Urban Soil Contamination by Potentially Risk Elements

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Abstract: A high displacement of inhabitants into large towns, presence of industry, and constantly growing traffic have a high impact on the environment and considerable exposure of human health to environmental risks. Therefore, putting emphasis on the best environmental quality is necessary. In this work, the pollution level of urban parks was studied, the influence of the type of pollution source was analysed, and the effect of shading by trees was studied. The analyses were carried out on soil samples taken from thirteen parks in two towns of the Czech Republic, in Prague, a town considered to be mainly residential, and Ostrava, a predominantly industrial town (steel working plant). The sampling points were selected to cover the whole towns equally. In each park, two sampling points were chosen, the first one under trees, the second one in the open area. The sampling was done in the summer of 2006 in the depths of 0–10 and 10–20 cm. In addition to basic soil analyses performed by routine methods, potentially risk elements (Zn, Cd, Pb, Cu, and As) in cold 2M HNO_3 extract were determined. Differences between the sampling points shaded and not shaded by trees were evidenced, with higher concentrations of risk elements under trees. The element contents differed between both towns as well. Significantly higher values of lead (mean 86 mg/kg) and copper (mean 28 mg/kg) were found in Prague, as a traffic consequence, compared to Ostrava, where lead reached the mean of 41 mg/kg and copper of 18 mg/kg. Maximum permissible limits were exceeded in Ostrava parks especially with Cd, in Prague with Pb.

Keywords: contamination; risk elements; soil; urban park

Urban living is influenced to a large extent by the environment. The majority of inhabitants live in large towns and a high displacement of humans into them and their vicinity takes place. Large amounts of pollutants negatively influencing human health get into the environment this way. The pollutants enter the organism through food chain, inadvertent hand to mouth administration by children, or by inhaling (Kim & Fergusson 1993; Gutpa *et al.* 1996; Charlesworth *et al.* 2003; Imperato *et al.* 2003). Longer exposure to risk elements causes their accumulation in bones and organs, due to which the functions are disturbed, the nervous system is affected, tumour diseases develop (IPCS 1992, 1995; Li *et al*. 2001; Manta *et al*. 2002; Komarnicki 2005).

Aside from organic pollutants, human health is endangered by higher risk elements contents. Cadmium and lead are among the metals negatively affecting human health at the most. Chronopoulos *et al.* (1997) and Jonsson *et al.* (2002) consider just these two elements as highly hazardous. They assessed their contents in urban parks and sediment loads in an urban area. Bretzel and Calderisi (2006) dealt with a similar problem. In urban soils, i.e. also in parks, they monitored the contents of five risk elements. The highest amounts were found for Pb in the vicinity of roads.

Higher lead contents are often associated with traffic. Its concentrations are still very high although leaded gasoline is not used anymore. The reason for higher lead contents in soils is the low mobility of the metal and its stability. Current lead source is mainly pigment and battery production and ore processing (Sucharová & Suchara 1998; Jonsson

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et al. 2002; Bretzel & Calderisi 2006). Increased cadmium contents are largely linked to industry. Heavy metals contents in bryophyte in different parts of the Czech Republic were estimated by Sucharová and Suchara (1998). The assessed areas exhibited the highest Cd content in the north Moravian part of the Silesian black coal basin (called Black Triangle II territory), and the lowest one in some zones of north-western part of the Czech Republic (called Black Triangle I territory) and Krkonoše Mountains. The same trend was found for lead concentrations.

The objective of this study was to describe the soil pollution levels in several parks of two large towns in the Czech Republic and assess the risk of industrial and residential pollution. The comparison will be done between two depths (0–10, 10–20 cm) and localities covered by trees and those of opened areas.

MATERIAL AND METHODS

Risk elements in park soils were analysed in two towns of the Czech Republic, in Prague, the town situated in the centre of Bohemia, and in Ostrava located in the northeast part of the Czech Republic. Prague is considered to be mainly a residential town with traffic as the most significant source of pollution. Ostrava is an industrial town focused on metallurgy and steel production.

The sampling was done in thirteen urban parks of each town. The sampling points were chosen so as cover evenly the whole towns. In each park, two sampling sites were selected, the first one under trees, the second one in an open area. The sampling was carried out in June 2006 at two depths: 0–10 and 10–20 cm. The samples were air-dried, ground in a ceramic mortar, and sieved through 2 mm mesh. The basic soil analyses were done, i.e.: particle-size analysis by A. Casagrande; pH_{H_2O} and pH_{KCl} potentiometrically; organic carbon content (C_{ox}) by a modified oxidimetric Tyurin method; humus quality as the ratio of pyrophosphate soil extract absorbance at wavelengths 400 and 600 nm (A_{400}/A_{600}) (Pospíšil 1964, 1981; Podlešáková *et al.* 1992). The risk elements contents (Zn, Pb, Cd, Cu, As) in the soil were determined by extraction with cold 2M HNO_3 at the ratio soil: extractant 1:10 (w/v) (Zbíral *et al.* 2003) and afterwards determined by AAS method under standard conditions.

