

HORIZONTAL AND VERTICAL DISTRIBUTION OF PARTICULATE MATTERS IN DEPENDENCE ON TRAFFIC INTENSITY

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ABSTRACT

In the paper are presented partial results of the prescreening of particulate matters concentrations with aerodynamic diameters lower than 10 μm (PM_{10} and $\text{PM}_{2.5}$) in the air of locality impacted by the transport. The attention has been paid to influences of the vertical level measurement on the concentration and chemical composition of $\text{PM}_{2.5}$. There also are presented the partial results of horizontal differences in the cocentration of particulate matters in urban air. The Measurements have proceeded on the locality significantly burned by transport in spring and autumn 2004. Locality represents a typical street canyon neighbouring with marginal less heavily loaded roads. The statistically significant influences of the measurement conditions (humidity, temperature) on the acquired results are presented. In addition the content of selected inorganic pollutants sorbed to $\text{PM}_{2.5}$ was analysed. As for the measurement results of vertical distribution it is possible to note that the dependence of PM concentration on the locacion high levels of the sampling was not found. Also the differences in contents of measured pollutants depended to a location height level were not determined However the dependence on the air temperature and humidity was proved. The results of the 24-hours average contents of PM_{10} on the localities and their comparison with 24-hours average limit according to the Czech law 350/2002 (55 $\mu\text{g m}^{-3}$) shows that the highest pollution is in traffic peak and in the special cases the results are three-times higher than regulatory limit.

KEYWORDS: particulate matters, horizontal distribution, vertical distribution, transport, urban air pollution

1. INTRODUCTION

The traffic related emissions of particulate matters (PM) have probable negative impacts on human health, especially in cities with the high traffic intensity. The impact of their local concentrations and distance of residences from the main roads on the human mortality was proved (Künzli et al., 2000, Weijer et al., 2001, Adamec et al., 2004). The chronic exposition to their impact causes shortening of the expected life length due to heart and lung diseases. Recent studies refer also on possible development of lung cancer (Krzyzanowsky, 2005). The used LECKEL Medium Volume Sampler system can be fitted with a PM_{10} , $\text{PM}_{2.5}$ or $\text{PM}_{1.0}$ Inlet for size selection, as well as a TSP inlet for total suspended particles. The sampler operates as a single filter system and confirms to EU Directive 1999/30/EC and CEN standard EN 12341 for sampling of particulate matter for heavy metals analysis. The attention is paid to the share of individual fractions of particles and their chemical composition. Obtained information serves mainly for the finding of the actual emission situation and provide the main input information for the assessment of inhabitants exposition near roads. The measured data can be used for mathematical model of particles transport in the environment (Hirtl, 2005).

2. METHODOLOGY

Sampling

The street named "Kotlarska" (in Brno, Czech Republic) was selected as the sapling site. It is a relatively narrow street canyon ($H/W = 1.16$) with high vehicle flows (about 20 000 vehicles 24 hours⁻¹). Three samplers LECKEL MVS6, standard flow rate 2.3 $\text{Nm}^3 \text{hour}^{-1}$, (where the temperature = 273 K and the pressure = 1013 mbar are the standard conditions), were carried out using mixed cellulose filters (Millipore, porosity 1.2 μm , diameter 47mm) and located on the balcony floor (3 height levels) to find out the differences in $\text{PM}_{2.5}$ concentrations depending on the elevation. To detect the variations in the horizontal PM_{10}

concentrations, these samplers were located in four different positions along the main street and on the neighbouring streets. The conditions of the vertical level measurements and sample numbers are in the Table 1. The sampling period was generally 24 hours. To determine the horizontal variations, the one sampling period had duration one, two or six hours and after this that the filter was replaced. The traffic intensity was quantified in the same time period. The background measurement was done with two samplers in night hours. The meteorological conditions were not measured in the night.

Analyses

All filters were treated in the same way. Each filter was weighted after conditioning 48 hours with microbalance Mettler-Toledo MX5/A. The temperature and humidity were measured in one-minute intervals on the 5th floor during all sampling periods and their averages were calculated from acquired data. The filters were digested with mixture: 2 ml H₂O₂ + 3 ml HNO₃ + 1 ml HCl by means microwave digestion device with quartz glass vessels (working pressure 75 bar) Multiwave (Anton Paar), equipped with a combined pressure-temperature sensor accessory for reaction control. Determination of elements was carried out by inductively coupled plasma quadrupole mass spectrometry ICP-QMS (ELAN DRC plus, Perkin-Elmer).

Table 1: Sampling conditions during the PM_{2.5} measurements.

