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Potential health risk assessment for soil heavy metal contamination in the central zone of Belgrade (Serbia)

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Abstract: An investigation of the soil quality in the centre of Belgrade was performed to define how seriously the soil is polluted. On the basis of the heavy metal content (Zn, Cd, Pb, Co, Ni, Cu, Cr and Mn), the potential health risk assessment calculated for a lifetime of exposure (ingestion and inhalation), based on the USEPA model, was determined as the cumulative carcinogenic and non-carcinogenic risk for children and adults. The study proved that soil contamination in Belgrade is not insignificant; risk assessment indicated that the carcinogenic risk is completely insignificant but the cumulative non-carcinogenic risk tends to became significant, mainly for children, since it approaches unacceptable values. There is no particularly dangerous single heavy metal, but their cumulative effect, expressed as Child Soil Ingestion Hazardous Index, is for concern.

Keywords: health risk assessment; soil pollution; heavy metals; Belgrade.

INTRODUCTION

The city of Belgrade, capital of Serbia, is a conglomeration of 17 municipalities, 10 of which belong to the inner and 7 to the greater area. The latter have suburban and rural features. Belgrade is situated in South–Eastern Europe, on the Balkan Peninsula. It is located on the confluence of two rivers, the Danube and the Sava. They surround the city on three sides. The city has the coordinates $44^{o}49'14''$ of the northern geographical latitude and $20^{o}27'44''$of the eastern geographical longitude. Its height above sea level is 116.75 m, with the highest point within the city 248.6 m and the lowest 75.3 m above sea level. Belgrade has a circumference of 427 km, an area of 322,268 ha and a total population of 1,602,226 inhabitants.

The investigation of the soil quality in the centre of Belgrade had a special goal, *i.e.*, to define how seriously the soil is polluted and to determine its poten-

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tial health risk as a cumulative carcinogenic and non-carcinogenic risk for children and adults.

The whole procedure was based on the sampling of soil in the central (urban) area of Belgrade, its investigation by atomic absorption spectroscopy on heavy metals, *i.e.*, Zn, Cd, Pb, Co, Ni, Cu, Cr and Mn, and the calculation of potential health risk on the basis of the US Environmental Protection Agency health risk assessment model.[1]

EXPERIMENTAL

Sampling sites

The surface soil samples (0–5 cm) were collected at 16 locations near major and minor roads and 4 samples from park areas (Fig. 1).

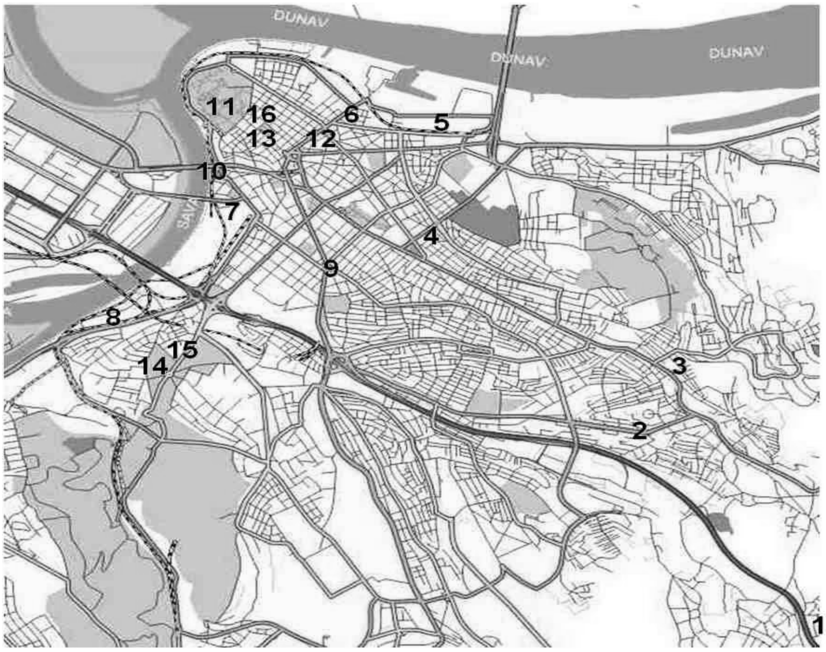

Fig. 1. Belgrade sampling sites: 1. pay toll ramp at the highway to Niš, 2. Ustanička Street, 3. Milana Rakića Street, 4. Ruzveltova Street, 5. Dunav Railway Station, 6. Francuska Street, lower, 7. Intercity bus station, 8. Belgrade Fair, 9. Slavija Square, 10. Brankov Bridge, 11. Kalemegdan Park, 12. Francuska Street, upper, 13. Student Park, 14. Park near Vojvode Putnika, 15. Boulevard Vojvode Putnika and 16. Rige od Fere Street.