RESULTS AND DISCUSSION

Basic soil analyses

The texture of the soil samples was classified according to NRSC USDA (Němeček *et al.* 2001). In Prague and Ostrava parks sandy loam and loam soils predominated. To compare pH values between the depths, paired *t*-test was used at alpha 0.05. A difference was found between 0–10 and 10–20 cm depths ($P < 0.001$, $t = 5.14$), with a higher pH in the deeper layer. No significant difference was found between the obtained values under trees and in open areas. Humus quality indicator A_{400}/A_{600} ranged from 2.8 to 5.8. Paired *t*-test showed differences between 0–10 and 10–20 cm depths ($P < 0.001$, $t = 5.41$). Humus quality increased with the depth, while the amount of C_{ox} was higher in the top layer ($P = 0.01$, $t = 2.65$). The differences between the values obtained in covered and open areas were not significant. *t*-tests showed a statistically significant difference between C_{ox} contents in covered and opened areas at the 95% confidence level. Higher mean values were found in Prague parks.

Risk elements

The investigation of the risk elements proved differences between Prague and Ostrava in cadmium, copper, and lead concentrations. Based on statistical analysis, a higher content of Cd was found in Ostrava, while Pb and Cu dominated in Prague soils, (Figures 1–3). The results manifest the dominance of lead in the towns heavily influenced by traffic, automobiles being until 2001 one of the major sources of lead emitted in to the environment. A significant input of Pb into atmosphere and, consequently, into soils occurred in the past years in Prague, in Ostrava up to the present, via major sources of emissions (REZZO 1) due also to fossil fuels combustion. Although lead emission measured in years 2000–2009 in atmosphere was higher in Ostrava than in Prague the trend was opposite with the soils. It was therefore presumed that the key sources of lead prevailed in the past in Prague. The enhanced copper content in Prague soil can be again related to the intensive traffic, as Cu is a common part of car components (Alov *et al.* 2001). Cadmium is a typical pollutant found in the vicinity of smelting works or fossil fuels processing factories and it predominates in Ostrava soils. Enhanced Cd and Zn concentrations in Os-

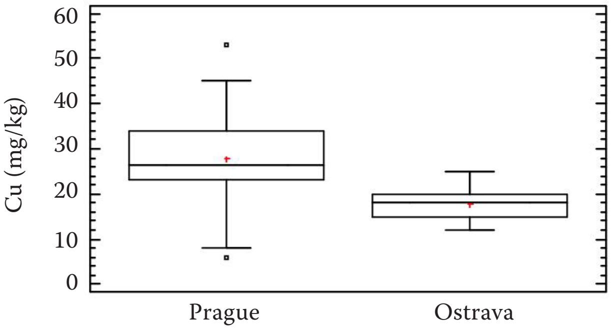

Figure 1. Copper concentration comparison between Prague and Ostrava soils (mg/kg) at the confidence level 95%

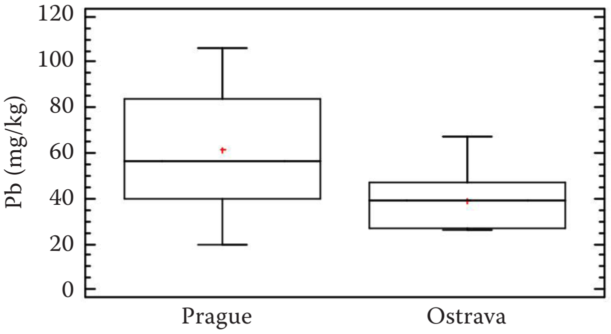

Figure 2. Lead concentration comparison between Prague and Ostrava soils (mg/kg) at the confidence level 95%

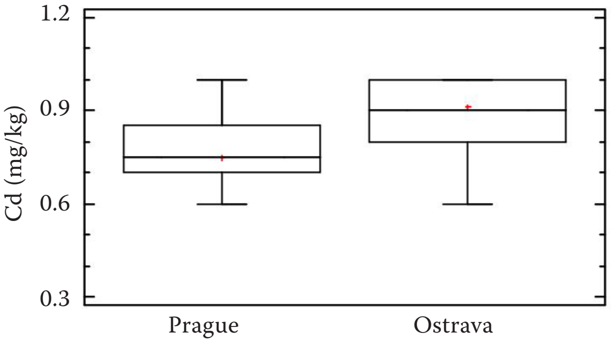

Figure 3. Cadmium concentration comparison between Prague and Ostrava soils (mg/kg) at the confidence level 95%

