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Original Research

Influence of Land Use on the Content of Select Forms of Cd, Cr, Cu, Ni, Pb, and Zn in Urban Soils

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Abstract

Cities are areas where soils are strongly transformed and heavy metals occur in high concentrations as a result of direct human activity, the influence of industrial and municipal buildings, industrial activity, and transportation. The purpose of this study is to determine the total and bioavailable concentrations of Cd, Cr, Cu, Ni, Pb, and Zn in urban soils of Lublin, Poland, and to estimate the relationships between their contents and different types of land use. The total contents of these metals do not exceed the limits permissible in Poland, and for comparison also in Holland and Germany. The heavy metal contents in the Lublin urban soils are similar to those occurring in other cities in Poland and in the world. The distribution of their total and bioavailable concentrations in urban soils indicates that soil contamination by heavy metals is mostly caused by industry and motor traffic. The proportion of total heavy metals that is bioavailable, being the indicator of its mobility, is the highest for Zn and Cd.

Keywords: bioavailability, heavy metals, land use, Lublin (eastern Poland), urban soils

Introduction

Cities are areas of high anthropogenic activity in which many local sources emit heavy metals, which are natural components of the pedosphere but whose higher concentrations are found mainly in cities where large amounts of dust, waste, and sewage are produced due to the development of various branches of industry. Contaminants can be released from different sources and in different ways: motor traffic emissions, chemical industry, coal, biomass and garbage burning, municipal solid waste, or contaminated dustfall [1, 2].

In urban areas, as a result of direct human activity, the influence of industrial and municipal buildings as well as industry and transport, soils are strongly transformed and heavy metals occur in high concentrations [3-5].

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Anthropogenic soils containing heavy metals can easily negatively impact human health through inhaled dust, eaten vegetables and fruits from urban gardens, or direct contact of contaminated soil with skin. Toxicological analyses indicate that such elements as Pb, Cd, and Cr accumulate in fatty tissue and affect the central nervous system [6]. Besides total concentrations of heavy metals in soils, their bioavailability is an important feature characterizing their geochemical circulation in soils because often only some proportion of heavy metals is taken up by plants or can migrate to groundwater, i.e., is active in geochemical circulation [7-9].

High concentrations of heavy metals (especially their bioavailable forms) in urban soils strongly disturb the natural geochemical cycle of the urban ecosystem. In the whole world the investigations of heavy metals in soils focus mainly on the determination of their concentrations depending on the contamination sources and comparison with different limits defining the level of risk to human health [9, 10]. Previous research on the circulation of heavy metals in urban soils and their bioavailability should be supplemented with investigations that also consider the types of land use.

The purpose of this study was to determine the total and bioavailable concentrations of Cd, Cr, Cu, Ni, Pb, and Zn in the Lublin urban soils and to estimate the relationships between their contents and different types of land use.

Materials and Methods

Studied sites and Soils

Lublin (N 51º14'; E 22º33') is a city in eastern Poland in the Lublin Upland on the Bystrzyca River (Fig. 1). The Bystrzyca valley divides the Lublin area into two parts: the left-bank with loess cover cut by gullies and dry valleys, and the right bank with lower and more gentle relief composed of the Upper Cretaceous (marls, opokas, gaizes) and Palaeocene rocks (gaizes) overlain by the Pleistocene sandy silts and loess-like silty sands [11].

Lublin is of average size founded in the 12th century, though the beginnings of settlement date back to the 6th century AD. A historical trading route from the Black Sea to Western Europe that ran through the city had a considerable influence of its development. Historical factors had a special role in the formation of anthropogenic soils in Lublin. Natural soils have been transformed as a result of building and craft development, war damage, moving of earth masses and rubble mounds, and the influence of industry and traffic [12]. The soils under study occur in different parts of the city (Fig. 1). They belong to different taxonomic types and are used in different ways. The following six main types of land use are distinguished: building investment areas (BA), industrial areas (IA), educational centre areas (EA), traffic areas (TA), housing areas (HA), and garden areas (GA).

According to the classification by WRB [13, 14] the investigated profiles represent the following soil units:

- Hypereutric Regosol (Endoloamic, Ruptic, Episiltic) – profile No. 1 (BA), occurring in the location where a shopping mall is being built, about 200 m from international roads E372 and E373
- Spolic Technosol (Calcaric, Humic, Amphiloamic) – profile No. 2 (IA), occurring in the industrial zone of the