Sampling Date	Temperature [°C]	Relative Humidity [%]	Balcony – Floor No.	Sample No.
3.5.2004	18.9	53.1	2	1
			4	2
			6	3
10.5.2004	13.1	69.2	2	4
			4	5
			6	6
17.5.2004	15.1	59.2	2	7
			4	8
			6	9

3. RESULTS AND DISCUSSION

The results of the analyses of the PM_{2.5} and the contents of metals in the air at standard conditions are summarised in the Table 2.

Table 2: Concentrations of PM_{2.5} and metals in air.

Sample No.	PM _{2.5}	Cr	Mn	Co	Ni	Cu	Zn	Rb	Sr	Zr	Mo	Cd	Sn	Sb	Ba	Pb
	µg Nm ⁻³	Ng Nm ⁻³														
1	17.8	1.05	18.1	0.0496	1.00	6.79	58.9	0.323	0.526	0.221	0.518	0.252	1.92	1.67	3.07	13.5
2	19.4	1.25	20.8	0.0575	1.16	6.16	67.0	0.357	0.548	0.243	0.573	0.291	2.16	1.74	3.24	15.0
3	18.4	1.24	21.0	0.0510	1.46	5.88	66.2	0.354	0.559	0.329	0.535	0.282	2.11	1.71	4.26	15.4
4	25.9	15.3	65.2	0.167	1.91	23.9	277	0.535	0.593	0.964	2.16	1.01	2.74	5.46	7.78	59.7
5	28.5	16.8	70.3	0.159	1.80	20.4	288	0.464	0.418	0.801	2.03	1.09	2.74	4.79	6.97	61.7
6	25.1	16.6	68.1	0.150	2.08	19.0	284	0.469	0.432	0.694	1.92	1.10	2.50	4.36	6.46	61.7
7	21.6	3.33	6.85	0.0497	3.34	14.0	27.0	0.237	0.444	0.680	1.22	0.346	1.44	3.54	5.20	7.49
8	21.2	4.05	6.72	<LOQ	3.37	12.2	26.2	0.199	0.873	0.731	1.14	0.357	1.36	3.36	4.73	7.44
9	20.8	3.73	6.31	<LOQ	3.43	10.4	25.5	0.199	0.433	0.535	1.00	0.347	1.21	3.04	3.99	7.30

The contents of individual metals per a unit of PM_{2.5} are in the Table 3. The influences of temperature, humidity and the location of sampling points on the content of metals sorbed on PM are schematically shown in the table 4. The PM_{2.5} vertical dependency for three day of measurement is shown on Fig. 1. Because the statistically significant dependence of PM_{2.5} vertical distribution was not found, the influences of other conditions (relative humidity and air temperature) on the particles concentrations have been searched. As an example, the regression between relative humidity and PM_{2.5} concentration is shown on Fig. 2.

Table 3: Contents of metals in PM_{2.5}

Sample No.	Cr	Mn	Co	Ni	Cu	Zn	Rb	Sr	Zr	Mo	Cd	Sn	Sb	Ba	Pb
	ng mg ⁻¹ of PM _{2.5}														
1	58.9	1 010	2.78	55.9	381	3 310	18.1	29.5	12.4	29.1	14.2	108	93.9	172	755
2	64.2	1 070	2.96	59.7	317	3 450	18.4	28.2	12.5	29.5	15.0	111	89.3	167	772
3	67.4	1 140	2.77	79.4	319	3 600	19.3	30.4	17.9	29.1	15.3	115	92.7	232	835
4	592	2 520	6.46	73.9	922	10 700	20.7	22.9	37.2	83.3	39.0	106	211	301	2 310
5	588	2 460	5.57	63.3	716	10 100	16.3	14.6	28.1	71.2	38.2	96,0	168	244	2 160
6	662	2 720	5.97	83.1	757	11 300	18.7	17.2	27.7	76.6	44.0	100	174	258	2 460
7	154	317	2.30	155	646	1 250	11.0	20.6	31.5	56.5	16.0	66,5	164	241	347
8	191	316	<LOQ	159	574	1 240	9.39	41.1	34.4	53.8	16.8	63,9	158	223	350
9	180	304	<LOQ	165	500	1 230	9.58	20.8	25.7	47.9	16.7	58,3	146	192	351

Table 4: Schematic representation of humidity, temperature and vertical localization of samplers influence on regression coefficients. The symbol (+) represents positive regression, symbol (-) represents negative regression and (0) means statistically nonsignificant value of regression factor.

Parameter = A + (Balcony – Floor No.)*B + (Temperature)*C + (Humidity)*D, where B, C, D are regress coefficients and A is absolute

Parameter/	Cr	Mn	Co	Zn	Rb	Cd	Sn	Pb	Ni	Sb	Zr	Mo	Cu	Ba	Sr	Coefficient
Balcony - Floor No.	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	B
Temperature	+	+	+	+	+	+	+	+	-	-	-	0	0	0	0	C
Humidity	+	+	+	+	+	+	+	+	-	0	0	+	0	0	0	D

Fig. 1: Vertical distribution of PM_{2.5}.