Methods

Metal extraction was performed in several steps (sequential extraction procedure)[2] and the obtained sum of each metal were taken as the final concentration of the available metal from the soil.

Metal determination in the extracts was performed by atomic absorption spectroscopy, using a "Perkin Elmer 2380" instrument.

Health risk assessment

Health risk assessment models were developed basically in Europe[3] and in the United States.[1,4] The European model is still under development and is not as straightforward as the American model. Therefore, it was decided to apply the American model developed by USEPA. This model has been developed in all details and is fully available through Risk Assessment Information System (RAIS) (http://rais.ornl.gov/) and is supported by the Toxicological profiles developed and gathered by the USEPA Integrated Risk Information System (IRIS) (http://cfpub.epa.gov/ncea/iris/index.cfm) and by the US Agency for Toxic Substances and Disease Registry – Toxicological profiles (ATSDR) (http://www.atsdr.cdc.gov/toxfaq.html).

The risk assessment is a multi-step procedure that comprise (1) data collection (gathering and analyzing the site data relevant to human health), (2) exposure assessment (estimation of the magnitude of actual and/or potential human exposures), (3) toxicity assessment (determination of adverse health effects associated with exposure to different chemicals) and (4) risk characterization (summarizes and combines the outputs of the calculations of exposure and toxicity assessments).[5]

In the present case, Cd, Cr, Co, Cu, Pb, Mn, Ni and Zn were identified as potential hazardous agents in the soil at different locations in Belgrade which are relevant to human health (Fig. 1).

In the case of exposure assessment, a specific approach characteristic for human exposure to soil in residential urban areas was applied, taking particularly care of the different exposure rates for children and adults[6] (usually expressed as exposure factors, USEPA). In addition, the magnitude of exposure and, consequently, the intake or dose (consumed or inhaled amount) of contaminated soil is almost always different for different individuals. Therefore, a very useful and valuable approximation was made, *i.e.*, the risk was calculated for the lifetime exposure, the total exposure to a substance that a human would receive in a lifetime – usually assumed to be 70 years. All other parameter that may be site characteristic were taken to be constant through the whole calculating procedure for all elements and all sites, since their importance becomes less significant in case of the lifetime exposure approximation.

RESULTS AND DISCUSSION

Total contents of heavy metals in the soil of Belgrade are presented in Table I. Most of the data does not need further comments but additional argumentation is required in the case of Cr. The presence of Cr(VI) in natural environments requires a rather high redox potential, over 700 mV for a pH of around 5.0, but a redox potential of 400 mV for pH 7.0 to 8.0 is sufficient for Cr(VI) to dominate in the system.[7] The redox potential in soil usually varies from a minimum of –550 to maximum of 700 mV, but aerated soil most frequently has a redox potential up to 400 mV.[8] Therefore, it is assumed that Cr(VI) in the streets of Belgrade was the dominating chromium species since the measured soil pH was around 7.8.[9]

Plain data on the metal content of soil is sometimes insufficient to describe the full risk that arises from the exposure of humans, both children and adults, to different heavy metals from soil, particularly in the case when more details on human health risk are required.

Following the toxicological profiles of all the investigated elements,[10–12] it can be seen that most of the heavy metals have adverse health effects on humans, so-called toxicological effects, but some of the metals are additionally carcinogenic. For example, the investigated Co, Cr and Cd, induce both non-carcinogenic and carcinogenic risk, while Zn, Ni, Mn and Cu (Table II) induce only non-carcinogenic risk. Lead is a specific element, since there are no published data for this metal yet which are relevant for risk assessment calculations, although there is no doubt that Pb is a toxic element. A comprehensive and up-to-date literature overview on lead toxicity is collected in the ATSDR toxicological profile for lead.[13] Even so the available evidence is considered to be inadequate to contradict or demonstrate any potential carcinogenicity from lead exposure for humans.