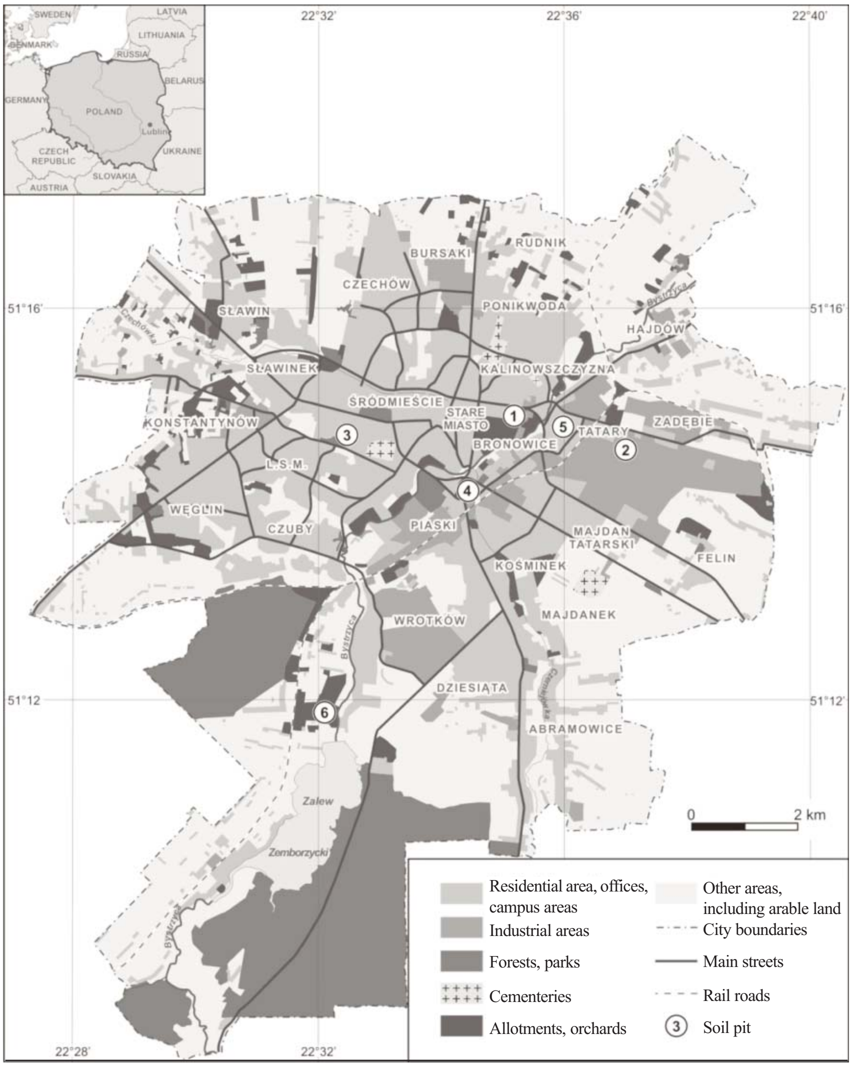

Fig. 1. Map of Lublin, Poland, with locations of sampling sites.

Table 1. Basic properties of urban soils of Lublin.