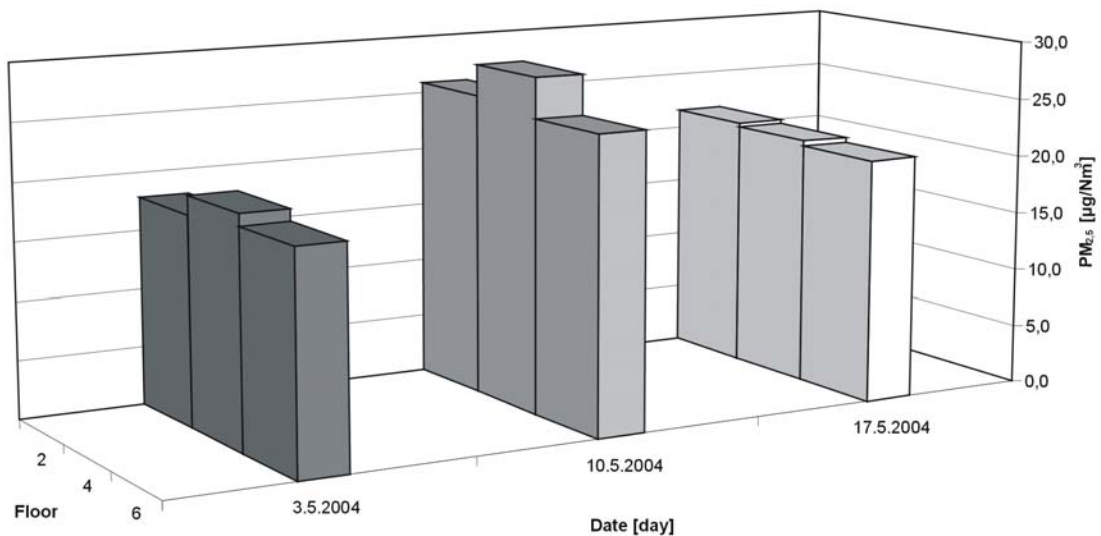


Fig. 2: Regression Curve for PM_{2.5} vs. relative humidity.

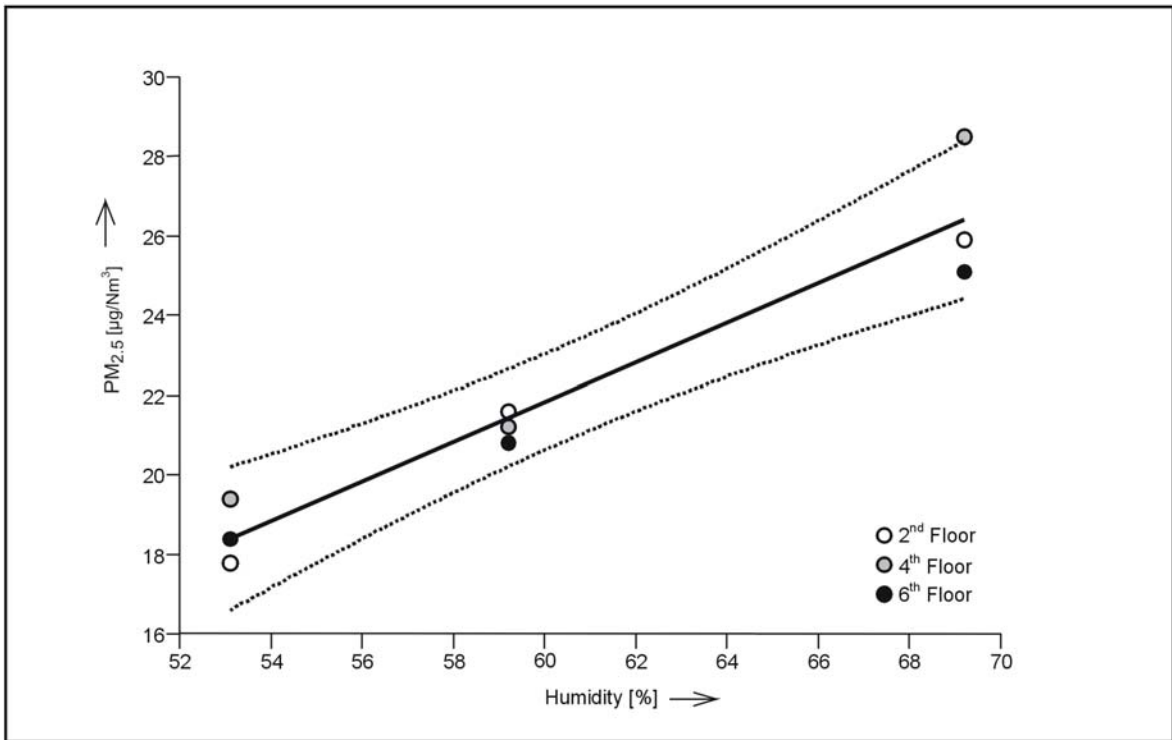


Fig. 3: Metals on PM_{2.5}.

