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THE INDICATORS OF HEAVY METAL LOAD AFFECTING PEOPLE IN URBAN ENVIRONMENT: THE SPATIAL CHANGE OF THE HEAVY METAL CONTENT OF GREEN AREA SOILS AND DEPOSITED AEROSOLS IN SZEGED

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Introduction

The living conditions, the feeling of comfort, the health risk of urban citizens can be characterised by several factors. Regarding these, the heavy metal load on the human body is of stressed importance, since, it is not its acute but rather the permanent, continuous low-grade-load that makes it dangerous. Usually this permanent load causes organic diseases and cancer only after long years.

The heavy metal load can affect the human body in five ways (*Fig. 1*): through nutrition, ingestion, direct contact, drinking water, and inhalation. In case of the first four ways of exposure, soil acts either as a direct or indirect factor. While, regarding the examination of inhalation, the spatial distribution of the heavy metal content of deposited aerosols must be investigated.

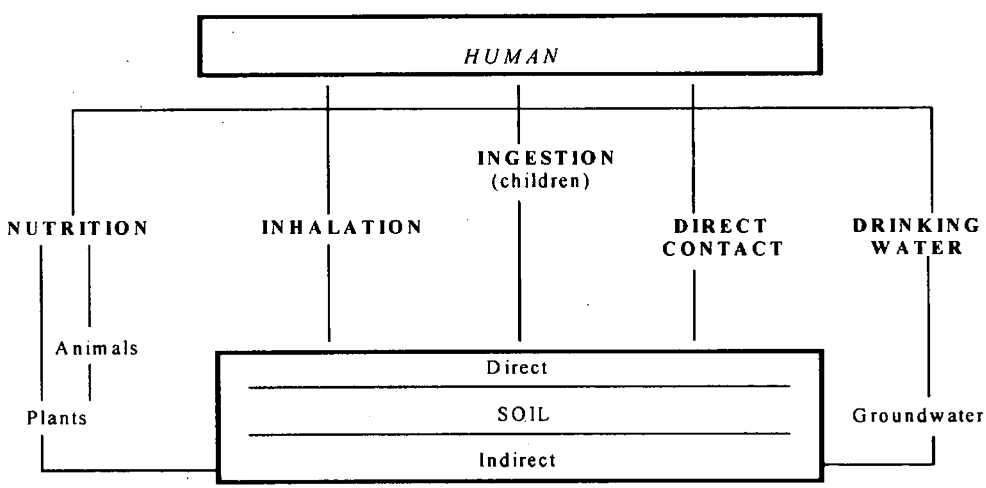

Figure 1 Heavy metal load, ways of exposure (*Ruck, 1990*)

The soils of the urban ecosystem can be classified into three groups (*Blume et al.*):

- natural soils that were built over
- natural, autochtonous soils that have suffered significant alteration
- artificial depositions containing both natural and technogenous (building rubble) materials

The soil classification system of the FAO puts these soils in a distinct soil group: Anthrosol (*Stefanovits et al. 1999*), containing anthropogenic soils that were formed or significantly transformed (removal of the upper level, deposition of other materials, etc.) by human activity. Concerning these soils the original soil-forming factors and the soil horizons can not be identified.

Threshold limit values on soils of different use (e.g. playgrounds, or gardens) refer to the possibility of acute or chronic damage of human health if thresholds are exceeded. However, the currently used threshold systems, like the Dutch list, the Berlin list, or the Eikman-Kloke type limit values can not be reasoned properly from a toxicological point of view (*Kádár 1998*), because the toxicological exposure, that depends on the use and the characteristics of the soil (physical soil type, pH, clay mineral content and quality, organic material content), can occur at lower and higher degrees of pollution as well.