Prof. No.	Horizon [39]	Depth [cm]	Grain-size distribution [%]						$C_{org.}$ [g·kg^{-1}]	pH 1M KCl	$CaCO_3$ [g·kg^{-1}]	Hh	TEB	CEC	BS [%]
			1.0-0.1	0.1-0.05	0.05-0.02	0.02-0.005	0.005-0.002	<0.002				[mmol(+)·kg^{-1}]			
			[mm]												
Building investment areas (BA)															
1	A	0-46	11.9	15.1	29.0	21.0	9.0	14.0	52.0	7.1	195.0	9.8	660.6	670.4	98.5
	2C	46-72	33.7	7.3	20.0	16.0	4.0	19.0	3.0	7.4	8.0	4.0	229.1	233.2	98.3
	3C1	72-107	54.9	5.1	16.0	10.0	4.0	10.0	8.0	7.5	49.0	2.4	417.6	420.0	99.4
	3C2	107-117	54.2	3.8	15.0	11.0	3.0	13.0	4.0	7.3	51.0	2.4	424.0	426.5	99.4
Industrial areas (IA)															
2	Au	0-28	64.3	6.7	8.0	10.0	5.0	6.0	39.0	7.3	154.0	4.9	594.0	598.9	99.2
	Cu	28-82	53.5	6.5	13.0	9.0	4.0	14.0	19.0	7.2	181.0	5.2	637.7	642.9	99.2
	2Cu	82-100	32.0	13.0	17.0	13.0	6.0	19.0	10.0	7.4	178.0	3.6	592.1	595.7	99.4
Educational centre areas (EA)															
3	A1	0-5	53.4	7.6	16.0	10.0	5.0	8.0	26.6	7.8	52.1	5.6	406.2	411.8	98.6
	A2	5-20	52.0	12.0	17.0	7.0	5.0	7.0	22.8	7.8	120.6	5.6	399.5	405.1	98.6
	Cu1	20-30	53.6	10.4	16.0	8.0	5.0	7.0	21.0	7.7	42.8	6.4	436.4	442.8	98.6
	Cu2	30-40	52.3	9.7	19.0	8.0	4.0	7.0	27.0	7.6	36.6	7.2	428.1	435.3	98.4
	Cu3	40-60	52.3	10.7	17.0	8.0	5.0	7.0	15.9	7.8	47.2	6.4	405.8	412.2	98.5
	C	60-80	60.0	9.0	14.0	7.0	3.0	7.0	10.8	7.6	37.5	5.6	380.2	385.8	98.6
Traffic areas (TA)															
4	A	0-4	50.9	6.1	21.0	10.0	6.0	6.0	38.0	7.6	50.0	10.8	453.6	464.4	97.7
	2Cu1	4-12	72.1	4.9	8.0	4.0	4.0	7.0	8.0	7.9	59.0	5.3	412.6	417.9	98.7
	2Cu2	12-18	68.0	6.0	8.0	7.0	5.0	6.0	59.0	7.6	44.0	10.8	498.6	509.3	97.9
	2Cu3	18-38	65.9	5.1	11.0	6.0	3.0	9.0	13.0	7.9	51.0	4.6	543.7	548.3	99.2
	2C	>38	60.9	6.1	14.0	8.0	5.0	6.0	18.0	7.8	50.0	6.9	483.6	490.5	98.6
Housing areas (HA)															
5	A	0-5	36.7	16.3	24.0	15.0	6.0	2.0	26.0	7.1	19.0	7.2	324.4	331.6	97.8
	Au	5-20	43.3	12.7	24.0	13.0	4.0	3.0	18.0	7.3	0.0	5.6	322.2	327.8	98.3
	Cu1	20-30	48.7	11.3	20.0	12.0	6.0	2.0	8.0	7.6	45.0	3.1	444.6	447.8	99.3
	Cu2	30-50	33.0	15.0	30.0	13.0	5.0	4.0	8.0	7.5	21.0	2.8	357.8	360.6	99.2
Garden areas (GA)															
6	A	0-20	33.0	13.0	20.0	13.0	2.0	19.0	18.3	7.1	12.1	8.7	439.5	448.2	98.1
	C	20-32	36.0	10.0	22.0	11.0	3.0	18.0	8.6	7.1	8.2	7.9	405.5	413.4	98.1
	2C	32-50	17.0	10.0	14.0	11.0	6.0	42.0	13.7	7.2	12.8	10.2	441.7	451.9	97.7
	3C	50-70	22.0	20.0	17.0	13.0	6.0	22.0	4.6	7.1	8.8	5.9	398.3	404.2	98.5

Megatem coal power plant; the soil is characterized by a considerable content of industrial dusts, slag, building rubble, and asphalt

- Urbic Technosol (Eutric, Humic) – profile No. 3 (EA) occurring in the campus area, which is also a recreational area
- Spolic Technosol (Ruptic) – profile No. 4 (TA), occurring near the most jammed road and rail hub in Lublin; the profile is characterized by a considerable content of industrial dusts, slag, building rubble, and asphalt
- Urbic Technosol (Loamic) – profile No. 5 (HA), occurring in the square of the housing estate; the profile contains a considerable amount of bricks, concrete, pavement and paving stones, and organic garbage
- Eutric Regosol (Loamic, Ruptic) – profile No. 6 (GA) occurring in the allotment area; the soil is used for

Table 2. Heavy metal concentrations in urban soils in Lublin ($mg\cdot kg^{-1}$).

	Cr-tot	Cr-dtpa	Zn-tot	Zn-dtpa	Cd-tot	Cd-dtpa	Pb-tot	Pb-dtpa	Cu-tot	Cu-dtpa	Ni-tot	Ni-dtpa
Min.	7.11	0.01	9.62	0.82	0.23	0.01	7.25	0.20	3.29	0.09	3.06	0.04
Max.	25.35	0.36	199.28	6.99	1.73	0.17	122.16	6.26	71.42	3.09	20.96	0.37
Mean	14.12	0.11	61.17	3.42	0.83	0.08	31.85	1.59	15.67	0.66	8.27	0.21

growing common fruits (apples, prunes, cherries, raspberries, strawberries, etc.) and vegetables (carrots, lettuce, onion, cucumber, radish, etc.)

The thickness of a level corresponds to the depth of soil samples.

