Title: Soil contamination with zinc, cadmium and lead in the city of Zabrze

Author: Marta Kandziora-Ciupa, Aleksandra Nadgórska-Socha, Ryszard Ciepał, Artur Słomnicki, Gabriela Barczyk

Citation style: Kandziora-Ciupa Marta, Nadgórska-Socha Aleksandra, Ciepał Ryszard, Słomnicki Artur, Barczyk Gabriela (2013). Soil contamination with zinc, cadmium and lead in the city of Zabrze. „Ecological Chemistry and Engineering A" (2013, no. 1, s. 47-54), DOI: 10.2428/ecea.2013.20(01)005

DOI: 10.2428/ecea.2013.20(01)005 ECOL CHEM ENG A. 2013;20(1):47-54

Marta KANDZIORA-CIUPA[1], Aleksandra NADGÓRSKA-SOCHA[1], Ryszard CIEPAŁ[1], Artur SŁOMNICKI[1] and Gabriela BARCZYK[1]

SOIL CONTAMINATION WITH ZINC, CADMIUM AND LEAD IN THE CITY OF ZABRZE

ZANIECZYSZCZENIE GLEBY CYNKIEM, KADMEM I OŁOWIEM NA TERENIE ZABRZA

Abstract: Heavy metal concentrations were evaluated in topsoil (0–10 cm) in the city of Zabrze. Soil samples were taken from 71 sites distributed evenly throughout the city, in the vicinity of emitters, roads, residential areas and parks, representing various biotopes – mainly green belts, squares, fields, brownfields, lawns, forests and meadows. Average Zn concentrations ranged from 31.7 mg · kg^{-1} (meadows) to 2057.1 mg · kg^{-1} (brownfields). The highest Cd concentrations were also found in brownfields. The average Cd concentrations ranged from 0.15 up to 13.1 mg · kg^{-1}. The Pb concentrations ranged from 31.5 to 520 mg · kg^{-1} and were the lowest in meadows. The highest heavy metal pollutions were in soil samples collected in the vicinity of roads and industrial plants. Results indicate the necessity of soil pollution mapping in cities, especially for proper human risk assessment and for the prevention of further pollution spread.

Keywords: heavy metals, zinc, lead, cadmium, pollution

Introduction

Urban soils are known to have peculiar characteristics, such as unpredictable layering, poor structure and high concentrations of trace elements [1]. Soils in urban environments have a highly variable and often unknown history as a result of differences in land use, transfer between sites and mixing in connection with excavations, addition of new soil material etc. [2].

In urban soils the anthropogenic sources of heavy metals include traffic emissions (vehicle exhaust particles, tyre wear particles, weathered street surface particles, brake lining wear particles), industrial emissions (power plants, coal combustion, metallurgical industry, auto repair shops, chemical plants, etc.), domestic emissions, weathering of buildings and pavement surfaces, atmospheric deposition and so on [3].

[1] Department of Ecology, Faculty of Biology and Environment Protection, University of Silesia, ul. Bankowa 9, 40-007 Katowice, Poland, phone: +48 32 359 11 18, email: marta.kandziora-ciupa@us.edu.pl

Heavy metals are considered to be one of the main sources of environmental pollution and have a significant effect on soil ecological quality [1]. An assessment of the environmental risk due to soil pollution is of particular importance because heavy metals, which are potentially harmful to human health, persist in soils for a very long time [4]. Cadmium, lead, and zinc are good indicators of contamination in soil because they appear in gasoline, vehicle exhaust, car components, industrial emissions etc. [5].

The aim of this study was to investigate the concentrations of selected heavy metals (Zn, Cd, Pb) in topsoil samples in the city of Zabrze (southern Poland, Silesia province) as a basis for assessment of the degree of anthropopressure.

Material and method

The investigation was carried out on topsoil in the city of Zabrze in 2010. Samples of soil (from the level 0–10 cm) were taken from 71 sites (Table 1) located evenly throughout the city in the vicinity of emitters, roads, residential areas and parks. The investigated areas represented various biotopes (green belts, squares, fields, brownfields, lawns, forests and meadows).