TABLE I. Total content of heavy metals in the soil of Belgrade (mg/kg)

Sampling site	Cd	Cr	Co	Cu	Pb	Mn	Ni	Zn
Pay toll ramp at highway to Niš (1)	13.41	159.96	38.91	48.61	148.79	644.50	360.95	272.50
Ustanička Street (2)	17.75	59.21	34.20	88.65	443.80	658.70	115.66	259.25
Milana Rakića Street (3)	10.18	43.15	22.70	65.90	635.07	409.71	89.95	200.13
Ruzveltova Street (4)	9.64	65.82	15.24	314.80	321.54	393.82	57.65	247.69
Dunav Railway station (5)	5.18	81.99	12.03	101.54	204.76	422.70	119.66	358.43
Francuska Street lower (6)	9.06	55.92	13.33	56.41	51.35	845.63	107.17	132.63
Intercity bus station (7)	7.79	66.83	28.24	60.09	85.10	810.42	85.83	140.41
Belgrade Fair (8)	9.75	56.81	26.25	79.85	262.22	537.55	97.66	216.95
Slavija Square (9)	11.30	71.65	18.57	255.19	243.58	666.63	106.04	296.18
Brankov Bridge (10)	7.76	57.67	18.45	119.87	285.80	413.16	211.36	734.16
Kalemegdan Park (11)	9.12	49.65	22.41	90.95	262.94	787.57	109.14	201.58
Francuska Street upper (12)	5.22	67.39	28.83	131.68	180.78	667.61	119.83	309.25
Student Park (13)	5.34	59.58	27.12	107.32	180.03	763.57	108.71	192.34
Park near Vojvode Putnika (14)	8.60	64.08	34.22	118.63	46.51	1020.08	84.06	195.11
Boulevard Vojvode Putnika (15)	4.01	92.91	27.45	134.95	1847.64	561.62	84.56	260.51
Rige od Fere Street (16)	8.32	71.01	41.57	182.26	401.06	665.52	120.42	276.72
Minimum concentration	4.01	43.15	12.03	48.61	46.51	393.82	57.65	132.63
Maximum concentration	17.75	159.96	41.57	314.80	1847.64	1020.08	360.95	734.16
Median concentration	8.83	64.95	26.69	104.43	252.90	662.11	107.94	253.47
Geometric mean	8.32	66.95	24.08	106.69	230.83	617.74	112.24	246.51
Arithmetic mean	8.90	70.23	25.59	122.29	350.06	641.80	123.67	268.37

Exposure of humans to soil actually is through dust exposure that comprises inhalation and/or oral exposure (ingestion). For such exposition, the most recent EPA guidance recommends daily rates of 200 mg/day for children and 100 mg/day for adults.[6,14]

Risk characterization relevant for the present investigation comprises calculations of carcinogenic and non-carcinogenic risk for ingestion and inhalation of soil. Sometimes dermal exposure to soil is included as well, but since these risks are about 100 times smaller then the risk that arises from ingestion and inhalation, it was omitted here.

TABLE II. Some toxicological characteristics of the investigated elements[10,12]

Characteristic	Cd	Cr	Co	Cu	Pb	Mn	Ni	Zn
Minimal risk level (*MRL*)[a] oral (mg/kg/day)	0.0002		0.01	0.01		?		
Minimal risk level (*MRL*) inhalation (mg/m^3)		0.00004	0.0001				0.00004	0.0002
RAIS oral chronic reference dose (mg/kg/day) (*RfD*)	0.001	0.003	0.02	0.04	0.3	0.046	0.14	0.02
RAIS dermal chronic reference dose (mg/kg/day)	0.00001	0.0075	0.016	0.012		0.04	0.0056	0.0054
Cancer EPA weight-of-evidence classification[b]	B1	Cr(VI)A Cr(III) D	B2 (B1?)	D	B2	B2	B2	B2
Inhalation Unit Risk[c] (mg/m^3)$^{-1}$	1.8	1.2	2.8			?		0.48

[a]Minimal risk level (MRL): an estimate of the daily human exposure to a hazardous substance that is likely to be without an appreciable risk of adverse non-cancer health effects over a specified route and duration of exposure; [b]cancer EPA weight-of-evidence classification: A – human carcinogen, B1 – probable human carcinogen, B2 – probable human carcinogen, C – possible human carcinogen, D – not classifiable as to human carcinogenicity, E – good evidence for absence of carcinogenicity; [c]Unit risk: excess lifetime cancer risk per unit concentration of the substance in the medium where human contact occurs (1 μg/l in water or 1 μg/m^3 in air), usually expressed in units of proportion (of a population).