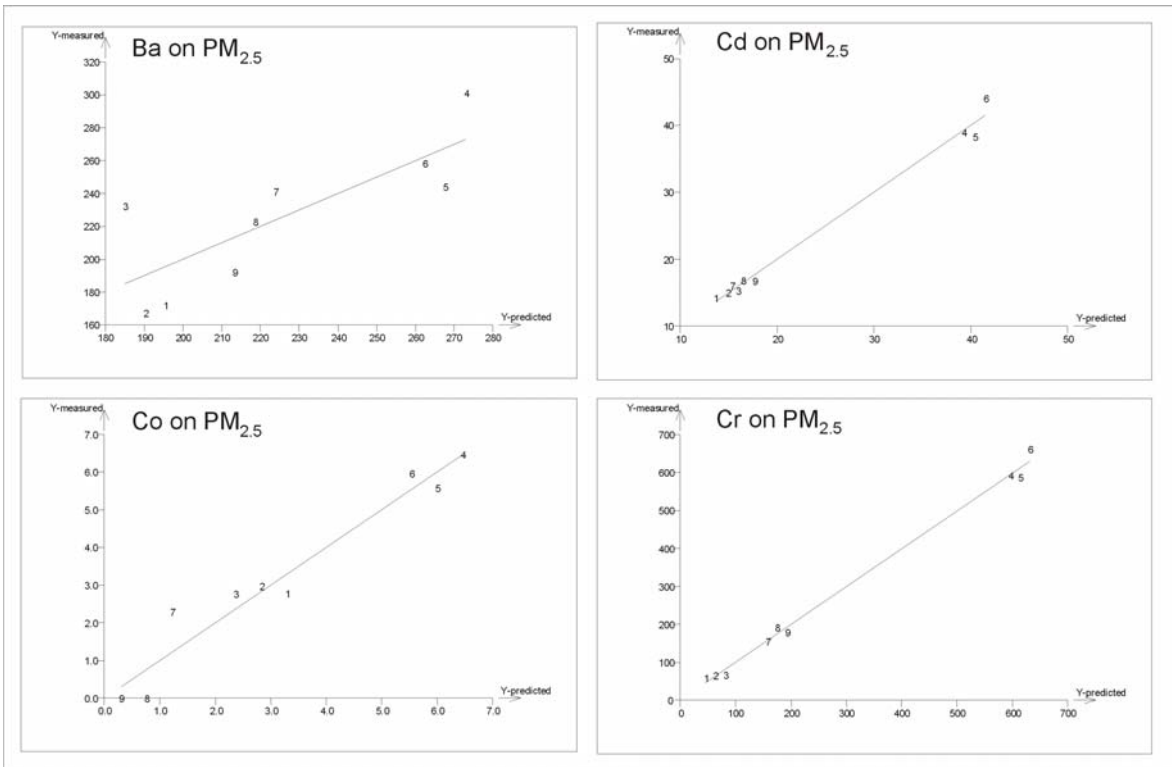


Fig.4: Metals on PM_{2.5}.