trava soils were also observed in 1990's by Smrček *et al.* (1993). They found out a higher pollution in agricultural soils, and especially in the soils closer to the city centre, where Vítkovice steelworks are situated. However, although As content was expected to be higher in Ostrava soils as a consequence of industrial activity, the mean values were comparable in the selected parks of both towns. Therefore, the origin of the element in Prague could be attributed to fossil fuels combustion in power plants in 1990's. The elements concentrations varied significantly in the towns between the individual parks. The most polluted park in Prague was the Karlovo náměstí, where the concentrations of Pb reached up to 96, Zn 94, Cd 1.0, As 5 and Cu 53 mg/kg in 0–10 cm depth. This fact reflected the very close presence of road and traffic lights. The trend towards higher concentrations of metals where stop-start manoeuvres are performed in the traffic such as at traffic lights, was also mentioned by Charlesworth *et al.* (2003). In Ostrava, parks Sad J. Jabůrkové and Husův Sad were considerably polluted. In the case of Husův Sad, high metals inputs were probably caused by traffic in addition to industry. High Zn, Cd, and Pb contents are, as Li *et al.* (2001) showed in their work, good indicators of contamination coming from gasoline and car components; this concerns especially Zn, which is used as a vulcanisation agent in vehicle tyres. The second mentioned park, Sad J. Jabůrkové, is situated in urban neighbourhood of old steelworks agglomeration. Significant quantities of Pb, As, Cd, Zn, and Fe were detected in industrial emissions in the area (Matýsek *et al.* 2008). In the case of Sad J. Jabůrkové, the highest concentrations were found in the 10–20 cm depth, with a decrease to the top layer. This could indicate the burying of the original material under a new layer. Diverse soil materials traced in the sampling confirmed the supposition.

The risk elements contents analysed in cold 2M HNO_3 were compared with the valid limits set by the regulation of the Ministry of Environment 13/1994 Coll for agricultural soils, because there are no reference or limit values set up for urban soils in the Czech Republic. The results are presented in Table 1. Maximum permissible limits were exceeded especially for lead in three Prague localities, namely the Královská obora, Kinského Sady and the Karlovo náměstí, and for cadmium in all Ostrava parks. Arsenic concentration exceeded the limits in both towns. Almost all of the samples studied exceeded the background values given by Němeček *et al.* (1995) which pointed out the anthropogenic impact.

The differences between the depths were not statistically confirmed. Paired *t*-tests showed statistically significant differences at the 95% confidence level between the samples taken in open areas and under trees for all tested elements. Higher elements concentrations measured in locations covered by trees can be explained by atmospheric deposition

Table 1. Risk elements contents extracted in cold 2M HNO_3 (mg/kg) in Prague and Ostrava parks

Locality	Depth (cm)	Open areas					Areas covered by hardwood stands				
		Zn	Cd	Cu	Pb	As	Zn	Cd	Cu	Pb	As
Prague parks											
Královská obora	0–10	90	0.7	37	81	17	76	1.0	33	77	30
	10–20	88	0.7	35	80	16	56	0.6	27	81	22
Obora Hvězda	0–10	21	0.6	8	23	4	20	0.3	7	28	4
	10–20	14	0.2	6	20	2	12	0.5	5	20	3
Kinského sady	0–10	63	0.8	32	86	10	63	0.9	33	108	12
	10–20	63	0.8	33	97	10	70	0.9	32	96	13
Střelecký ostrov	0–10	99	0.8	25	58	14	133	0.7	27	71	16
	10–20	111	0.8	28	62	5	97	0.7	25	61	11
Karlovo náměstí	0–10	94	1.0	53	96	5	119	1.0	62	90	5
	10–20	98	0.9	45	106	7	97	1.0	56	98	8
Park Družby	0–10	48	0.6	23	43	8	44	0.6	30	44	8
	10–20	47	0.7	24	45	16	42	0.7	29	51	20
Park Přátelství	0–10	46	1.0	23	37	7	45	1.0	18	33	4
	10–20	46	1.0	21	37	6	34	0.8	17	32	4
Malešický park	0–10	39	0.7	26	55	7	43	0.8	27	57	6
	10–20	35	0.7	27	54	7	36	0.7	28	51	7
Mean		63	0.8	28	61	9	62	0.8	29	62	11
Median		56	0.8	27	57	7	51	0.8	28	59	8
Order 13/1994 Coll.		100	1.0	50	70	4.5					
Background values		20	0.2	8	19	1.8					
Ostrava parks											
Husův sad	0–10	76	1.0	20	47	7	109	1.2	28	60	10
	10–20	64	1.0	20	44	6	105	1.2	28	66	10
Plzeňská	0–10	43	0.9	19	47	7	64	0.9	31	49	8
	10–20	52	0.8	21	45	7	85	1.1	36	45	9
Sad J. Jabůrkové	0–10	38	0.9	13	34	7	104	1.6	32	83	7
	10–20	71	1.3	25	67	13	88	1.3	26	80	12
Sad Míru	0–10	31	0.8	17	30	6	65	1.0	16	50	8
	10–20	28	0.9	15	27	6	58	1.0	17	74	7
Sad M. Gorkého	0–10	26	0.6	12	27	4	34	1.0	18	51	8
	10–20	27	0.9	15	26	5	27	0.8	17	48	7
Mean		46	0.9	18	39	7	74	1.1	25	61	9
Median		41	0.9	18	39	7	75	1.1	27	56	8
Order 13/1994 Coll.		100	1.0	50	70	4.5					
Background values		20	0.2	8	19	1.8					