Basic formulas and values used for the calculation of ingestion and inhalation of soil are presented in Table III.

TABLE III. Calculation of carcinogenic and non-carcinogenic risk for ingestion and inhalation of soil[1,15]

CDI, chronic daily intake for carcinogenic risk (ingestion of soil)

Carcinogenic: $CDI\ (\text{mg/kg/day}) = CS \times IF \times EF / AT$,

$$\text{where } IF = \frac{IR_{\text{Adult}} \times ED_{\text{Adult}}}{BW_{\text{Adult}}} + \frac{IR_{\text{Child}} \times ED_{\text{Child}}}{BW_{\text{Child}}}$$

Non-carcinogenic: $CDI\ (\text{mg/kg/day}) = CS \times IN \times EF \times ED / BW \times AT$

CDI, chronic daily intake (inhalation of soil dust) for carcinogenic and non-carcinogenic risk

$$CDI(\text{mg/m}^3) = \frac{CS \times IF \times EF(\frac{1}{PEF} + \frac{1}{VF})(ET_{\text{Outdoor}} + (ET_{\text{Indoor}} DF_{\text{Indoor}}))}{AT}$$

Variable	Value used
AT – averaging time for non-carcinogens	365 days/year/$ED_{\text{Chhild or adult}}$
AT – averaging time for carcinogens	365 days/year/70 years
BW_{Adult} – body weight adult	70 kg
BW_{Child} – body weight child	15 kg
CS – concentration in soil or sediment	Chemical specific (mg/kg)
EF – exposure frequency	350 days/year
ET_{Indoor} = Exposure time indoor	0.683
ET_{Outdoor} = Exposure time outdoor	0.073
DF – dilution factor indoor	0.4

TABLE III. Continued

Variable	Value used
IN – inhalation rate	20 m^3/day
PEF – particulate emission factor, climate specific[15]	m^3/kg
VF – volatilization factor, chemical specific[15]	m^3/kg
IF – intake factor	–
IR_{Adult} – ingestion rate adult	0.0001 kg/day
IR_{Child} – ingestion rate child	0.0002 kg/day
ED_{Child} – exposure duration child	6 years
ED_{Adult} – exposure duration adult	24 years (for general case: 30 years)

For carcinogens, the risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. The basic equation for calculating the excess lifetime cancer risk is:

$$\text{Risk} = CDI \times SF \quad (1)$$

where "Risk" is a unitless probability of an individual developing cancer over a lifetime; *CDI* is the chronic daily intake or dose (mg/kg/day); *SF* is the slope factor, expressed in $(\text{mg/kg/day})^{-1}$. It converts the estimated daily intake averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer.

The basic equation for calculating systemic toxicity or non-carcinogenic hazard for a single substance/element is expressed as the hazard quotient:

$$\text{Non-cancer hazard quotient} = CDI/RfD \quad (2)$$

where the non-cancer hazard quotient is a unitless number that is not expressed as the probability of an individual suffering an adverse effect. As a rule, the greater is the value of *CDI*/*RfD* above unity, the greater is the level of concern, since *CDI* is greater than *RfD*. It is also the ratio of a single substance exposure level over a specified time period to a reference dose for that substance derived from a similar exposure period. *CDI* is the chronic daily intake of a toxicant expressed in mg/kg/day and *RfD* is the chronic reference dose for the toxicant expressed in mg/kg/day. It is a mg/kg/day of the daily exposure level for the human population, including sensitive subpopulations, which is likely to be without an appreciable risk of deleterious effects during a lifetime.

All risks are cumulative, hence it is possible to calculate the cumulative cancer risk expressed as the total cancer risk, or non-carcinogenic hazard expressed as the hazard index.

The cancer risk equation which describes estimates of incremental individual lifetime cancer risk for the simultaneous exposure to several carcinogens is as follows:

$$\text{Total cancer risk} = \sum_{k=1}^{n} CDI_k SF_k \quad (3)$$

where CDI_k is the chronic daily intake or dose (mg/kg/day) for substance k, SF_k is the slope factor, expressed in $(\text{mg/kg/day})^{-1}$, for substance k and $CDI_k \times SF_k$ is the risk estimate for the k^{th} substance.

