Soil Pollution Caused by Landfilling of Nonhazardous Waste from Steel Production Processes

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Investigated was the soil at an old metallurgical landfill site of CMC Sisak Ltd. which has been exposed to the direct influence of metallurgical nonhazardous waste for many years. Concentrations of heavy metals (Cd, Cr, Cu, Hg Ni, Pb, and Zn) after extraction in *aqua regia* were determined. Heavy metal concentrations, except Hg, were determined by inductively coupled optical emission spectrometry and inductively coupled plasma mass spectrometry (ICP-OES, ICP-MS). Concentration of Hg was determined by atomic absorption spectrometry.

Our objective was to assess the pollution level according to the potentially unacceptable risk limit levels for industrially used soil prescribed by the Croatian Soil Monitoring Program, and levels permitted by some EU member countries.

The results of heavy metal concentrations in composite samples of landfill soil were also compared with the results obtained from the reference sample taken in the nearby park, outside the battery limits. The obtained results qualify the analysed landfill soil as contaminated with Cu according to the legislation of all observed EU countries, with Cd according to the legislation of Italy, Poland, and Belgium (Wallonia), and with Cr according to the legislation of Finland and Poland. To allow future use of the landfill certain measures of soil treatment will be necessary.

Key words: *Soil, pollution, landfill, nonhazardous waste*

Introduction

From the environmental point of view, metallurgical production is a particularly important industrial branch, considering the applied technology (processes of roasting and sintering of metal ores, processes of raw iron and steel production, production and processing of ferrous and nonferrous metals). The pollutants from these processes harmful to air, water and soil, are significant amounts of gas and solid pollutants.[1] The most common pollutants occur as: dust, SO_2, NO_x, NH_3, H_2SO_4, HCl, HF, HCN, H_2S, CO, CO_2, CH_4, heavy metals (Hg, Pb, Cr, Ni, Zn, Cd, Cu) in wastewaters, and gases, benzene, phenol, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans, cyanide, oil, grease, *etc*.

The type of pollution or pollutant from the metallurgical production process depends on the nature of the technological operation conducted on a given location and the duration of the process. The intensity of the pollution depends on the type of pollutant emitted from the process and its interaction with the environment in real life conditions. In addition to air and water pollution, metallurgical processes can contribute to soil pollution by emissions of metal-containing fumes and dust transported by air and eventually deposited into the soil and vegetation. Additional pollutant influence, spatial impact of heavy metals, can be prolonged if by-products and/or waste (unprocessed slag, mill scales, linings and refractories, sludge, *etc*.) are uncontrollably disposed in the so-called industrial landfill. Metallurgical waste materials disposed of at industrial landfills are major sources of potentially toxic metals and may constitute a serious environmental problem in the area where they are disposed. The release of toxic heavy metals from the waste materials during weathering leads to pollution of the surrounding soil, as well as surface and ground waters.

Specialized papers commonly discuss the types of pollution and emission impact of various metallurgical processes, either during the process itself[2–5] or the influence of the created waste or the harmful substances it contains on the environment.[6–8] However, a limited number of articles discuss the impact that disposed metallurgical waste material can have on soil pollution.[9–17]

Since the mid-nineteenth century, the growing activity of steel and iron smelting factories in industrialized nations has been generating large amounts of metallurgical waste, which is generally deposited on or close to the production

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sites in areas called industrial landfills/dumps. Although this waste contains high levels of heavy metals (Hg, Pb, Cr, Ni, Zn, Cd, Cu), most of the former or existing metallurgical landfills/dumps, areas which may extend over several hectares, are now abandoned without adequate safety measures and their environmental impact has been poorly studied.

Consequently, as the potential hazardousness of these highly polluted sites is still largely unknown, it is very difficult to propose remediation techniques or new occupational plans. Unfortunately, according to the available papers in Europe, only a few dump sites of metallurgical factories have been extensively examined, both for their heavy metals content and speciation, and for their pedological characteristics.[12,13,18–20]

According to *E. Remon et al.*[14] the only way to influence or minimize the presence, *i.e.* concentration of toxic heavy metal is to control and stabilize the existing landfill areas. In this respect, restoration of an adequate plant cover[21,22] could be an effective alternative in treating polluted metallurgical landfills, which could serve dual objectives. The first is a sustainable site reclamation, and the second a visual improvement of highly degraded areas.