interception and their subsequent washing by rain into the soil. The rate of interception depends, according to Augusto *et al.* (2002), on many factors. Is supposed to be higher with coniferous species due to their greater heights and leaf area index (LAI), as compared to hardwood stands. It is possible to assume that the divergence between the open areas and those covered by trees could be very distinct in Ostrava and Prague, as the sampling was done only under hardwood stands.

To examine the interrelations between the variables, the factor analysis was used. In this case, three factors were extracted (Figuer 4). Together they account for 79.3% of the total variability. The first factor with 39.5% of the total variability reflects the strong relationship between C_{ox} and Cu, Pb, As, and Zn. Borůvka and Drábek (2004) described a strong lead sorption in humus and its accumulation in the organic top layer of the soil profiles as a consequence. Copper is known to be bound by organic matter and to form stable complexes (Kabata-Pendias & Pendias 1992; Herawati *et al.* 1998). The second factor (27.6% of variability) showed a relationship between soil pH and humus quality. Indirect relationship between pH and A_{400}/A_{600} reflected pH decreasing with decreasing humus quality. You *et al.* (1999) pointed out in their study that at low pH values the prevailing compound is fulvic acid. The third factor (12.3% of variability) is the factor of clay and cadmium. Inverse relationship is expressed by Cd decrease with the clay increase. The fact could be explained by prevailing binding of the element in non clay fraction.

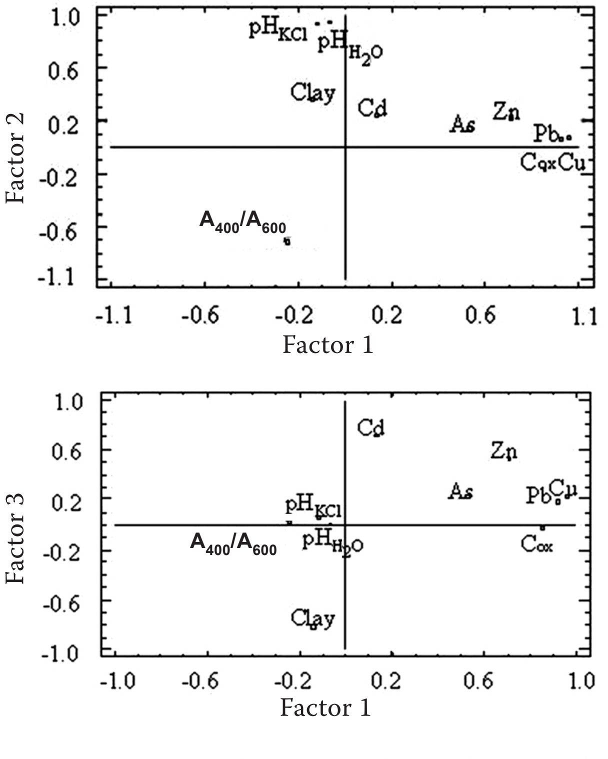

Figure 4. Factor analysis: interrelations between the variables

CONCLUSION

Risk elements monitoring in urban parks of two different towns of the Czech Republic proved their high contents in several parks. The most influenced were those situated in a close vicinity of roads, especially those equipped with traffic lights. The concentrations of the elements were enhanced in both towns, mainly those of Pb, As, and Cd. In the case of Cd, the highest values were found in industrial Ostrava in the samples taken from areas covered by trees. Statistical analysis confirmed significant differences between the samples taken in the open areas and the areas covered by trees. Higher concentrations were found in the locations covered by trees as a consequence of atmospheric deposition interception and subsequent washing by rain into the soil. A close relationship was found out between C_{ox} and risk elements (Cu, Zn and Pb) contents. Indirect relationship between pH and A_{400}/A_{600} was found. This reflects the fact that with decreasing pH A_{400}/A_{600} increases and humus quality decreases.

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