In many cases, the examination of the soils of the urban ecosystem is equal with the analysis of the pollution of soils along roads of heavy traffic. Based on the results of such analyses, it can be ascertained that the heavy metal pollution of traffic origin is the highest to a distance of 50-100 m from roads, to a depth of 20-25 cm (*Árkosi, Buna 1990*). Nevertheless, the soils of these linear areas, due to the way of their use, do not have a major role in endangering the health of citizens. The situation is different in case of the soils of parks, playgrounds and urban green spaces. It is true that these soils contain 1.5-4 times less pollution in the upper horizon than those collected beside roads, but if we consider the possible ways of exposure, then the chance of affecting people is much greater in their case: inhalation of aerosols transported by wind, direct touch of the soils of playgrounds and sand boxes, children taking earth in their hands and mouth, cultivation of gardens within the urban area, eating of plants grown there etc. Based on experiments that were carried out on playgrounds (*Ruck 1990*), children around the age of two 0.4-1.5 times touch their mouths with their earthy hands in every minute. This kind of ingestion is called as the "pica" phenomenon. The 50-60 % of children between 14-24 months takes up soil orally. During another experiment the dirt was removed and collected from children's hand, and the daily amount of soil getting into their body was estimated based on these samples. The result was 100 mg/day. Such, so called ingestional exposure of children is characteristic between the ages of 1-6.

The analysis of the heavy metal content of soils is important from more point of views at the same time: it is one of the factors of soil pollution, and through inhalation it represents a significant proportion of the heavy metal load getting into the human body. During respiration the inhaled dust particles and aerosols, depending on their size, accumulate at different organs of the body. Pollutants larger than 5 μm first accumulate in the upper respiratory organs, then get to the stomach. Smaller ones can travel down even to the bronchi, and can cause various lung diseases.

Consequently, the air and environment pollution of a city is also resembled in the chemical composition of its soils and aerosols (*Kovács, Nyári 1984*). Data referring to these, provide information on the degree and spatial variation of potential danger on citizens.

Methods

The analysed 44 soil samples were collected in parks and playgrounds, if it was possible close to sand boxes (*Fig. 2*). Samples were taken from the upper 5-10 cm of the soil profile. After adequate preparations pH (H_2O), physical type following the Arany method, and organic material content (H_2SO_4 with the presence of 0.33 M $K_2Cr_2O_7$) were determined. The heavy metal content of soils was extracted in two ways. The "total" content was extracted with nitrohydrochloric acid, the environmentally mobile content with the method of Lakanen-Erviö (0.02 M EDTA solution of pH 7, set with ammonium acetate). The concentration of seven metals: Cd, Co, Cr, Cu, Ni, Zn, Pb were determined with atomic adsorption spectrophotometer, Perkin-Elmer 3110.

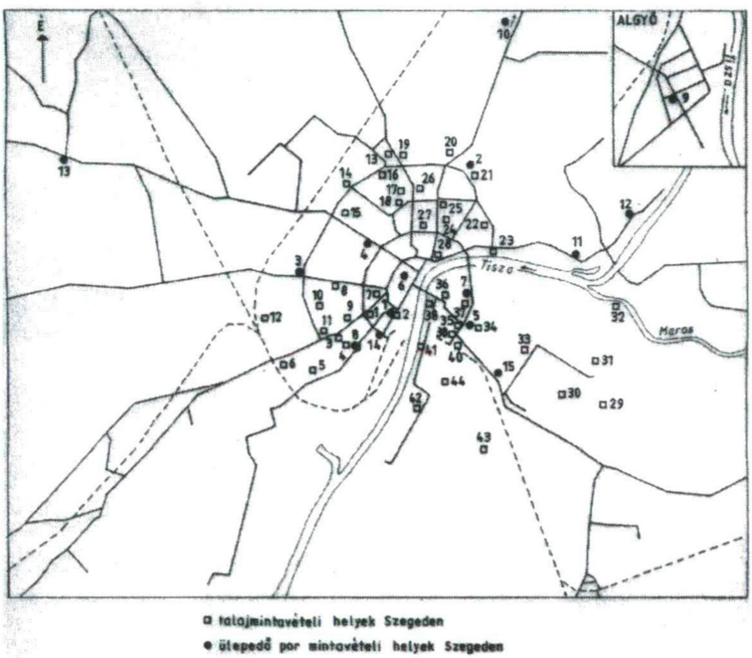

Figure 2 Sampling sites (*see also Table 3*)

The samples of deposited aerosols were collected in co-operation with the Csongrád County Institution of the ÁNTSZ (Public Health and Medical Officer's Service) at 15 sites of the city (*Fig. 2*) once in a month during the first half of year 2000, by following the MSZ 21454/1-1983 standard. Beside measuring the amount of deposited aerosols ($g/m^2/30$ days), Cd, Pb and Cu concentrations were also determined. The extraction was carried out with nitrohydrochloric acid (MSZ 21454/5-1988, MSZ 21454/11-1987), atomic adsorption spectrophotometer, Perkin-Elmer 3110.