We investigated the soil at an old metallurgical landfill area (size of active area about 3000 m^2) of CMC Sisak Ltd., which has been exposed to the direct influence of metallurgical non-hazardous waste for a long time. Our objective was to determine the content of the heavy metals by chemical extraction procedures as a first step towards assessing the pollution, as well as choosing methods for its treatment and preparation for continued industrial use in accordance with applicable Croatian laws.

Fig. 1 – *Uncontrolled waste disposal site on the landfill within battery limits*

Slika 1 – *Izgled nekontrolirano odlaganog industrijskog otpada na odlagalištu unutar kruga tvornice*

Fig. 2 – *Landfill after cleaning and removal of waste*

Slika 2 – *Izgled odlagališta nakon čišćenja i odvoza otpada*

Experimental

Sampling

The soil was sampled after waste removal and cleaning of the landfill where the nonhazardous waste from the steel and pipe production processes had been disposed. This unordered, so-called factory landfill had served as a disposal site for several types of industrial nonhazardous waste over a period of 50 years (waste key number: 10 02 02 – unprocessed slag; 10 02 10 – mill scales; 16 11 04 – other linings and refractory from metallurgical processes; 19 09 02 sludges from water clarification; 19 09 03 – sludges from decarbonation). In addition to industrial waste, the examined site was also used for disposing other nonhazardous waste, mainly generated from maintenance, reconstruction, and building of new production lines and buildings (15 01 03 – wooden packaging; 20 01 01 – paper and cardboard; 20 01 39 – plastics; 20 03 07 – bulky waste; 17 01 07 – mixture of concrete, bricks, tiles and ceramics), Fig. 1.

After waste removal and landfill cleaning (Fig. 2), sampling of individual soil samples, and the forming of average soil samples was organized according to the directions given by the Croatian Soil Monitoring Program.[23]

Considering the size of the investigated polluted area (about 3000 m^2) and recommendations given by the Croatian Soil Monitoring Program[23] on the average number of samples for potentially polluted areas, two composite samples from the investigated landfill area were collected. It is important to emphasize that when an average sampling method is applied, the investigated terrain should be homogeneous, *i.e.* there should be no difference in exposition, inclination, altitude, soil usage *etc*.

Due to research complexity of potentially polluted locations and considering the pollutant heterogeneity on a relatively small area, the forming of composite samples is preferred in practice. Two composite samples A1 and A2 were prepared from soil samples collected in an imaginary circle of 20 and 50 m radius from the centre of the landfill.

Several composite samples weighing 2000 g were prepared. Each composite sample was made by mixing 4 sub-samples of an exact amount (250 g each to a total of 1000 g) collected in an imaginary circle north, west, south and east from the landfill centre. The samples were mixed at the collection point.

To determine soil pollution caused by emissions from production processes, additional samples (B1–B9) from surface layer (callow) 0–10 cm (B1–B9) were taken from the area around the melt shop and pipe mill. Sampling density for B1–B9 was 4 samples/km^2 with 5 sub-samples (one composite sample of 1500 g) at the sampling site, collected from each corner and the centre of the square (2 m × 2 m). Concentrations of heavy metals were determined (Cd, Cr, Cu, Hg Ni, Pb and Zn) both in those samples and in the composite samples from the landfill.

In addition, one reference sample was collected from the surface layer (callow) 0–10 cm at the sampling site collected from each corner and the centre of the square 2 m × 2 m in a nearby park outside the CMC Sisak Ltd. battery limits approximately 1500 m air-line distance in north-west direction. Activities carried out at the landfill have no direct influence on the park where the reference sample was collected, and as such represent the soil image of a wider area. The reference soil sample was collected in the same manner as samples used for preparation of composite samples.