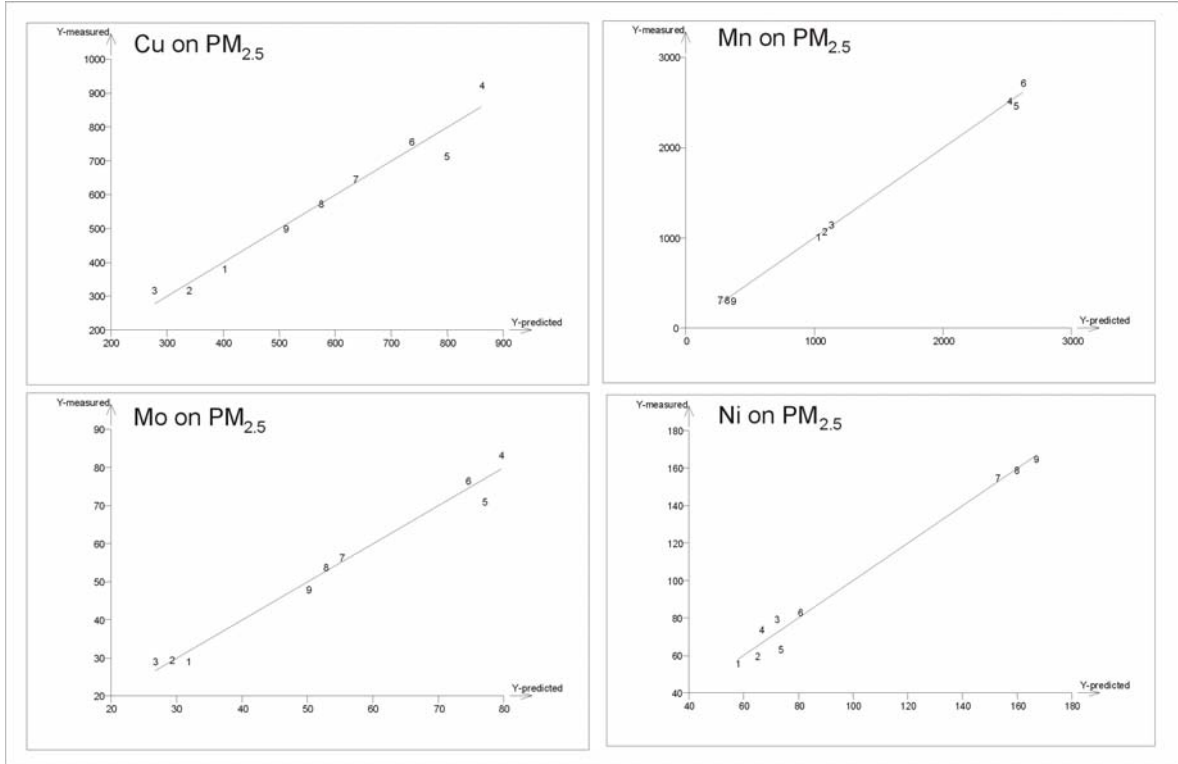


Fig. 5: Metals on PM_{2.5}.