Soil Analysis

Air-dried soil samples were ground and sieved through a 1-mm sieve. Then their particle-size distribution was determined using the areometric method after Casagrande, as modified by Prószyński [15]. The samples were dispersed with Calgon (35.7 g of sodium hexametaphosphate + 7.49 g of anhydrous sodium carbonate filled with distilled water to a volume of 1,000 ml). Names of granulometric groups were given according to the classification published by the United States Department of Agriculture (USDA), with appropriate conversion made by the Polish Society of Soil Science [16].

In the soil samples the pH was measured potentiometrically in 1M KCl, organic carbon by a wet combustion method [17], $CaCO_3$ content by Scheibler's volumetric method [13], the sum of exchangeable bases (TEB) (Ca, Mg, K and Na extracted from soil with 1M ammonium chloride) using the AAS technique, and hydrolytic acidity (Hh) using the Kappen method. Cation exchange capacity (CEC) of soils is calculated as a sum of hydrolytic acidity (Hh) and total exchangeable bases (Ca, Mg, K, Na; TEB). Bioavailable forms of Cu, Cd, Cr, Ni, Pb, and Zn (denoted by dtpa) were extracted using the method described by Lindsey and Norvell [18]. In order to measure the pseudo-total content of heavy metals (denoted by tot), the soil samples were dissolved with aqua regia and then the elements were determined using the AAS technique [19].

Results

Some Soil Properties

Particle-size fraction < 1 mm in the studied soils is not varied (Table 1). Some fluctuations of the proportions of individual fractions, as well as high content of sand in the near-surface horizons, are found in the profiles collected in the industrial area (IA) and traffic area (TA). The studied soils are mainly sandy loam, and also loam, clay loam, and silt loam.

All studied soils have similar, alkaline reaction (pH from 7.1 to 7.9). The CEC analysed varies from 233.2 to 670.4 $mmol\cdot kg^{-1}$, and the saturation of soil sorption complex with alkaline cations reaches over 97%. The content of organic carbon fluctuates from 3.0 to 59.0 $g\cdot kg^{-1}$, and the highest values occur in the surface horizons of soils from the areas characterized by different land use. Only in the soil strongly affected by traffic (TA; profile No. 4) was the increased content of organic carbon found in a deeper horizon.

Heavy Metal Concentration

Main statistical data about heavy metal concentrations are presented in Table 2.

The total concentration of Cr in the present study varied from 7.1 $mg\cdot kg^{-1}$ to 25.35 $mg\cdot kg^{-1}$ with a mean of 14.12 $mg\cdot kg^{-1}$. In most samples the Cr concentration was lower than the world median content of this element, which is estimated to be 54 $mg\cdot kg^{-1}$. In the studied soils the concentration of Cd varied from 0.01 $mg\cdot kg^{-1}$ to 1.73 $mg\cdot kg^{-1}$. According to Kabata-Pendias [20], a global mean concentration is 0.41 $mg\cdot kg^{-1}$, and the typical concentration of Cd in uncontaminated soils occurs in the range of 0.06-1.1 $mg\cdot kg^{-1}$. Lead and zinc showed a very broad range of concentrations in the examined soils (Pb 7.25-122.16 $mg\cdot kg^{-1}$, mean – 31.85 $mg\cdot kg^{-1}$; Zn 9.62-199.28 $mg\cdot kg^{-1}$, mean –1.17 $mg\cdot kg^{-1}$). The highest concentration of Zn is typically found in the calcereous and organic soils (up to 100 $mg\cdot kg^{-1}$) and the lowest in the light sandy soils (31-61 $mg\cdot kg^{-1}$). The range and the mean world content of lead in soils are 3-90 and 27 $mg\cdot kg^{-1}$, respectively. The concentration of Cu in the studied area varied from 3.29 to 71.42 $mg\cdot kg^{-1}$, with a mean of 15.67 $mg\cdot kg^{-1}$. Typical concentration of copper in soils ranges from 14 to 109 $mg\cdot kg^{-1}$, being highest in the loamy soils and lowest in the light sandy soils. An average world abundance of Ni in soils is 29 $mg\cdot kg^{-1}$, but the natural concentration of this metal depends on the soil properties, reaching 18-92 $mg\cdot kg^{-1}$ in calcareous, and 25-50 $mg\cdot kg^{-1}$ in heavy loamy soils [20]. The Ni concentration in the examined soils is in the range of 3.06-20.96 $mg\cdot kg^{-1}$ with a mean of 8.27 $mg\cdot kg^{-1}$.

Total concentrations of heavy metals (Cd, Cr, Cu, Ni, Pb, Zn) do not exceed the permissible limits [21]. The results are also compared with the permissible concentrations of heavy metals in soils in Holland and Germany [22, 23]. No exceeding value was found.