Table 1

Sampling sites

Sampling sites no.	Latitude	Longitude	Sampling sites no.	Latitude	Longitude
1	50°17′54.17″N	18°47′18.14″E	36	50°22′46.51″N	18°48′39.20″E
2	50°18′7.83″N	18°47′18.45″E	37	50°21′43.26″N	18°49′0.06″E
3	50°18′18.86″N	18°46′57.42″E	38	50°22′5.36″N	18°47′25.30″E
4	50°15′36.98″N	18°45′36.36″E	39	50°17′27.57″N	18°47′33.83″E
5	50°15′20.97″N	18°46′9.51″E	40	50°16′59.18″N	18°47′21.50″E
6	50°17′55.97″N	18°47′58.09″E	41	50°16′37.13″N	18°47′1.36″E
7	50°17′39.65″N	18°48′30.99″E	42	50°16′18.92″N	18°46′37.75″E
8	50°17′41.04″N	18°49′27.14″E	43	50°15′56.83″N	18°45′58.89″E
9	50°18′6.31″N	18°50′15.07″E	44	50°16′26.80″N	18°47′42.71″E
10	50°18′12.63″N	18°49′36.53″E	45	50°16′8.10″N	18°47′45.96″E
11	50°18′15.95″N	18°48′53.73″E	46	50°16′48.51″N	18°47′51.75″E
12	50°18′2.84″N	18°48′14.33″E	47	50°17′53.67″N	18°46′47.49″E
13	50°18′25.81″N	18°46′27.11″E	48	50°17′28.41″N	18°46′57.95″E
14	50°18′19.17″N	18°46′0.86″E	49	50°16′49.49″N	18°48′29.50″E
15	50°18′17.62″N	18°45′26.63″E	50	50°16′51.30″N	18°49′24.12″E
16	50°18′20.73″N	18°44′25.18″E	51	50°17′18.39″N	18°48′55.67″E
17	50°18′41.32″N	18°44′45.44″E	52	50°19′5.03″N	18°46′35.59″E
18	50°18′40.21″N	18°45′19.93″E	53	50°19′37.93″N	18°46′25.38″E
19	50°18′43.01″N	18°46′2.93″E	54	50°20′2.83″N	18°46′1.52″E
20	50°18′40.40″N	18°47′8.24″E	55	50°19′41.77″N	18°51′43.02″E
21	50°19′1.03″N	18°47′5.76″E	56	50°20′15.90″N	18°49′36.41″E

Table 1 contd.

Sampling sites no.	Latitude	Longitude	Sampling sites no.	Latitude	Longitude
22	50°19′29.31″N	18°47′10.53″E	57	50°20′35.53″N	18°49′12.37″E
23	50°19′56.08″N	18°46′51.09″E	58	50°19′40.10″N	18°49′18.64″E
24	50°20′21.10″N	18°46′46.38″E	59	50°16′58.24″N	18°46′44.39″E
25	50°20′46.48″N	18°46′11.33″E	60	50°16′51.58″N	18°46′1.09″E
26	50°21′8.73″N	18°46′7.72″E	61	50°17′4.51″N	18°45′19.46″E
27	50°21′37.18″N	18°46′11.06″E	62	50°17′40.55″N	18°45′52.87″E
28	50°22′20.77″N	18°46′49.93″E	63	50°17′58.27″N	18°46′8.32″E
29	50°18′40.62″N	18°47′53.36″E	64	50°17′58.35″N	18°44′45.30″E
30	50°19′6.49″N	18°48′55.57″E	65	50°19′13.39″N	18°44′35.09″E
31	50°19′29.44″N	18°49′50.37″E	66	50°19′19.56″N	18°45′27.68″E
32	50°19′51.08″N	18°50′34.86″E	67	50°19′42.02″N	18°45′37.10″E
33	50°21′29.03″N	18°47′43.74″E	68	50°20′11.64″N	18°45′4.94″E
34	50°21′49.80″N	18°48′4.17″E	69	50°19′36.38″N	18°44′54.99″E
35	50°22′21.57″N	18°48′13.26″E	70	50°20′18.77″N	18°46′15.90″E
			71	50°20′53.80″N	18°48′7.33″E

The topsoil samples were air-dried and sieved through a 1 mm sieve. Metals were extracted with 10 % HNO_3 [6]. The concentrations of metals (Zn, Cd and Pb) were measured by flame absorption spectrometry (Unicam 939 Solar). The quality of the analytical procedures was controlled using reference material (Certified Reference Material CTA-OTL-1 Oriental Tobacco Leaves). Fig. 1–3 were drawn using the Surfer 8 program.