For each chronic non-carcinogenic exposure, the separate chronic hazard index (*HI*) should first be calculated from the ratios of the chronic daily intake (*CDI*) to the chronic reference dose (*RfD*) for the individual chemicals and then the obtained results summed as described in the equation:

$$\text{Chronic hazard index} = \sum_{k=1}^{n} CDI_k / RfD_k \tag{4}$$

where the hazard index is a unitless number that is not expressed as the probability of an individual* suffering an adverse effect. As a rule, the greater is the value of E/RfD above unity, the greater is the level of concern. It is the sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways, CDI_k is the chronic daily intake of the k^{th} toxicant in mg mg/kg/day and RfD_k is the chronic reference dose for the k^{th} toxicant in mg/kg/day.

By incorporation of the obtained measured data (Table I) into the above described formulas (Table III), values for the non-carcinogenic hazard index and carcinogenic lifetime risk for individual elements, the cumulative risk for different exposure pathways for individual elements and the cumulative risk for all elements were obtained (Table IV).

The investigations show that the measured soil concentrations of all the investigated element generates no significant carcinogenic lifetime risk due to ingestion and/or inhalation of soil. No matter how small the probability is, a carcinogenic risk exists and varies from the maximum value of 2×10^{-7} in case of Cr(VI) to the minimum value of 7×10^{-10} for Cd (Table IV). According to data obtained from Belgrade Public Health Institute,[16] the real cancer occurrence in Belgrade for 2006 was around 4×10^{-3}. This is a very high value in comparison to the results obtained in this study. Hence, the risk that evolves due to exposure to heavy metals in soil contributes so little to the total cancer risks that it is completely insignificant.

On the other hand, the non-carcinogenic risk, expressed as the hazardous index, is not so benevolent; the cumulative index is close to one or even exceeds that value, particularly in cases of the exposure of children (Table IV). Generally speaking, the hazardous index (*HI*) for the ingestion of soil by children is some

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* Simultaneous exposures to several chemicals could result in an adverse health effect. The magnitude of the adverse effect will be proportional to the sum of the ratios of the subthreshold exposures to acceptable exposures. While any single chemical with an exposure level greater than the toxicity value will cause the hazard index to exceed unity, for multiple chemical exposures, the hazard index can also exceed unity even if no single hazard quotient exceeds unit.[1]

10 times greater in comparison to the corresponding results obtained for adults. From the point of view of *HI*, there is no particularly dangerous single heavy metal, but their cumulative effect is for concern (Table IV), since the cumulative risk for the median values was 0.7 and cumulative risk for the maximum values was 1.6. This is an alarming value for toxicologists since it indicates that the heath of children is endangered, but what kind of health effects could evolve from cumulative effects of heavy metals in soil and their influence on children was not the in the scope of this investigation.

For cadmium, the most serious chronic effect of oral exposure is renal toxicity. Renal *NOAEL** for Cd is 0.0021 mg/kg/day.[17] *MRL* for Cd is 0.0002 mg/kg/day (Table II). Since the minimum calculated value of the non-carcinogenic *CDI* for Cd for child ingestion of soil is 0.0002 mg/kg/day and that for the median value 0.0001 mg/kg/day, it could be concluded that there is no potential non-carcinogenic risk that could be eventually caused by Cd for children who are exposed to soil dust on the streets of Belgrade.

Chromium risk analysis predicts that the current occupational standards for hexavalent chromium permit a lifetime excess risk of dying of lung cancer that exceeds 1 in 10 for Cr concentrations in air of 1 mg/m^3.[18] The calculated risk in the case of Belgrade soil and soil dust is very small (2×10^{-7}), hence there is no respective cancer risk. Corresponding toxicological effects can arise when a daily intake is above the *RfD* of Cr or 0.003 mg/kg/day. The present calculations revealed that the daily intake is very near to the value of child non-carcinogenic *CDI* (0.00084 mg/kg/day for Cr median and 0.002 mg/kg/day for Cr maximum value), hence a child non-carcinogenic hazard is possible.

Cobalt is an essential element for humans and its dietary allowance is 0.1 μg. The average daily intake of cobalt from food is estimated to be 5 to 40 μg/day.[19] None of cobalt concentrations measured in Belgrade soil should provoke any concern since the adult and child ingestion of soil non-carcinogenic *CDI*s (0.036 μg/kg/day and 0.34 μg /kg/day, respectively) are sufficiently small in comparison with average daily intake of cobalt from food.