Soil profiles occurring in industrial (IA) and traffic areas (TA) contain higher contents of most heavy metals than other studied profiles, though the maximum values of Cd and Cr are found in the surface horizons of soil from the allotment (GA) (Fig. 2). The mean total contents of Cd in

Lublin urban soils occurs in the following order: GA>IA>TA>EA>BA>HA; those of Pb and Cu: TA>IA>GA>HA>BA>EA. The highest mean concentrations of Zn occur in the building investment area (BA), while Zn contents in the industrial area (IA), educational centre area (EA), and traffic area (TA) are lower and similar to each other. The mean contents of Ni occur in the following order: IA>TA>BA>EA>HA>GA.

The mean concentrations of heavy metal bioavailable forms in the soils of the industrial (IA), traffic (TA), building (BA), and garden areas (GA) occur in the following order: Zn>Pb>Cu>Ni>Cr>Cd (Fig. 2) – reaching 3.42 mg·kg^{-1}, 1.59 mg·kg^{-1}, 0.66 mg·kg^{-1}, 0.21 mg·kg^{-1}, 0.11 mg·kg^{-1}, and 0.008 mg·kg^{-1}, respectively.

Mean concentrations of bioavailable heavy metal forms in the soils of the educational centre area (EA) and housing area (HA) occur in the following order: Zn>Pb>Ni>Cu>Cr>Cd. In these two areas the mean bioavailable form percentages of heavy metal total contents occur in the following order: Cd>Zn>Ni>Cu>Pb>Cr.