Results and discussion

Zn, Pb and Cd contaminations in Zabrze based on metal content in soil was presented by means of isolines in the Fig. 1–3. The lowest values of concentration were marked with the bright color and the highest with the dark color. Contents of Zn, Pb and Cd in upper layer of the soil in various biotopes were presented by Fig. 4–6.

The average Zn soil concentrations in different countries fall within the range of 30–120 mg $\cdot$ kg^{-1}. The average Zn content for non-polluted soils in Poland is 40 mg $\cdot$ kg^{-1} and the permitted Zn concentration in soil is 300 mg $\cdot$ kg^{-1} [7].

In our study, Zn concentrations ranged from 31.69 to 2057.16 mg $\cdot$ kg^{-1}. The mean Zn soil content was 242.27 mg $\cdot$ kg^{-1}. The lowest Zn content was observed in the soils from meadows and forests, and the highest Zn content was recorded near the defunct landfill of the Zabrze smelter, with the limit value exceeded many times. The allowable concentration of zinc in Polish soils was also exceeded in 16 of the 70 research sites. For comparison, Indeka and Karaczun [8] in the city of Katowice reported significant exceeding of the soil limit values (680.0 mg $\cdot$ kg^{-1}). In the Krakow conurbation, the average Zn soil concentration was 104.2 mg $\cdot$ kg^{-1}, ranging from 36.1 to 732.0 mg $\cdot$ kg^{-1}

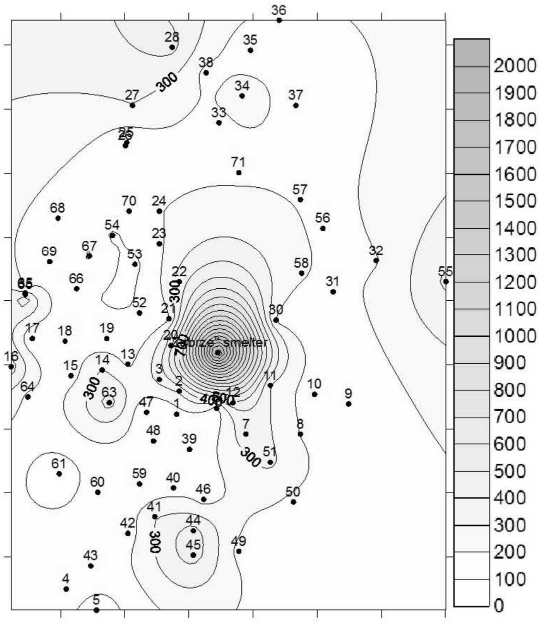

Fig. 1. Zn contamination in Zabrze based on metal content in soil [mg · kg^{-1} d.m.]

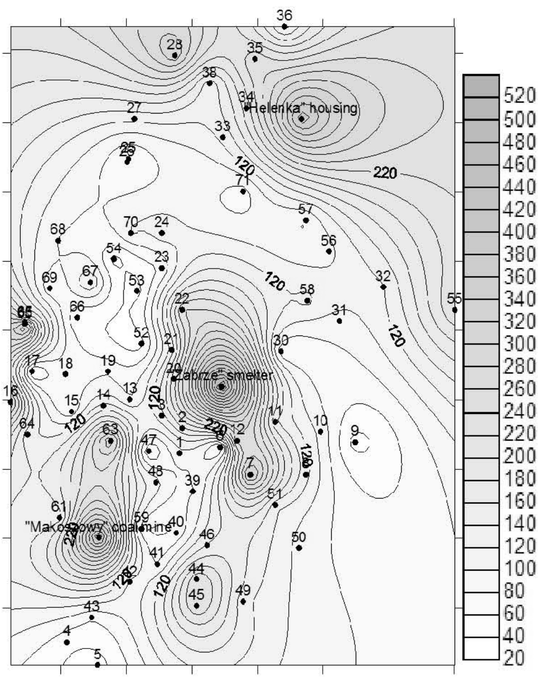

Fig. 2. Pb contamination in Zabrze based on metal content in soil [mg · kg^{-1} d.m.]