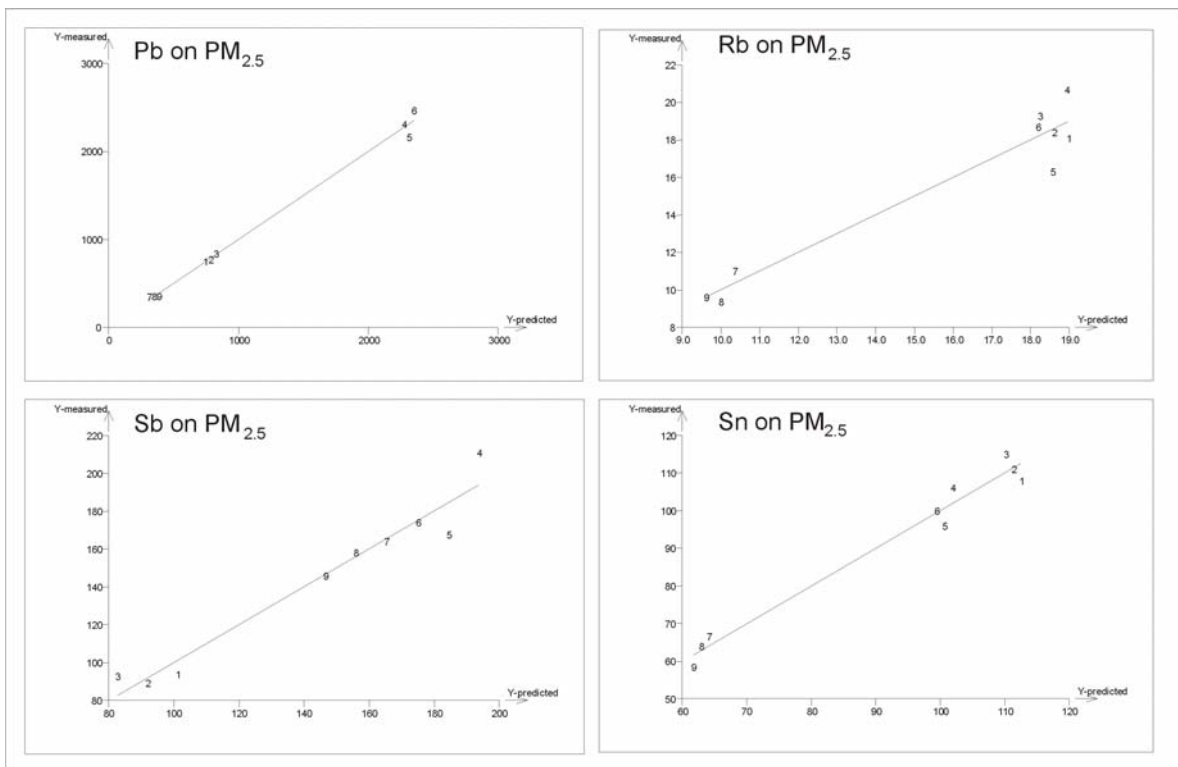
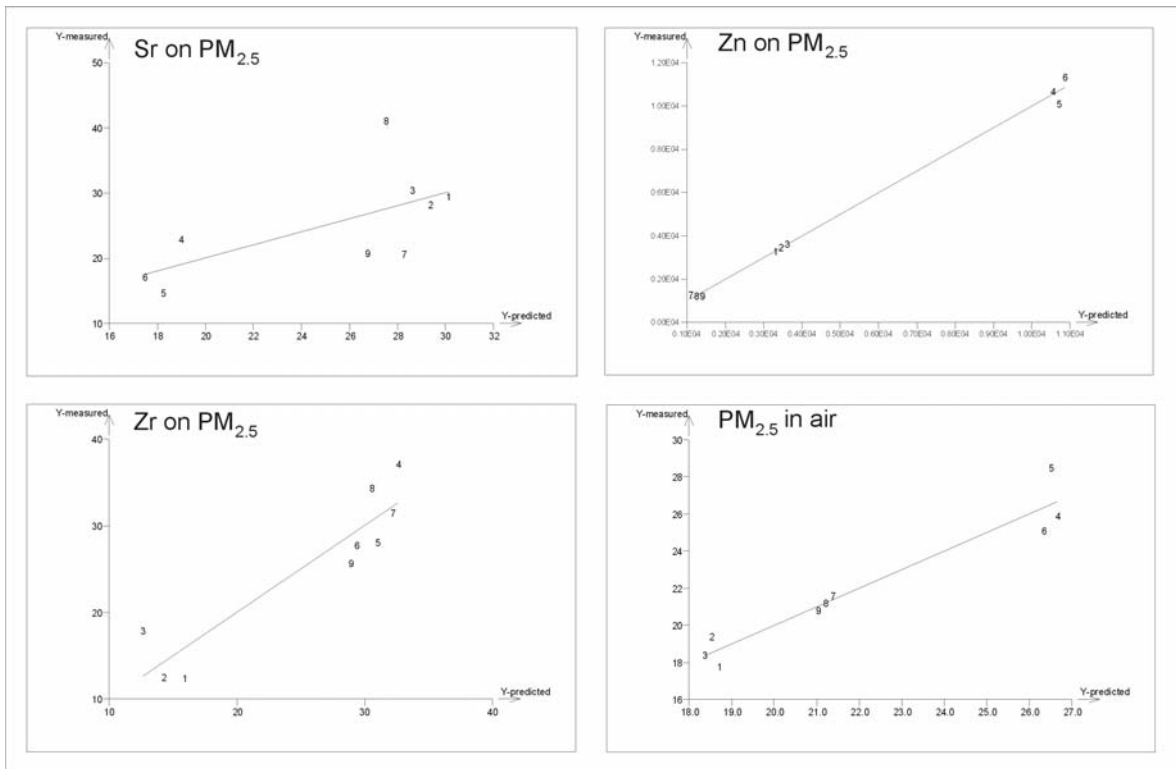