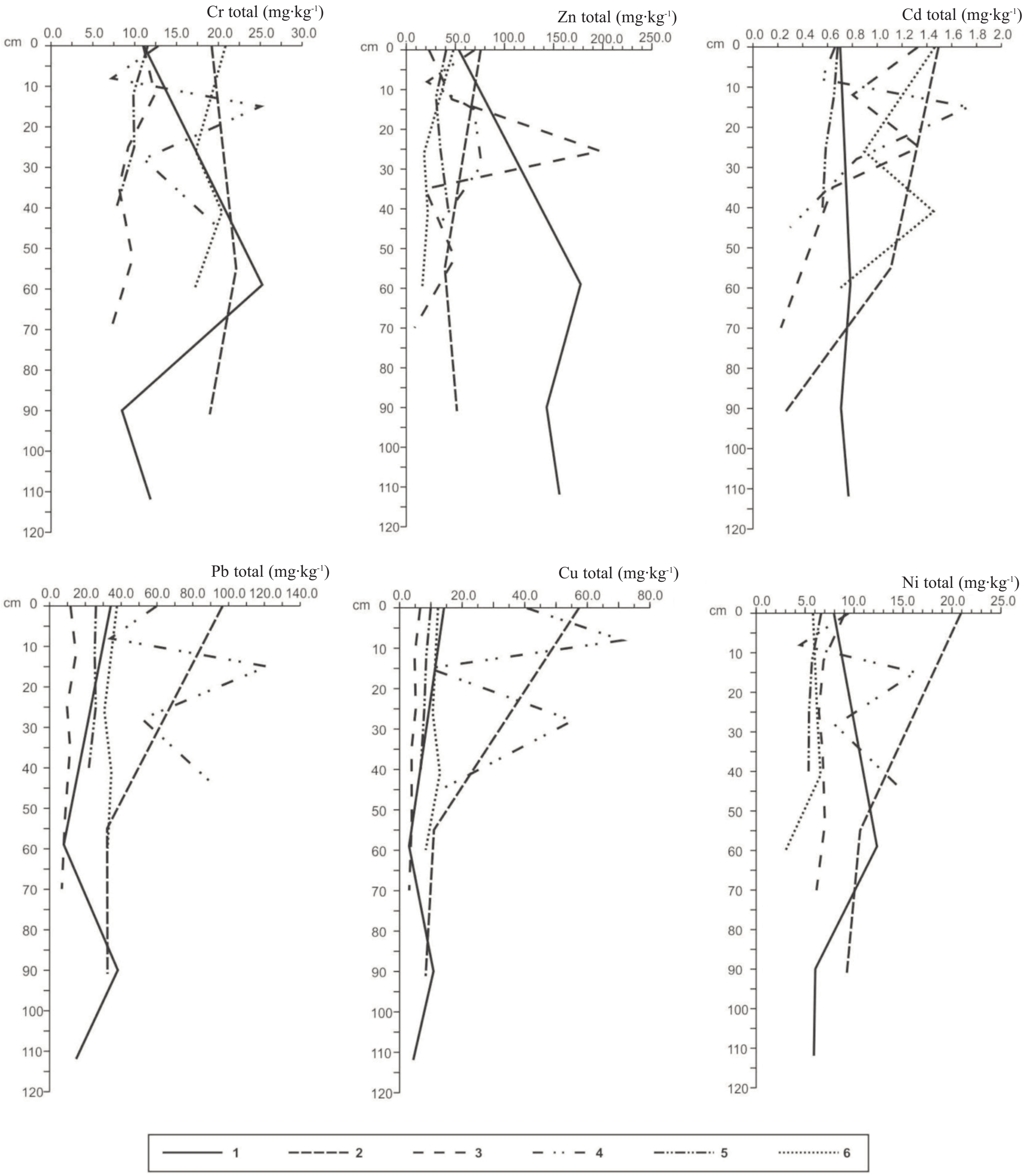

Fig. 2. Profile distribution of total and bioavailable contents of heavy metals in urban soils in Lublin (mg·kg^{-1}): 1) building investment areas (BA), 2) industrial areas (IA), 3) educational centre areas (EA), 4) traffic areas (TA), 5) housing areas (HA), and 6) garden areas (GA).

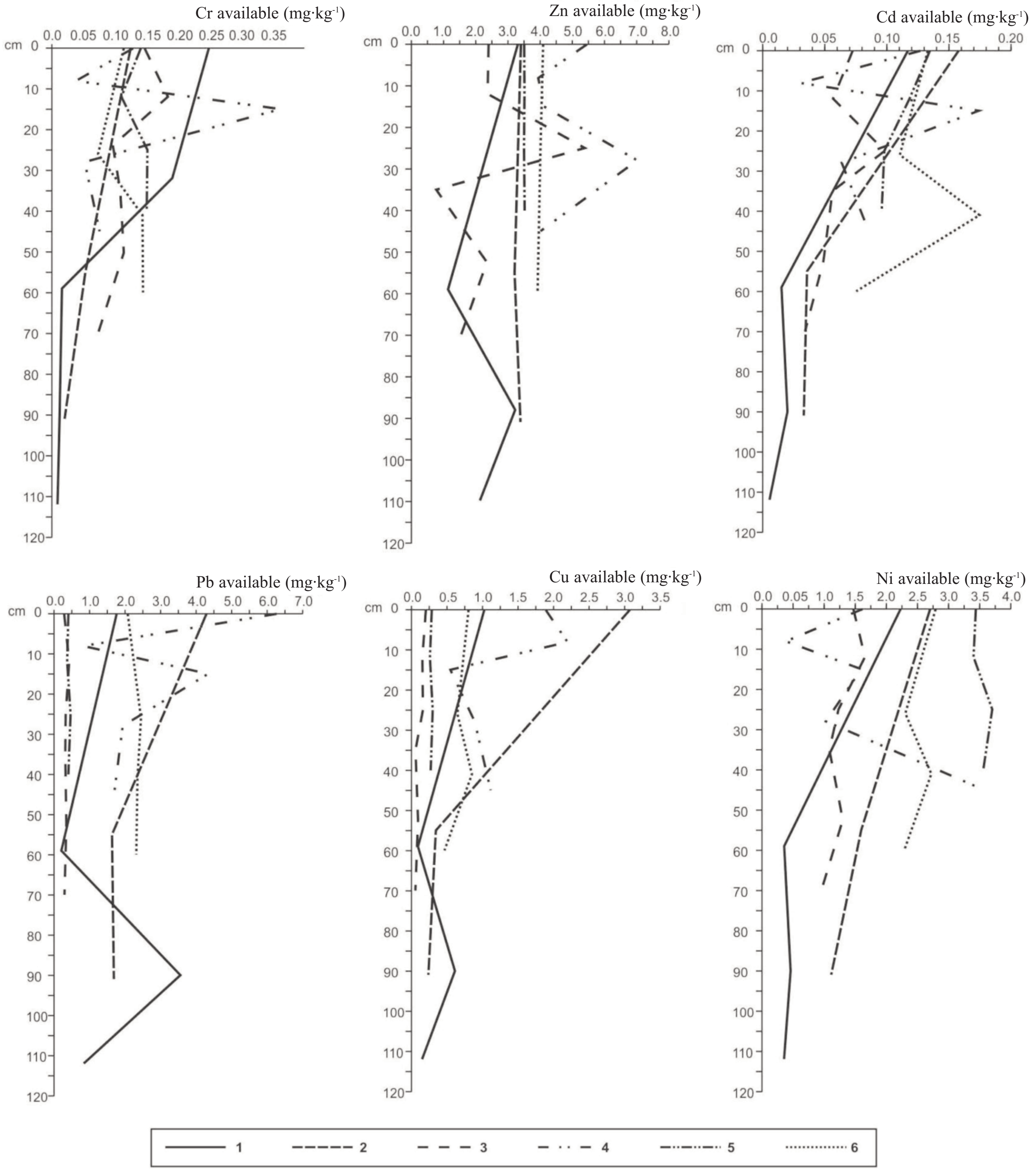

Fig. 2. Continued.