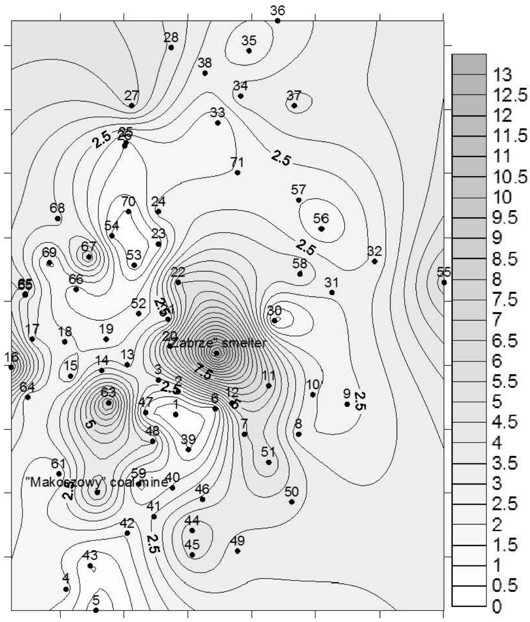

Fig. 3. Cd contamination in Zabrze based on metal content in soil [mg · kg^{-1} d.m.]

[9]. Average Zn content obtained in our study was much higher than that found by Grzebisz et al [4] in Poznan (72.98 mg · kg^{-1}) and Greinert [10] in the soils in the city of Zielona Gora (18.30 mg · kg^{-1}). Also Marjanovic et al [5] in Belgrade, Linde et al [2] in Stockholm and Lee et al [11] in Hong Kong observed lower Zn soil concentrations than in our current paper.

Pb content in soil closely depends on mineralogical and granulometric composition and derivation of soil bedrocks while at the same time occurrence of this element in topsoil is primarily connected with anthropogenic factors. Pb content in unpolluted soils should amount to 20 mg · kg^{-1}, although Gambus and Gorlach [9] increase this range to 25 mg · kg^{-1}, giving also Pb content for the polluted soils within 4560 mg · kg^{-1}. Permissible Pb concentration in soil is 100 mg · kg^{-1} [7], while the average Pb content in topsoils in Zabrze was 134.27 mg · kg^{-1}. In the majority of biotopes admissible Pb concentrations were exceeded. Also Lukasik et al [12] in studies on the area of Piekary Slaskie found a 4–25 times greater Pb concentration than permissible standards. Kabata-Pendias, Pendias [7] state that in Upper Silesia Pb concentration can reach from 6000 to 8000 mg · kg^{-1} of soil. A much lower Pb content was observed in soils in Krakow conurbation by Pasieczna [13] – 45.52 mg · kg^{-1}.

To the most Cd polluted soils can be found in southern Poland, especially Silesia and Malopolska Districts. From monitoring studies of Terelak et al [14] it results that soils of higher Cd content than natural make up 67.3 % of soils in Silesia and 45.3 % in Malopolska. The range of mean Cd content in world soils is within the 0.2–1.05 mg · kg^{-1} range, and in Poland it is 0.2 mg · kg^{-1} [7]. The maximum limit for Cd in soils

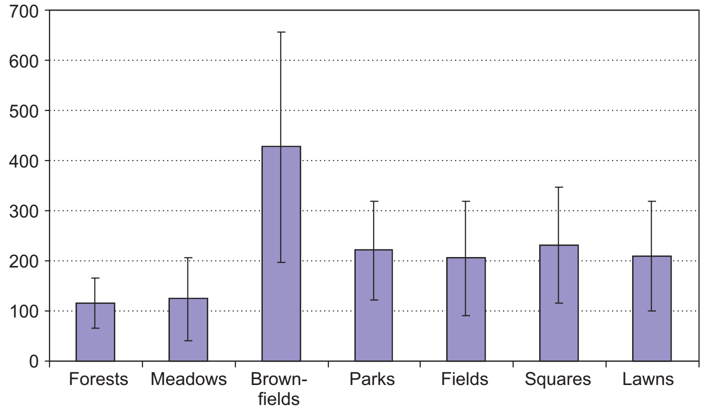

Fig. 4. Content of Zn in the upper layer of soil in various biotopes [mg · kg^{-1} d.m.]