Fig. 6: Metals on PM_{2.5}.



The Cr, Mn, Co, Zn, Cd, Sn and Pb contents increased with the increasing temperature and humidity and the Ni content decreased in reverse. The Mo content increased only with the increasing humidity. The Cu, Ba, Zr and Sb contents decreased with the increasing temperature. The statistically significant dependence of Sr content was not proved neither on humidity nor temperature.

The PM₁₀ concentrations were measured in traffic peak and in “normal” traffic time (see Table 6) Hourly transport intensities are in the Table 5. Meteorological conditions were measured both on SAPLING localities (micro measures) and on Veveri OFFIC city meteo-station (macro measures). The results of measurements were used as input data for the modelling of horizontal particulates distributions, depending on traffic intensity, meteorological conditions including ventilate effects of cross roads. The obtained results (Fig. 7) can be used to assess the potential exposure of population in the cities near the busy roads and for evaluation mathematic model of transport of particulate matters in the city environment.

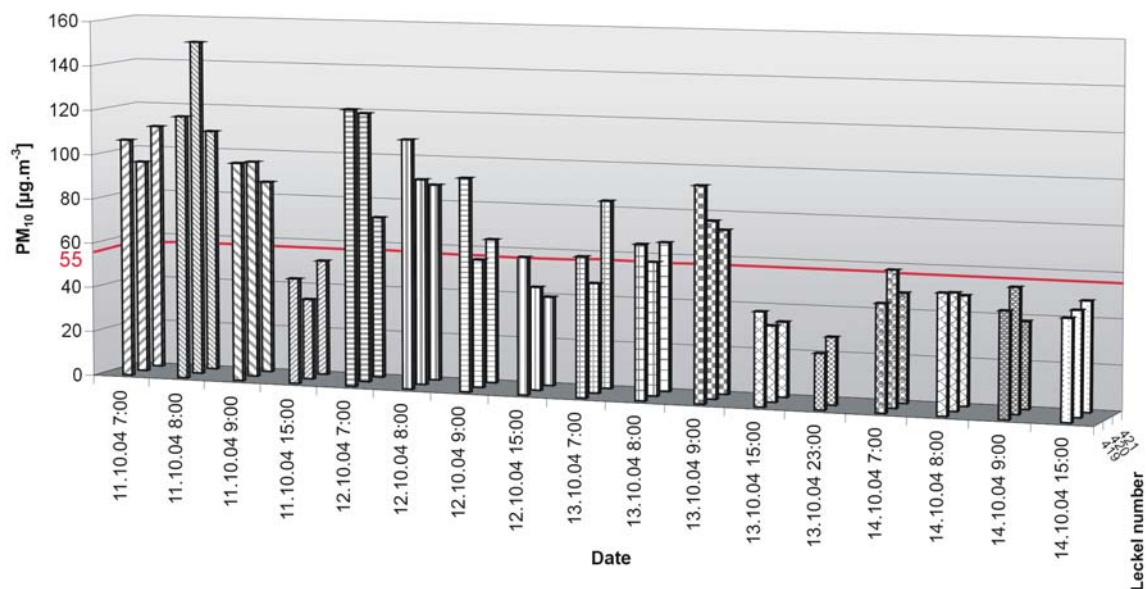
Table 5. Traffic intensity on the Kotlarska street for different categories of vehicles [vehicles amount h⁻¹]
 Description: LDV – Light Duty Vehicles, HDV – Heavy Duty Vehicles

Date	Time	Part of the Kotlarska street	LDVs	Trolleys	Buses	HDVs (old)	HDVs (new)	Motorcycles	Bicycles	Other
11.10.04	07:00 - 08:00	Tuckova - Botanicka	725	20	0	6	4	1	0	0
	08:00 - 09:00		708	16	5	8	6	2	2	0
	09:00 - 10:00		707	13	4	11	8	0	2	0
	15:00 - 17:00		879	17	3	4	4	5	3	0
	07:00 - 08:00	Botanicka - Tuckova	752	18	6	7	4	4	0	0
	08:00 - 09:00		760	16	4	9	8	0	0	0
	09:00 - 10:00		609	13	0	6	8	0	0	0
	15:00 - 17:00		630	15	0	3	3	2	0	1
12.10.04	07:00 - 08:00	Tuckova - Botanicka	752	19	2	8	13	2	0	0
	08:00 - 09:00		721	16	2	10	14	2	0	0
	09:00 - 10:00		672	13	3	12	9	2	0	0
	15:00 - 17:00		705	14	3	5	3	0	0	0
	07:00 - 08:00	Botanicka - Tuckova	758	21	8	12	6	5	3	0
	08:00 - 09:00		805	15	4	4	8	0	2	0
	09:00 - 10:00		666	13	4	7	6	5	0	0
	15:00 - 17:00		558	14	0	3	4	2	0	0
13.10.04	07:00 - 08:00	Tuckova - Botanicka	641	20	0	8	6	0	0	0
	08:00 - 09:00		691	15	4	6	7	0	0	0
	09:00 - 10:00		711	16	3	11	8	1	0	1
	15:00 - 17:00		842	14	2	5	1	1	1	0
	23:00 - 05:00		58	1	0	0	1	0	0	0
	07:00 - 08:00	Botanicka - Bayerova	597	20	0	8	5	0	0	0
	08:00 - 09:00		635	15	4	6	7	0	0	0
	09:00 - 10:00		656	16	3	9	8	1	0	1
	15:00 - 17:00		764	14	2	5	1	1	1	0
	23:00 - 05:00		55	1	0	0	1	0	0	0
	07:00 - 08:00	Bayerova - Botanicka	934	19	6	2	20	2	0	0
	08:00 - 09:00		955	21	4	3	19	2	0	0
	09:00 - 10:00		881	15	1	15	11	2	0	0
	15:00 - 17:00		837	15	1	4	18	2	4	0
	23:00 - 05:00		45	0	0	1	0	0	0	0
	07:00 - 08:00	Botanicka - Tuckova	770	19	6	2	11	2	0	0
	08:00 - 09:00		760	18	4	3	7	2	0	0
	09:00 - 10:00		716	12	1	15	3	2	0	0
15:00 - 17:00	637		15	1	4	5	2	4	0	
23:00 - 05:00	41		0	0	1	0	0	0	0	
14.10.04	07:00 - 08:00	Tuckova - Botanicka	734	16	4	7	0	0	0	0
	08:00 - 09:00		665	16	3	9	12	0	0	0
	09:00 - 10:00		606	15	2	7	8	5	0	0
	15:00 - 17:00		828	19	5	6	1	2	1	0
	07:00 - 08:00	Botanicka - Bayerova	658	16	4	6	0	0	0	0
	08:00 - 09:00		615	16	3	8	9	0	0	0
	09:00 - 10:00		545	15	2	5	5	5	0	0
	15:00 - 17:00		745	19	5	6	1	2	1	0
	07:00 - 08:00	Bayerova - Botanicka	860	20	6	9	10	3	1	0
	08:00 - 09:00		808	17	4	9	8	3	2	0
	09:00 - 10:00		741	12	0	17	3	0	1	2
	15:00 - 17:00		832	16	4	7	0	0	0	0
	07:00 - 08:00	Botanicka - Tuckova	684	20	6	8	7	3	1	0
	08:00 - 09:00		668	17	4	7	6	2	2	0
	09:00 - 10:00		573	12	0	16	1	0	1	2
	15:00 - 17:00		658	16	4	6	0	0	0	0