The percentage of bioavailable forms in the total content of heavy metals shows mobility of elements in studies areas (Table 3). The greater the part of bioavailable forms of the total content of elements, the higher the mobility of heavy metals in the soil. In the soils the highest bioavailability is characterized by Cd, and then Zn, Pb, Cu, Ni, Cr. Generally, though not always, in the anthropogenic soils the largest concentrations of the elements in bioavailable forms are present in surface levels.

Worthy of note is the fact that in all six studied soils the vertical distribution of total and bioavailable heavy metal concentrations in soils does not reveal distinct trends.

Discussion

The analysis of the main physico-chemical features of the studied soils indicates a considerable participation of anthropogenic factor in their formation and transformation.

Table 3. Percentage of bioavailable forms in total content of heavy metals in urban soils of Lublin.

Prof. No.	Horizon [39]	Depth [cm]	$Me_{dtpa}/Me_{tot} \times 100$ [%]					
			Cr	Zn	Cd	Pb	Cu	Ni
Building investment areas (BA)								
1	A	0-46	2.22	6.10	16.78	5.04	7.10	2.80
	2C	46-72	0.06	0.64	2.11	2.39	3.74	0.28
	3C1	72-107	0.14	2.25	2.82	9.25	5.92	0.70
	3C2	107-117	0.09	1.38	0.91	5.87	3.98	0.60
Industrial areas (IA)								
2	Au	0-28	0.65	4.43	10.59	4.44	5.41	1.28
	Cu	28-82	0.25	7.77	3.22	4.85	3.33	1.49
	2Cu	82-100	0.11	6.31	12.49	5.15	3.21	1.19
Educational centre areas (EA)								
3	A1	0-5	1.36	10.62	5.47	2.77	3.85	3.14
	A2	5-20	1.50	4.77	7.09	2.67	3.51	3.96
	Cu1	20-30	1.07	2.69	7.57	3.45	3.49	4.66
	Cu2	30-40	0.91	4.17	8.77	2.75	2.11	4.11
	Cu3	40-60	1.16	4.57	11.21	4.01	2.73	4.13
	C	60-80	1.03	16.15	15.30	4.33	2.49	5.14
Traffic areas (TA)								
4	A	0-4	0.98	7.62	19.67	8.02	4.65	1.68
	2Cu1	4-12	0.51	16.17	5.63	3.94	3.10	0.86
	2Cu2	12-18	1.45	5.81	10.12	3.50	5.75	0.98
	2Cu3	18-38	0.48	8.70	7.78	5.77	1.63	1.26
	2C	>38	0.39	12.39	27.68	7.00	8.28	2.37
Housing areas (HA)								
5	A	0-5	1.20	9.08	19.92	1.46	2.85	5.11
	Au	5-20	1.10	11.77	18.67	1.43	3.32	5.86
	Cu1	20-30	1.52	9.12	17.04	1.71	3.73	6.83
	Cu2	30-50	1.93	7.97	17.27	1.76	4.13	6.64
Garden areas (GA)								
6	A	0-20	0.54	8.37	9.14	5.47	6.55	2.32
	C	20-32	0.42	20.53	12.29	7.96	6.25	2.22
	2C	32-50	0.71	16.92	12.04	6.78	6.59	3.48
	2C	50-70	0.84	22.23	10.49	6.92	5.66	5.81

Particle-size distribution of these soils varies greatly, with sharp changes at the contacts between individual horizons. The described soils have features of urban soils that are defined by Burghardt during the First International Conference on Soils of Urban, Industrial, Traffic, and Mining Areas [24]. Such soils are also often characterized by a high content of sand in near-surface horizons. Urban soils in the investigated areas of Lublin city contain considerable quantities of components typical of the method of land use in particular zones. These components considerably influence physico-chemical features of the soils. Their distinct alkalization results from the fall of alkaline dust produced by motor traffic, the use of agents for clearing snow from the streets, and first of all from the occur-

Table 4. Average heavy metal concentrations (mg·kg^{-1}) in urban soils from different cities around the world.

	Cr-tot	Zn-tot	Cd-tot	Pb-tot	Cu-tot	Ni-tot	Reference
Lublin, Poland	14.12	61.17	0.83	31.85	15.67	8.27	This study
Toruń, Poland	2.28	43.00	0.33	29.00	22.50	6.60	[3]
Zielona Góra, Poland	–	80.00	0.40	39.50	24.80	11.10	[3]
Beijing, China	60.27	89.63	0.19	39.50	34.43	25.87	[5]
Palermo, Italy	34.00	138.00	0.68	202.00	63.00	17.80	[30]
Bangkok, Thailand	26.4	118.00	0.29	47.80	41.70	24.80	[38]

rence of anthropogenic calcium carbonate – which has been introduced to soils with building rubble containing debris of sandy-calcareous mortar [25].