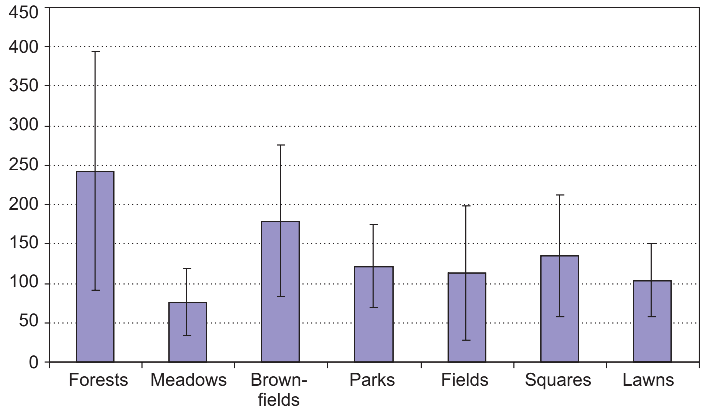

Fig. 5. Content of Pb in the upper layer of soil in various biotopes [mg · kg^{-1} d.m.]

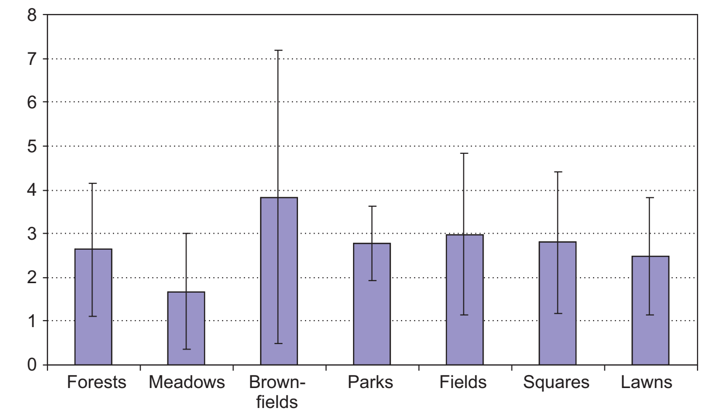

Fig. 6. Content of Cd in the upper layer of soil in various biotopes [mg · kg^{-1} d.m.]

is 4 mg · kg^{-1} (Polish Journal of Laws). At low pH values (4.5–5.5) Cd becomes very soluble and mobile. In surface environments, more than 90 % of Cd comes from anthropogenic sources [13, 15]. In our study, the average Cd content in soils was 2.87 mg · kg^{-1}, with the highest accumulation, exceeding the permissible content, near the defunct Zabrze Smelter (13.14 mg · kg^{-1}) and north of the "Makoszowy" coal mine. At the other sites and biotopes Cd did not exceed the permissible limit. Definitely lower cadmium content than the obtained in our study, was recorded by Arasimowicz [16] in Krakow conurbation (0.85 mg · kg^{-1}), Grzebisz et al [4] in soils in Poznan (0.755 mg · kg^{-1}), Linde et al [2] in Stockholm (0.40 mg · kg^{-1}) and De Miguel et al [17] in Madrid (0.14 mg · kg^{-1}).

The content of Zn, Pb and Cd in the soil within the city of Zabrze is highly variable. The highest heavy metals pollution was found in the soils samples collected in the vicinity of roads and industrial plants in the city. In general, pollution level mapping is necessary especially for proper human risk assessment and for further pollution spread prevention.

References

[1] De Moura MCS, Moita GC, Moita Neto JM. Analysis and assessment of heavy metals in urban surface soils of Teresina, Piaui State, Brazil: a study based on multivariate analysis. Comunicata Scientiae. 2010;1(2):120-127.

[2] Linde M, Bengtsson H, Oborn I. Concentrations and pool of heavy metals in urban soils in Stockholm, Sweden. Water Air Soil Pollut. 2001;1:83-101. DOI: 10.1023/A:1017599920280.

[3] Wei B, Yang L. A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. Microchem J. 2010;94:99-107. DOI: 10.1016/j.microc.2009.09.014.

[4] Grzebisz W, Cieśla L, Komisarek J, Potarzycki J. Geochemical assessment of heavy metals pollution of urban soils. Polish J Environ Stud. 2002;11(5):493-499.

[5] Marjanović MD, Vukčević MM, Antonović DG, Dimitrijević SI, Jovanović ĐM, Matavulj MN, Ristić MĐ. Heavy metals concentration in soils from parks and green areas in Belgrade, J Serb Chem Soc. 2009;74(12):697-706.

[6] Ostrowska A, Gawliński S, Szczubiałka Z. Metody analizy i oceny właściwości gleb i roślin. Warszawa: IOŚ; 1991.

[7] Kabata-Pendias A, Pendias H. Biogeochemia pierwiastków śladowych. Warszawa: PWN; 1993.