The heavy metal content of Szeged green area soils

The pH of soils at the green areas of Szeged is practically uniform, and varies between 7 and 7.9. Their organic material content is high, in average 6.5 %. Considering their physical type, determined following the Arany method, the samples can be classified to the silt or clayey silt category. Since the mobility of heavy metals in soils is influenced mainly by the factors above, their analysis is of great importance when examining the ways of exposure (uptake by plants -> food chain, ground water -> irrigation -> plant -> food chain etc.). Nevertheless, because in case of the examined samples the pH exceeds 7, the organic material content is high and the physical type is silt or clayey silt, it can be claimed that these soils have a high toxic element adsorption ability, i.e. environmental buffer capacity concerning all the seven analysed metals (*Stefanovits et al. 1999*).

Regarding the examined heavy metals the pollution of soils is diverse (*Table 1*). In case of samples extracted with nitrohydrochloric acid, the concentration of Pb, Zn, Cr and Ni only in 2-3 occasions, while that of Cu in all cases exceeded the "allowable maximum amount", determined by the technological directives of the agricultural, provisional sector. The measured concentrations in the soils of Szeged can be compared to other referential data as well. For determining the degree of pollution, the results of analyses performed on soils of a city of similar size can serve as a good base: in Rostock Kahle et al. (*1999*) examined the soils of playgrounds with the same methods of sampling and extraction. Regarding all the examined metals, with the exception of Cr, their results were lower than the Szeged values. By comparing the measured values with the values of soils free from direct anthropogenic influence, it can be seen that the load on the green area soils of Szeged, i.e. the "background pollution" of the city is very significant. When focusing on the different sampling points, it is striking that in case of each metals the results of the samples collected at the playground beside the Szőregi Road, and at the ramp of the Downtown Bridge are higher than the limit values for urban soils. The above sampling points are located near busy junctions, where there is not any natural or artificial formations (bushes, trees or buildings) that would filter or shield the pollution of traffic. The sampling point on the floodplain of the River Tisza also refers to a high load. In several countries (e.g. Germany) – as opposed to Hungarian practise – different threshold limit values are established according to the different ways of land-use. The German limit values (*Table 1*) that refer to playgrounds were exceeded in several occasions by the results of the soils collected on the playgrounds of Szeged. The stepping over of the C value (toxic value: the object of protection (plant, animal, human) is harmed, intervention is needed) of this threshold system is not rare either (e.g. in case of Cd and Cu at the above mentioned sites). These data stress the increased background pollution in certain parts of the city!

	Cd	Co	Cr	Cu	Ni	Pb	Zn
Mean heavy metal content of urban soils (0-10 cm)[1]	0,48	-	20	16,6	-	37,3	66
Mean heavy metal content of soils free from anthropogenic load. [2]	0,1 - 0,5	-	5 -100	2 - 40	5 -50	2 - 60	10 – 80
Suggested thresholds on the basis of the way of soil-use – playgrounds[3]	**2**	-	**50**	**50**	**40**	**200**	**300**
Mean heavy metal content of Szeged green area soils	**1,77**	**46,79**	**17,47**	**270,39**	**30,16**	**47,04**	**109,82**
Heavy metal content of Szeged green area soils. Minimum value	0.20	15.25	5.44	198.89	9.19	11.05	11.77
Heavy metal content of Szeged green area soils. Maximum value	13.29	69.85	73.46	509.04	58.96	332.81	650.64
Mean heavy metal content of soils of playgrounds in Rostock [4]	0.17	-	17.9	6.1	5.1	15.0	28.4
Allowable maximum value in soils (T=15-25)[5]	2	50	100	100	50	100	250