Copper in the soil surface, or aerated soil, is usually present as Cu(II). Although most copper salts occur in two valence states, *i.e.*, Cu(I) or Cu(II) ions, the biological availability and toxicity of copper is most likely associated with the divalent state.[20] Adult and child ingestion of soil non-carcinogenic *CDI*s for Cu (0.0013 mg/kg/day and 0.00014 mg/kg/day, respectively) are smaller then oral chronic *RfD* (0.04 mg/kg/day), hence copper generates risk neither for children nor for adults.

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* *NOAEL* (No-Observed-Adverse-Effect Level): the dose of a chemical at which there were no statistically or biologically significant increases in the frequency or severity of adverse effects seen between the exposed population and an appropriate control. Effects may be produced at this dose, but they are not considered to be adverse.

Table IV. Non-carcinogenic hazard index and carcinogenic lifetime risk for individual elements, cumulative risk for different exposure pathways for individual elements and cumulative risk for all elements

Element	Risk					
	Non-carcinogenic risk	Non-carcinogenic risk	Non-carcinogenic risk	Cumulative non-carcinogenic risk	Carcinogenic risk	Cumulative carcinogenic risk
	Type of risk					
	Child ingestion of soil, *HI*	Adult ingestion of soil, *HI*	Adult inhalation of soil particulates, *HI*	Adult total soil *HI* for a single element	Inhalation of soil particulates risk ($\times 10^7$)	Total soil risk for a single element ($\times 10^7$)
Cd minimum	0.0511	0.0055	0.0000	0.0055	0.008	0.008
Cd maximum	0.2270	0.0243	0.0000	0.0243	0.034	0.034
Cd median	0.1130	0.0121	0.0000	0.0121	0.017	0.017
Cr(VI) minimum	0.1840	0.0197	0.0001	0.0198	0.542	0.542
Cr(VI) maximum	0.6820	0.0730	0.0004	0.0734	2.010	2.010
Cr(VI) median	0.2770	0.0297	0.0002	0.0299	0.816	0.816
Co minimum	0.0077	0.0008	0.0001	0.0010	0.035	0.035
Co maximum	0.0266	0.0029	0.0005	0.0034	0.122	0.122
Co median	0.0171	0.0018	0.0003	0.0022	0.078	0.078
Cu minimum	0.0155	0.0017	0.0000	0.0017	–	–
Cu maximum	0.1010	0.0108	0.0000	0.0108	–	–
Cu median	0.0334	0.0036	0.0000	0.0036	–	–
Mn minimum	0.1090	0.0117	0.0019	0.0136	–	–
Mn maximum	0.2840	0.0304	0.0050	0.0354	–	–
Mn median	0.1840	0.0197	0.0032	0.0229	–	–
Ni minimum	0.0369	0.0040	0.0000	0.0040	–	–
Ni maximum	0.2310	0.0247	0.0000	0.0247	–	–
Ni median	0.0690	0.0074	0.0000	0.0074	–	–
Zn minimum	0.0057	0.0006	0.0000	0.0006	–	–
Zn maximum	0.0313	0.0034	0.0000	0.0034	–	–
Zn median	0.0108	0.0012	0.0000	0.0012	–	–
Cumulative soil risk for all elements – risk is additive						
Cumulative risk for min. values	0.4098	0.0439	0.0022	0.0461	0.585	0.585
Cumulative risk for max. values	1.5829	0.1694	0.0059	0.1753	2.166	2.1666
Cumulative risk for median values	0.7043	0.0755	0.0037	0.0792	0.911	0.911

The case of manganese is rather complex. The origin of manganese on Belgrade streets is twofold. Some of it is a natural part of soil but additionally it is brought there by traffic, since in Serbia “unleaded” gasoline is produced with MMT (methylcyclopentadienyl manganese tricarbonyl) additive. Manganese can bring forth a variety of serious toxic responses upon prolonged exposure to elevated concentrations, either orally or by inhalation. The central nervous system is the primary target. Initial symptoms are headache, insomnia, disorientation, anxiety, lethargy and memory loss. This combination of symptoms is a disease called "manganism", and these symptoms progress with continued exposure and eventually include motor disturbances, tremors, and difficulty in walking, symptoms similar to those seen with Parkinsonism.[21,22] However, manganese is also an essential trace element and is necessary for good health; the recommended dietary allowance for an adult human is 2–5 mg/day.[11] The present calculations for adult and child ingestion of soil non-carcinogenic *CDI*s for Mn (0.008 and 0.0009 mg/kg/day, respectively) show that these concentrations still do not exceed the chronic *RfD* for Mn (0.04 mg/kg/day) (Table II). However, since the contribution of traffic to the Mn content in Belgrade soil is not negligible, further monitoring of Mn is necessary.