Cd, Cr, Cu, Hg, Ni, Pb, and Zn concentrations

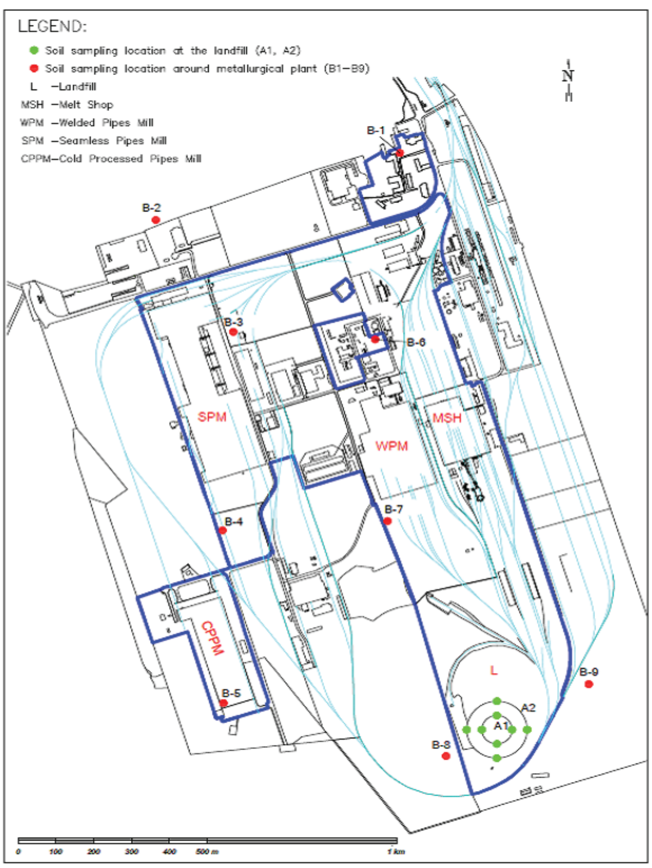
Concentrations of heavy metals (Cd, Cr, Cu, Hg Ni, Pb, and Zn) for samples A1, A2, and the reference sample, after extraction in *aqua regia* according to the HRN ISO 11466:2004 standard (Soil quality – Extraction of trace elements soluble in *aqua regia*) were determined. Heavy metal concentrations, except Hg, were determined by inductively coupled optical emission spectrometry according to the HRN EN ISO 11885:2010 standard (Water quality – Determination of selected elements by inductively coupled plasma optical emission spectrometry) using a Perkin-Elmer Optima 7000 DV ICP-OES apparatus. The concentration of Hg was determined by atomic absorption spectrometry, HRN EN 1483:2008 standard (Water quality – Method using atomic absorption spectrometry) on a Perkin-Elmer Atomic absorption spectrophotometer with Varian hydride-vapour generation system.

The B1–B9 composite samples were air-dried (<40 °C), sieved (<2 mm), homogenized and after *aqua regia* digestion for low and ultra-low determinations on soils, sediments and lean rocks were analysed by ICP-MS (Acme laboratories, Vancouver, Canada).

Results and discussion

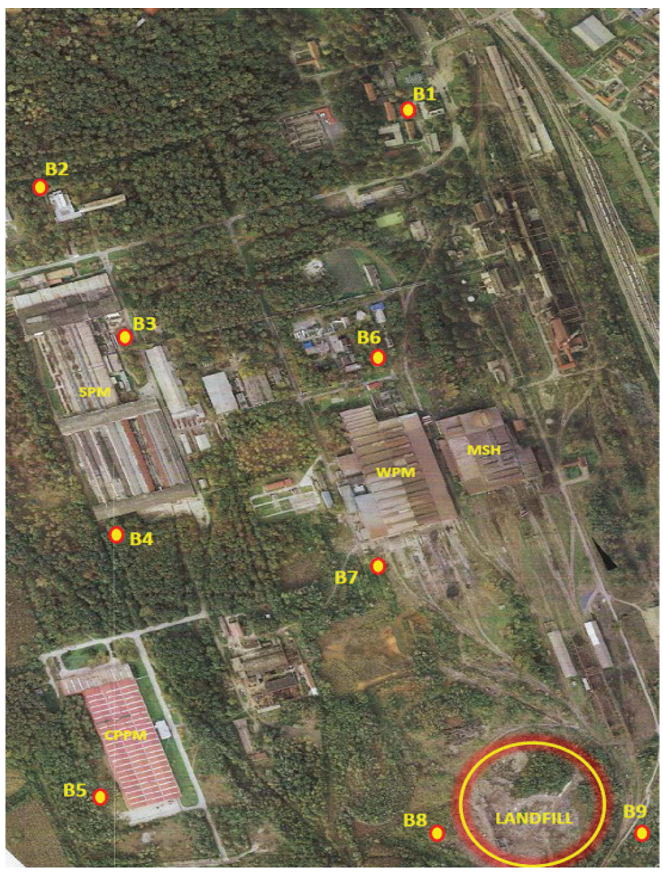
To determine the pollution level of any ecosystem component, including soil, it is necessary to determine the influence of pollution on human health. This is done in order to determine the limit values of a particular pollutant at which, based on scientific knowledge, there is not even the slightest possible risk of harmful effect on human health and/or the environment.