The mean contents of Cu, Cr, Cd, Pb, and Zn are higher than the average values found in mineral soils of Poland, while the concentrations of other elements are lower [20]. The concentration of heavy metals in the Lublin urban soils is similar to the concentrations presented for other cities in Poland and other parts of the world (Table 4). Only the mean content of Cd measured in this experiment was higher than all data achieved in Poland, Europe, and the world.

In general, alkaline reaction reduces mobility of some heavy metals and contributes to their accumulation in different soil horizons [26, 27]. For this reason, the highest concentrations of heavy metals are often not found in near-surface horizons. In soil affected by strong anthropopression, consisting of mixing soil horizons or bringing in new earth layers of unknown origin in order to level ground, the maximum heavy metal concentrations often occur at different depths. The occurrence of building materials in soils considerably influences ion exchange in the sorption complex (BS). Low values of hydrolytic acidity and the saturation with alkaline cations reaching over 97% result in strong bonding of heavy metals and, in consequence, low proportions of total heavy metals that are bioavailable. The researchers studying heavy metals in soils of Sewille city parks found that the low proportions of total heavy metals that are bioavailable (especially of Cr and Ni) indicate their natural origin and the same origin of all horizons composing a soil [4]. The bioavailable concentrations reaching over 10% of total contents may indicate great heterogeneity of soils and anthropogenic origin of heavy metals [28].

In the studied urban soils of Lublin heavy metals are not very mobile. From several to about 10 percent of total heavy metals is bioavailable. Many papers indicate that the main role in bonding of heavy metals in soils is played, among other things, by humus and clay mineral, and also some properties of soils, e.g. alkaline reaction of soils [27-29]. Vertical distribution of organic carbon in deeper horizons of the studied profiles is varies greatly, which is typical of anthropogenic soils (e.g., due to bringing in a new earth layer or mixing the soil material). The comparison of total and bioavailable heavy metal concentrations with the contents of humus and granulometric fractions (in it of clay mineral) in the urban soils of Lublin indicates that their relationship is weak.

The type of land use in the selected areas in Lublin influences the contents of analysed heavy metals in soils, and these regularities are in accordance with observations made by other authors [5, 30, 31]. The highest contents of heavy metals in the near-surface horizons and the increased concentrations in the whole profiles are found in the soils of industrial (IA) and traffic (TA) areas. The profile from the industrial zone is located in the area of Daewoo Motor Polka's bankrupt estate near the power plant. The soil is contaminated by the products of coal combustion and metal treatment, as well as chemicals from the car paint shop. Heavy metals occurring in the soil of the traffic area are mainly produced by motor traffic. In the studied zone different parts of cars are being worn and petrol fumes are emitted especially intensively during frequent traffic jams. This results in the increased concentrations of heavy metals, especially Pb, Cu, and Cd, which is typical of zones affected by intensive traffic [32-34]. Increased concentrations of Cd and Cr are also found in the garden area (GA). This is probably caused by several problems that are unresolved in this area, i.e. collection of municipal waste and worn out elements of small agricultural equipment, garbage burning, over-fertilization of soil in order to obtain better crops, dustfall, and traffic contamination [35-37].

Lower concentrations of heavy metals are found in the soils of other studied areas where the sources of contaminants are less numerous. The comparison with heavy metals contents in urban soils of other cities in Poland, Europe, and the world indicates that Lublin's urban soils are not very contaminated. However, there is a relationship between the heavy metal contents and type of urban land use, as also observed by other authors [3, 5, 31, 37, 38].

The present quality of anthropogenic soils in Lublin, manifested by the content of heavy metals (Cd, Cr, Cu, Pb, Ni, Zn), is influenced by a set of anthropogenic factors – from the proximity of industrial plants through the activity of allotment holders, bringing in new earth layers of unknown origin to motor traffic.

Conclusions

Total contents of Cu, Cd, Pb, and Zn in the Lublin urban soils are higher than the average values found in mineral soils of Poland, but do not exceed the limits permissible in

Poland, Germany, and Holland. The heavy metal concentrations in the Lublin urban soils are similar to those occurring in other cities in Poland and the world. The increased contents of Cu, Ni, and Pb are found in the soils of industrial (IA) and traffic (TA) areas, Zn in the building area (BA), and Cd in the garden area (GA). Distribution of total and bioavailable heavy metal contents in urban soils indicates that industrial activity and motor traffic are most responsible for soil contamination with heavy metals. The proportion of total heavy metals that are bioavailable, being the indicator of its mobility, is the highest for Zn and Cd.

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