Table 6. The results of analyses of PM₁₀ contents and meteorological conditions
Description: H - humidity, T - temperature, P – pressure, n – not measurement

Start sampling	Sampling duration	T	H	Dew point	T	P	H	Wind speed	Solar radiation		PM ₁₀ [$\mu\text{g m}^{-3}$]		
Day hour	Hour	Locality			Veveri meteo - station			M_GS R	M_IGS R	Leckel number			
		°C	%	°C	°C	hPa	%	m s ⁻¹	W m ⁻²	kJ m ⁻²	419	420	421
11.10.04 07:00	1:00	4.1	79.8	0.9	2.5	981.7	88.3	2.32	27	19	106.5	95.2	110.0
11.10.04 08:00	1:00	51	76.7	1.3	4.3	981.3	82.3	2.58	171	146	117.9	150.2	108.6
11.10.04 09:00	1:00	6.2	73.7	1.9	7.2	981.2	70.8	1.54	222	246	97.8	97.0	86.4
11.10.04 15:00	2:00	18.1	22.5	-4.2	9.3	983.6	33.6	7.07	293	279	47.0	35.9	51.5
12.10.04 07:00	1:00	2.7	64.4	-2.9	1.2	989.4	71.3	3.86	30	22	123.5	120.4	72.2
12.10.04 08:00	1:00	4.7	56.1	-3.0	3.3	988.6	62.8	5.65	177	143	110.9	91.7	87.8
12.10.04 09:00	1:00	6.5	45.4	-4.0	5.7	989.0	47.3	6.68	330	281	94.8	57.0	64.3
12.10.04 15:00	2:00	12.5	40.3	-0.6	12.0	987.2	36.3	7.85	273	272	60.9	45.9	39.7
13.10.04 07:00	1:00	7.9	58.9	0.3	6.6	986.2	64.5	5.14	8	5	62.2	48.7	83.5
13.10.04 08:00	1:00	7.9	60.6	0.7	6.7	985.5	66.0	5.14	72	58	68.7	59.1	66.1
13.10.04 09:00	1:00	8.5	58.4	0.8	7.1	986.1	64.8	5.67	147	121	95.2	78.3	72.6
13.10.04 15:00	2:00	10.8	49.5	0.7	8.7	984.1	56.6	7.85	82	76	41.5	33.5	33.3
13.10.04 23:00	6:00	n	n	n	6.4	982.0	69.0	5.44	0	0	24.6	29.7	n
14.10.04 07:00	1:00	7.2	68.7	1.8	6.1	976.9	74.0	6.94	0	0	47.4	60.0	48.3
14.10.04 08:00	1:00	7.0	71.4	2.2	6.2	976.7	75.8	5.67	6	5	53.0	51.3	48.3
14.10.04 09:00	1:00	7.3	71.4	2.4	6.2	975.2	76.5	6.68	19	16	46.5	54.8	38.3
14.10.04 15:00	2:00	8.8	67.3	3.0	7.1	974.2	75.4	7.98	16	15	44.6	46.1	48.3

Figure 7. PM₁₀ concentrations and their comparison with the PM₁₀ imission limit for the year 2004.



4. CONCLUSIONS

The dependence between the PM_{2.5} content and monitored inorganic pollutants, related to the vertical distribution of samplers, was not found. The statistically significant influence of the relative air humidity on the PM concentration was proved. The air temperature and relative humidity had the statistically significant influences on the metals contents. PM₁₀ concentrations were significantly higher than Czech legislative limit ($55 \mu\text{g m}^{-3}$, law 350/2002) during the first two days of measurements. The highest transport intensities are in the mornings and as it was assumed PM₁₀ concentrations were highest in this time.

5. ACKNOWLEDGEMENTS

The study was supported by Czech Ministry of Education, Youth and Sport (Programme Kontakt, project “Analysis of Air Particulate Matter for the Assessment of the Influence of Traffic on Environment and Health”) and COST 633 “Particulate Matter: Properties Related to Health Effects” as a research project.

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