[8] Indeka L, Karaczun ZM. Cynk w glebach położonych przy ruchliwych trasach komunikacyjnych [Zinc accumulation in soils located near traffic routes]. Zesz Nauk Komitetu "Człowiek i Środowisko" PAN. 2002;33:213-220.

[9] Gorlach E, Gambuś F. Potencjalnie toksyczne pierwiastki śladowe w glebach (nadmiar, szkodliwość i przeciwdziałanie). Zesz Probl Post Nauk Roln. 2000;472:275-296.

[10] Greinert A. Selected heavy metals and their behaviour in urban soils versus soil qulity standarts. Environ Protect Eng. 2010;36(1):45-53.

[11] Lee CS, Li XD, Shi WZ, Cheung SC, Thorton I. Metal contamination in urban, suburban and country park soils of Hong Kong: A study based on GIS and multivariate statistics. Sci Total Environ. 2006;356:45-61. DOI: 10.1016/j.scitotenv.2005.03.024.

[12] Łukasik I, Palowski B, Ciepał R. Lead, cadmium, and zinc contents in soil and leaves of selected tree and shrub species grown in Urban parks of upper Silesia. Ecol Chem Eng. 2002;9(4):431-439.

[13] Pasieczna A. Atlas zanieczyszczeń gleb miejskich w Polsce. Warszawa: Państwowy Instytut Geologiczny; 2003.

[14] Trelak H, Motowicka-Trelak T, Stuczyński T, Pietruch C. Trace elements (Cd, Cu, Ni, Pb, Zn) in agricultural soils of Poland (in Polish). Warszawa: Inspekcja Ochrony Środowiska; 2000.

[15] Dziadek K, Wacławek W. Metale w środowisku. Część I: Metale ciężkie (Zn, Cu, Ni, Pb, Cd) w środowisku glebowym. Chem Dydakt Ekol Metrol. 2005;10(1/2):33-44.

[16] Arasimowicz M. Zawartość kadmu, ołowiu i niklu w glebie oraz szpilkach sosny zwyczajnej (*Pinus sylvestris* L) z terenu aglomeracji krakowskiej. Krakowska Konferencja Młodych Uczonych. 2009;245-253.

[17] De Miguel E, Irribarren I, Chacon E, Ordonez A, Charlesworth S. Risk-based evaluation of the exposure of children to race elements in playgrounds in Madrid (Spain). Chemosphere. 2007;66:505-513. DOI: 10.1016/j.chemosphere.2006.05.065.

ZANIECZYSZCZENIE GLEBY CYNKIEM, KADMEM I OŁOWIEM NA TERENIE ZABRZA

Katedra Ekologii, Wydział Biologii i Ochrony Środowiska
Uniwersytet Śląski

Abstrakt: Oceniano zanieczyszczenie wierzchniej warstwy gleby na terenie Zabrza. Próbki gleby pobierano z 71 stanowisk równomiernie rozłożonych na terenie tego miasta: w pobliżu emitorów zanieczyszczeń, tras komunikacyjnych, z terenu osiedli mieszkaniowych, parków. Stanowiska badań reprezentowane były przez różne biotopy m.in. pasy zieleni, skwery, pola uprawne, nieużytki, trawniki, lasy i łąki. Średni poziom Zn mieścił się w granicach od 31,7 (łąka) do 2057,1 (nieużytki) $mg \cdot kg^{-1}$. Najwyższe stężenia Cd stwierdzono w próbkach gleby pobieranych na terenie nieużytków. Średnia zawartość Cd wahała się od 0,15 do 13,1 $mg \cdot kg^{-1}$. Najniższe koncentracje Pb stwierdzono w próbkach gleby pobieranych na łąkach. Średni poziom zanieczyszczenia tym pierwiastkiem mieścił się w granicach od 31,5 do 520 $mg \cdot kg^{-1}$. Najwyższe poziomy analizowanych metali ciężkich wykazano w próbkach gleby pobieranych w pobliżu emitorów zanieczyszczeń i tras komunikacyjnych. Tworzenie mapy zanieczyszczeń wydaje się być konieczne i pomocne w oszacowaniu ryzyka narażenia zdrowia ludzi, a także może posłużyć w zapobieganiu dalszego rozprzestrzeniania się zanieczyszczeń.

Słowa kluczowe: metale ciężkie, cynk, ołów, kadm, zanieczyszczenie