Nickel is a probable human carcinogen, only some industrial Ni compounds exhibit carcinogenic effects, but many others do not. The most common adverse health effect of nickel in humans is an allergic reaction.[11] The present results showed that the current concentrations of Ni in Belgrade soil are below any alerting values.

Zinc is an essential element with a recommended daily allowances ranging from 5 mg for infants to 15 mg for adults. Too little zinc can cause health problems, but too much zinc is also harmful. Harmful health effects generally begin at levels in the 100 to 250 mg/day range.[11] The present results showed that the current concentrations of Zn in Belgrade soil are below any alerting values.

The presence of lead in Belgrade streets and soil is exclusively related to traffic and use of leaded gasoline.[23] Serbia is one among a few countries in Europe that have not ceased to produce and use leaded gasoline. Lead can affect almost every organ and system in the human body. Evidence shows that lead is a multi-target toxicant, causing effects in the gastrointestinal tract, hematopoietic system, cardiovascular system, central and peripheral nervous systems, kidneys, immune system and reproductive system. The most sensitive systems are the central nervous system, particularly in children, and the cardiovascular system. Irreversible brain damage occurs at blood Pb levels greater than or equal to 100 μg/dl in adults and at 80–100 μg/dl in children.[11] Pb blood levels over 4.62 μg/dl in children are associated with higher resting blood pressure.[24] Assuming the worst case scenario, for children with daily soil intake rates of 200 mg/day and maximal concentration of Pb of 1847.64 mg/kg in the soil, the calculated chronic daily intake for non-carcinogenic risk or *CDI* is 0.024 mg/kg/day. Hence, for a 15 kg child, the *CDI* is 0.36 mg/day (360 μg/day), and if all that Pb would enter into the blood, which is not the case, the child should have serious health problems.

CONCLUSION

This study has proven that soil contamination in Belgrade is not unimportant; risk assessment, calculated for a lifetime exposure, indicated that the carcinogenic risk is completely insignificant but the non-carcinogenic risk tends to became significant, mainly for children, since it approaches values which could be unacceptable. There is no particularly dangerous single heavy metal, but their cumulative effect, expressed as the child soil ingestion hazardous index, is for concern. Similar, but still rare literature data, describe urban soils that contain heavy metals.[25–27] They report evident corresponding non-carcinogenic hazard index which is around or above one, but they do not report carcinogenic lifetime risk for any individual element.

The investigation that remains, which was not in the scope of this study, is research by biomedical experts which should reveal the exact adverse effects that heavy metal contamination of soil might induce in humans, particularly among individuals in vulnerable populations, such as children.

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ИЗВОД

ПРОЦЕНА ПОТЕНЦИЈАЛНОГ РИЗИКА ПО ЗДРАВЉЕ ЉУДИ УСЛЕД ПРИСУСТВА ТЕШКИХ МЕТАЛА У ЗЕМЉИШТУ ЦЕНТРАЛНЕ ЗОНЕ БЕОГРАДА

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Испитивање земљишта централне зоне Београда рађено је са циљем да се одреди ниво његове загађености тешким металима. Полазећи од садржаја тешких метала (Zn, Cd, Pb, Co, Ni, Cu, Cr и Mn) процењен је кумулативни потенцијални канцерогени и неканцерогени здравствени ризик (за ингестију и инхалацију) за животни век човека, деце и одраслих, полазећи од модела који је развила америчка агенција за заштиту животне средине. Истраживања показују да загађење земљишта у Београду није занемарљиво иако процена канцерогеног ризика указује да је он занемарљив, али да неканцерогени ризик постаје значајан, посебно у случају деце. За сада не постоји одређени тешки метал који се може идентификовати као опасан, али кумулативни ефекат свих испитиваних метала исказан кроз ингестиони хазардни индекс за децу постаје забрињавајући пошто се приближава вредностима које се сматрају неповољним.

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