
C_{25}	31,2	31,8	30,2	31,3	23,5
C_{75}	56,3	57,1	54,3	62,1	49,3
C_{98}	79,3	75,5	84,9	113,1	83,4

Daily concentrations follow the same trend at each measured sites (Figure 1-5). Concentrations peaks are not locally caused. Higher concentration values during winter stable conditions were observed in the previous investigations (Bešlić, 2003). Weather conditions play significant role in Zagreb air pollution since Zagreb is situated between mountain at north and river at south. Stable weather conditions with high air pressure values during winter do not allow enough air mixing and cause pollution accumulation. Further, long range pollution transport probably causes simultaneous concentration peaks at each measuring site (Klaić, 1996). Concentration trends shown in figures 1-5 confirm previously observed seasonality.

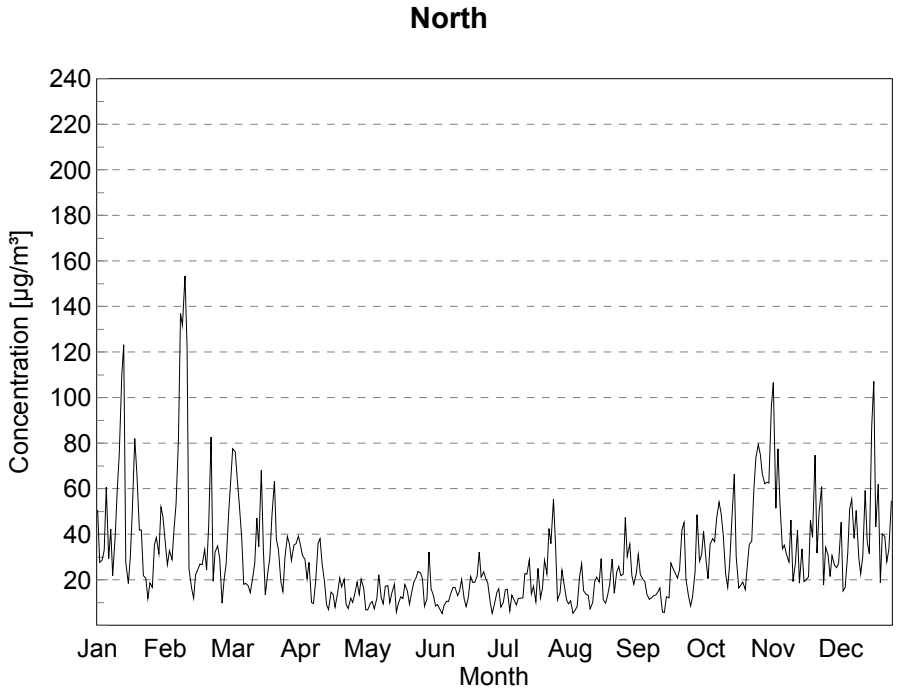

Figure 1. Trend of PM2.5 concentration at northern measuring site during 2005

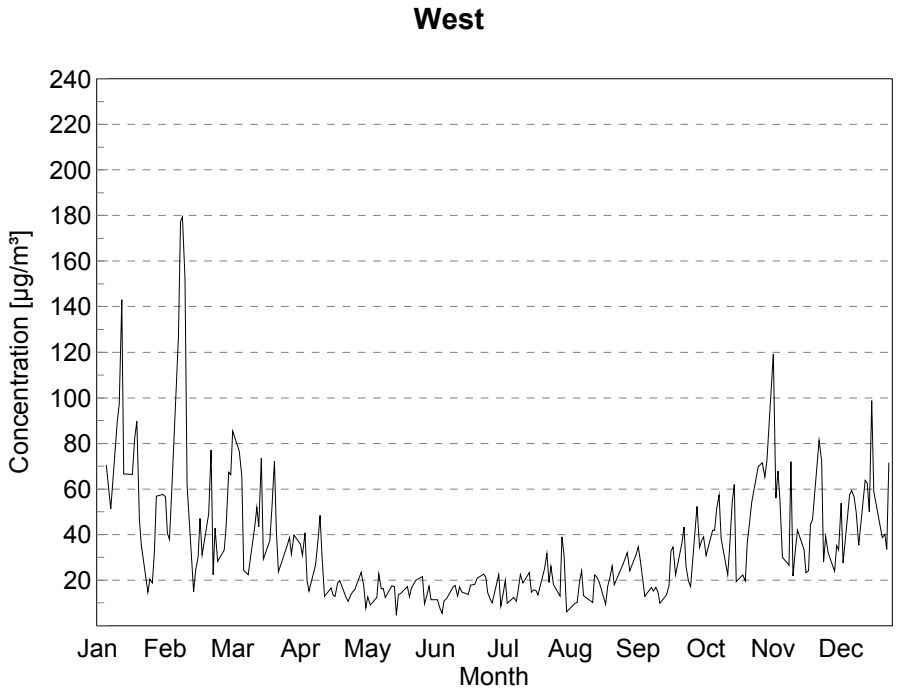

Figure 2. Trend of PM2.5 concentration at western measuring site during 2005

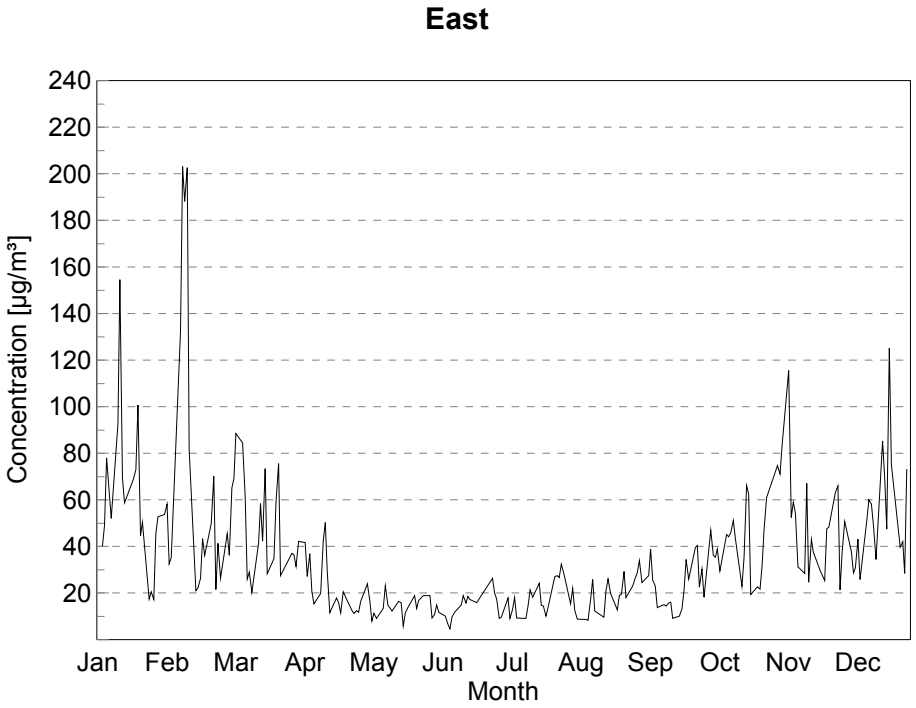

Figure 3. Trend of PM2.5 concentration at eastern measuring site during 2005

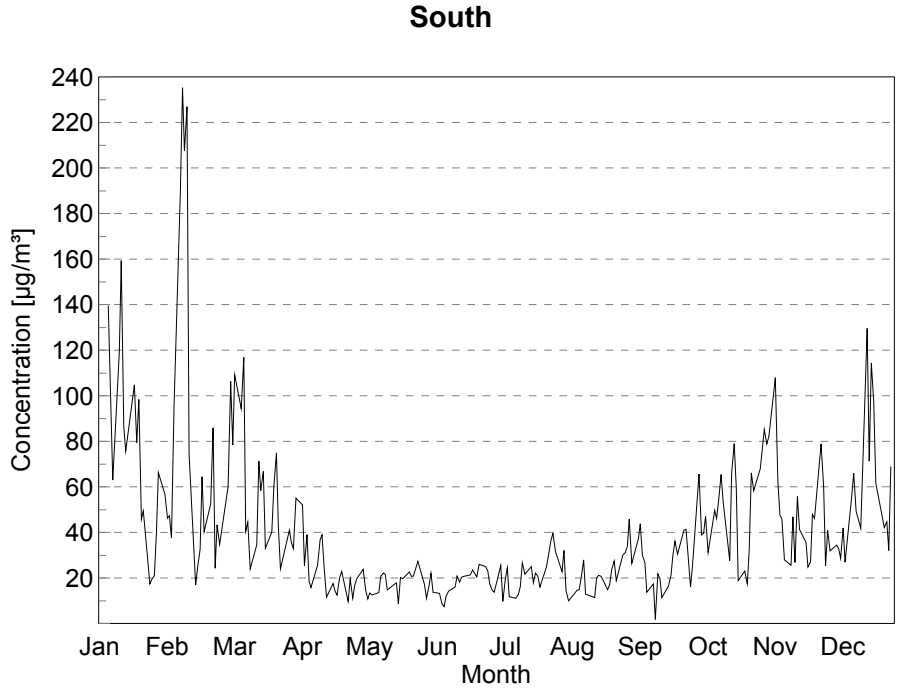

Figure 4. Trend of PM2.5 concentration at southern measuring site during 2005

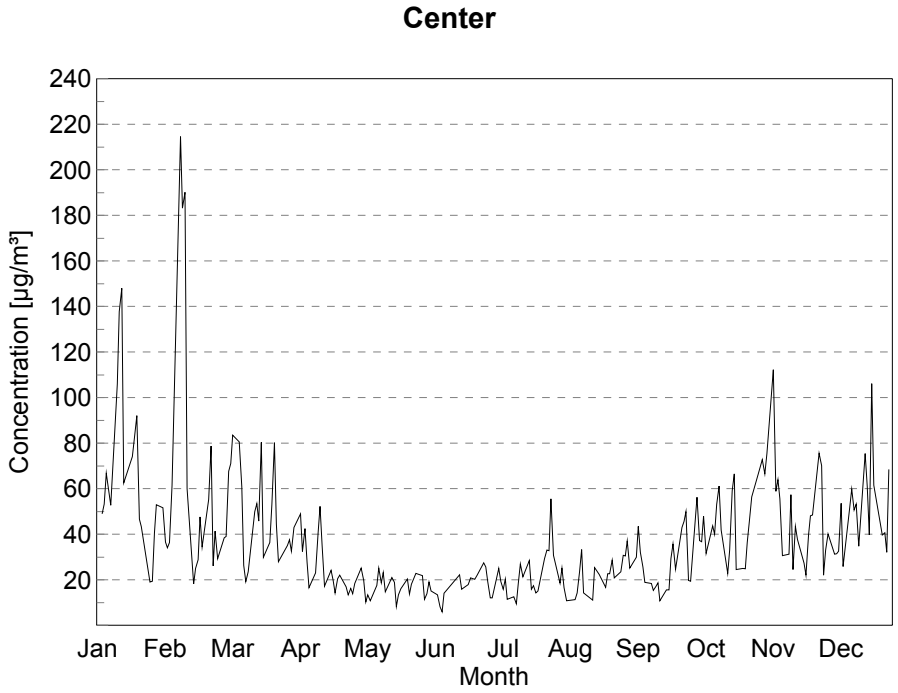

Figure 5. Trend of PM2.5 concentration at measuring site located in center during 2005

CONCLUSIONS

Investigation presented in this paper points out significant spatial and seasonal distribution of PM2.5 concentration in Zagreb air. Higher PM2.5 concentration values are expected in center of town characterized by dense traffic and street canyons, as well as at southern part of town characterized by dense traffic.

Further, higher PM2.5 concentration values are expected during cold season. This situation is the consequence of stable weather conditions with high air pressure, and intense space heating.

The main conclusion could be that Zagreb air is high polluted by fine particles. Annual average concentrations values are twice higher compared to the proposed concentration range (12 to 20 µg/m³). Further, more than 25% of daily concentrations at each measured site during 2005 were higher than the proposed value of 35 µg/m³. Further investigations will be focused on finding dominant fine particle pollution sources, as well as on expanding monitoring network.

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