Table 1 Heavy metal pollution of the soils of Szeged ("total" content, given in ppm)
1. Fiedler, Rösler 1993, 2. Brümmer et al. 1991, 3. Kloke 1980, 4. Kahle et al. 1999 5. Technological directives of the agricultural and provisional sector (January 1991)

In case of the mobile element content, the problem of exceeding thresholds is more obvious. Therefore, the results were compared to suggested (*Kádár 1998*), temporary threshold limit values (*Table 2*). According to this, on the whole territory of the city the Co and Ni concentrations remain under the allowed value, while the other elements, not rarely by several times, step over the limits. At the above mentioned sampling sites the Cu and Pb concentrations exceed the threshold by 3 and 5 times, respectively.

	Cd	Co	Cr	Cu	Ni	Pb	Zn
Mobile heavy metal content of Szeged green area soils (mean) (ppm)	0.205	3.913	**3.253**	**38.02**	5.467	**24.786**	14.486
Mobile heavy metal content of Szeged green area soils (minimum) (ppm)	< 0.01	1.19	1.08	13.03	2.77	6.55	1.59
Mobile heavy metal content of Szeged green area soils (maximum) (ppm)	2.69	5.29	**7.39**	**166.42**	8.79	**193.9**	**111.95**
Suggested, temporary threshold for the mobile element content (ppm) of soils (NH4 acetate + soluble EDTA) (B value)	-	10	3	40	20	25	20

Table 2 Environmentally mobile heavy metal content (ppm) of Szeged green area soils compared to the suggested, temporary threshold limit value (B value: the concentration above which the soil can be declared polluted), 1. Kádár, 1998.

The heavy metal content of deposited aerosols on the territory of Szeged

The heavy metals emitted to the air attach to the floating particles, aerosols (<1µm) of the atmosphere, and travel with these in the air. After a certain time they deposit onto the surface of the soil, plants and water. The travelled distance, and the time of atmospheric presence depends on the size of the aerosol and the meteorological conditions. Larger particles deposit quickly close to the source, while those, smaller than 10 μm leave the air very slowly, remain in the atmosphere for 7-30 days, and may travel several thousand km. When examining the urban environment, several other factors must be considered, too. The meteorological conditions that determine the principles of deposition (direction of wind, precipitation) are modified by numerous parameters: e.g. the built over ratio, vegetal coverage, high buildings modifying the direction of air currents, microclimate; the effect of which may result in great differences even in relatively small distances, too. Besides, regarding the different pollutants, the great variety of possible sources (transportation, industry, combustion of fossil energy sources etc.) makes the situation even more complicated. When examining the temporal course of the amount of deposited aerosols, we experienced in the winter months higher, while in the spring months lower values during year 2000 (*Table 3*). Values that exceeded the threshold limit values (depending on the degree of protection, 12-16 g/m^2/30 days) occurred only in March at certain parts of the city.

Number and location of station	January	February	March	April	May	June
1. Boldogasszony sgt.	2,5	2,5	11,5	7,9	6,9	8,2
2. Tarjáni óvoda	1,7	1,4	11,6	3,9	5,9	5,7
3. Vasöntöde	3,2	2,8	3,3	6,4	8,6	2,3
4. Kórház (Kossuth L. u)	1,9	1,7	1,5	6,6	11	2
14. Bécsi krt.	2,7	2,2	5,2	5,8	3,9	8,5
5. ÁNTSZ	1,9	1,6	3	4,7	6,4	3,8
9. Algyő, gyógyszertár	1,9	2	13,6	5,4	6,7	3,8
10. Algyő, olajos központ	1,5	1,7	6,9	5,4	7,2	3,4
11. Tápé, Budai N. A. u.	0,9	1,5	10,7	4,8	10,9	4,9
13. Kiskundorozsma	4,3	2,4	4,1	10,9	5,9	3,8
7. ÁVI, Újszeged	5,8	0,9	8,1	7,9	5	5,2
15. Ifjúgárda	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6. Széchenyi tér	4,2	1,5	4	8,3	n.a.	n.a.
8. Mátyás tér	n.a.	n.a.	2,3	3,9	7,1	3,6
12. Tápé, Templom	14,4	2	5	4,6	5	5,9

Table 3 Temporal change of the amount of deposited aerosols in Szeged, Jan.-Jun. 2000 (g/m^2/30 days). Air quality threshold limit value: 12 g/m2/30 days (MSZ 21854-1990)

In case of aerosol samples the concentrations of three heavy metals: Cd, Cu, Pb were determined. Compared to the 1990 standard about the requirements of the environmental air clearness, the Cd content of the deposited aerosols exceeded the 180 μm/m^2/30 days threshold value only once. In case of Pb – similarly to values in soils – the concentration in aerosols did not even reach the limits (*Table 4*). Regarding Cu, there is currently no threshold limit value (*Table 5*). However, if we count with an average 6000 μg/m^2/30 days Cu load in Szeged, then it results in a 0.48 ppm annual increase in the upper 10 cm of soils. These values – if we consider the already high concentrations in the soils of the city – can be regarded high, though, for finding the sources, further analyses would be necessary. It is characteristic of both the temporal course of Cu and Pb that during the winter months the concentrations in deposited aerosols are higher (*Fig. 3*).

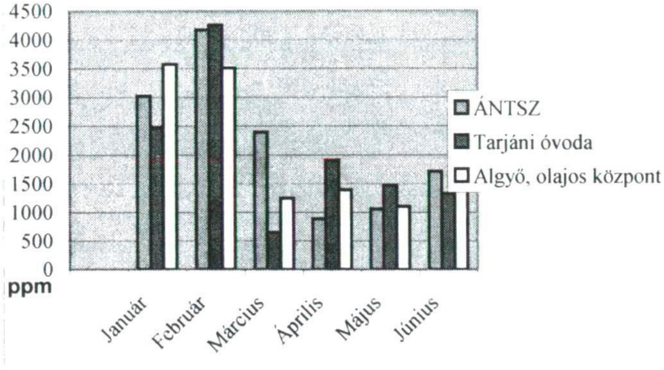

Figure 3 Temporal change of the Cu content of deposited aerosols in Szeged at three measuring points during the first half of year 2000 (*see also Table 3*)

Number and location of the station	January	February	March	April	May	June
3. Vasöntöde	476,224	361,536	256,212	991,616	3037,9	406,686
4. Kórház (Kossuth L. sgt.)	339,758	366,928	111,945	451,044	770,44	400,92
14. Bécsi krt.	420,633	383,372	825,968	213,092	230,95	167,365
5. ÁNTSZ	348,517	202,464	186,3	118,44	176	291,688
9. Algyő, gyógyszertár	1413,239	269,58	1538,70	294,138	578,41	295,716
10. Algyő, olajos központ	429,525	273,343	-	240,624	211,82	240,21
11. Tápé, Budai N. A. u.	167,967	374,715	2759,74	181,872	-	329,672
13. Kiskundorozsma	-	302,016	258,464	706,865	448,87	473,29
7. ÁVI, Újszeged	-	222,219	778,977	573,935	298,2	374,036
15. Ifjúgárda	-	-	-	-	-	-
6. Széchenyi tér	637,392	444,315	915,2	201,192	-	-
8. Mátyás tér	-	-	138,368	-	390,5	984,96
12. Tápé, Templom	1057,392	143,58	338,1	228,574	232,5	902,641

Table 4 Temporal change of the Pb content of deposited aerosols in Szeged, Jan.-Jun. 2000 ($\mu g/m^2/30$ days). Air quality threshold limit value: 12000 μg/m2/30 days (MSZ 21854-1990)

Number and location of the station	January	February	March	April	May	June
1. Boldogasszony sgt.	5669,75	8409,6	4754,79	8535,634	7847,232	7872,328
2. Tarjáni óvoda	4202,111	5961,284	7486,176	7451,769	8640,491	7581,798
3. Vasöntöde	4546,784	4573,52	9098,76	9645,184	10051,25	6958,742
4. Kórház (Kossuth L.)	7375,078	7473,251	6680,595	8574,852	10056,75	6623,24
14. Bécsikrt.	5063,958	6145,832	4555,356	6574,822	6600,009	3527,33
5. ÁNTSZ	5746,626	6674,464	7187,19	4200,719	6788,544	6512,972
9. Algyő, gyógyszertár	3834,447	4120,54	3941,008	7925,958	8560,791	7028,822
10. Algyő, olajos központ	5369,01	5964,11	8645,562	7528,95	7988,688	6167,838
11. Tápé, Budai N. A.	6741,171	5750,94	7836,038	4858,992	-	6882,54
13. Kiskundorozsma	-	4019,136	6725,599	17631,84	9283,532	7235,922
7. ÁVI, Újszeged	-	6233,337	64854,68	9346,095	8219,95	8814,884
15. Ifjúgárda	-	-	-	-	-	-
6. Széchenyi tér	5471,844	3420,45	8230,4	15701,69	-	-
8. Mátyás tér	-	-	6289,051	-	8794,841	6094,404
12. Tápé, Templom	7034,832	7441,58	7221,2	7049,914	8155,75	7948,244

Table 5 Temporal change of the Cu content of deposited aerosols in Szeged, Jan.-Jun. 2000 ($\mu g/m^2/30$ days)

In order to reveal the spatial distribution of the concentrations, detailed microclimatic investigations are needed.

Conclusion

The quantitative and qualitative examination of deposited aerosols is an important additive in the proper judgement of the health of our environment, and the surveying of the background load on soils and citizens. This was the aim when we analysed the heavy metal content of the 44 soil samples collected from the green areas, parks, playgrounds of Szeged, and that of the aerosol samples gained at 15 measuring stations of the city. Our results, compared to the values measured in other cities, and the referring threshold limit values, imply significant background pollution. Therefore, we suggest that the decrease of anthropogenic health risk would need a greater attention. Possible methods of treating the problem can be the establishment of green stripes beside junctions of heavy traffic, the ensuring of continuous vegetal coverage (grass) in order to avoid the formation of dust and inhalative pollutants.

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References

Árkosi I., Buna B. (1990): A közlekedésből származó nehézfémek (ólom) talaj- és növényszennyező hatásának vizsgálata, Környezetgazdálkodási kutatások 3.

Brümmer et al. (1991): Schwermetallbelastung von Böden, Mitteilungen Dt. Bodenkundliche Gesellschaft 63.

Farsang A. (1996): Talaj nehézfémtartalmának térbeli eloszlása mátrai mintaterületen, különös tekintettel az antropogén terhelésre, Ph.D. értekezés, kézirat

Fiedler H.J., Rösler H.J. (szerk.) (1993): Spurelemente in der Umwelt, Gustav Fischer Verlag, Jena - Stuttgart.

Kádár I. (1998): Kármentesítési kézikönyv 2. A szennyezett talajok vizsgálatáról (Kármentesítési program), Környezetvédelmi Minisztérium

Kahle P., Marzusch P., Spank U. (1999): Untersuchungen zur Schwermetallsituation auf Spielplätzen im Stadtgebiet von Rostock, Mitteilungen der Deutsche Bodenkundliche Gesellschaft Bd. 91, Heft 1.

Kloke, A. (1980): Richtwerte 80' Orientierungsdaten f-r tolerierbare Gesamtgehalte einiger Elemente in KulturbOden, Mitteilungen VDLUFA. Heft. 1/3.

Kovács M., Nyári I. (1984): Budapesti közterületek talajainak nehézfémtartalma, Agrokémia és Talajtan 33. Pp. 501-510.

Mezőgazdasági és élelmezésügyi ágazati műszaki irányelv 1991 január.

MSZ 21845-1990: A környezeti levegő tisztasági követelményei (Országos szabvány)

Ruck, A. (1990): Bodenaufnahme durch Kinder – Abschatzungen und Annahmen, In Bodenschutz, Szerk.: D. Rosenkranz, G. Einsele, H.-M. Harress, Erich Schmidt Verlag, 1988.

Stefanovits P., Filep Gy., Füleky Gy. (1999): Talajtan, Mezőgazda Kiadó, Budapest p. 470.

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