Croatian legislation defines the Ordinance on the Protection of Agricultural Land against Pollution[24] as the only regulation defining the quality of agricultural soil. Limit values



F i g . 3a – *Scheme of sampling locations on the landfill (A1 and A2) and areas around the production processes (B1–B9)*

S l i k a 3a – *Shematski prikaz lokacija uzorkovanja tla na odlagalištu (A1 i A2) i prostoru oko proizvodnih pogona (B1 – B9)*



F i g . 3b – *Locations of soil sampling on the landfill and areas around the production processes (B1–B9) – aerial view*

S l i k a 3b – *Prikaz lokacija uzorkovanja tla na odlagalištu i prostoru oko proizvodnih pogona (B1 – B9), fotografija iz zrakoplova* of pollutants, including heavy-metal concentration limits for soil used for industrial purposes are not prescribed.

In Croatia, there is no legal regulation directly related to monitoring soil condition and collection of data regarding potentially polluted or polluted soil. Problems with potentially polluted or polluted soil are only indirectly mentioned in legislation. Some EU member countries regulate the limit values of soil pollutants[24] according to the land usage principle (agricultural, residential, recreational, *etc.*), which was adopted in the preparation of the Croatian Soil Monitoring Program.[23]

The aim of the measurements conducted during the research was to determine whether the disposed non-hazardous waste (unprocessed slag, mill scales, linings and refractories from metallurgical processes, sludge from water clarification, sludge from decarbonation, etc.) in the unprotected area represented a potential local source of anthropogenic pollution of the soil (despite its use for industrial purposes) and groundwaters. The Croatian Soil Monitoring Program[23] was used for identification and interpretation of the results. Based on the potential sources of soil pollution and the type of possible pollutant emissions listed in the Program,[23] the concentrations of Cd, Cr, Cu, Hg, Ni, Pb, and Zn as pollutants originating from metal industry were determined.

The results of landfill soil analysis were compared to the recommended limit values (LV) of soil pollutants allocated for industrial and commercial usage according to the Croatian Soil Monitoring Program[23] (Table 1).

Results for the determination of heavy metals in composite soil samples (A1 and A2) from the landfill area (Table 2) show that concentrations were mostly below limit values (LV) of soil pollutants in industrial and commercial areas according to the Croatian Soil Monitoring Program.[23] Exceptions were concentrations of Cu and Cr, resp.

Table 2 – *Results from composite sample analysis from the landfill area compared to the LV of soil pollutants in soil for industrial and commercial areas according to the Croatian Soil Monitoring Program*[23]

Tablica 2 – *Rezultati analize kompozitnih uzoraka tla s odlagališta u usporedbi s GV onečišćujućih tvari u tlu namijenjene područjima industrije i u komercijalne svrhe prema Programu trajnog motrenja tala Hrvatske*[23]

Elements Elementi	Metal content in soil (dry matter) / mg kg^{-1} Sadržaj metala u tlu (suha tvar) / mg kg^{-1}		
	A1	A2	LV GV
Cd	19.33	17.72	50
Hg	0.034	0.667	50
Pb	24.73	81.62	1000
Ni	313	399	500
Cu	916	1018	500
Cr	756	766	750
Zn	78.01	296	1200

The determined heavy metal concentrations in the composite soil samples collected from the landfill area correspond to the results of most soil samples taken around the production facilities.

Higher deviations were noticed for Cu and Cr, where concentrations in the landfill samples were higher than con-

Table 1 – *Limit values (LV) of soil pollutants according to land usage*[23]

Tablica 1 – *Granične vrijednosti (GV) onečišćujućih tvari u tlu prema različitim načinima upotrebe tla*[23]

Type of soil pollution Vrste onečišćenja u tlu	Agricultural land Tlo za poljoprivrednu proizvonju	Playground Igralište	Resident areas Područje stanovanja	Parks and recreation areas Parkovi i rekreacijska područja	Industrial and commercial areas Područja industrijske i komercijalne primjene
Metali izlučeni u zlatotopci Metals extracted in *aqua regia*	Content in dry matter / mg kg^{-1} Udjel u suhoj tvari / mg kg^{-1}				
Cd and compounds Cd i spojevi	2	5	10	30	50
Hg and compounds Hg i spojevi	2	5	10	30	50
Pb and compounds Pb i spojevi	100	100	100	500	1000
Ni and compounds Ni i spojevi	50	50	70	200	500
Cu and compounds Cu i spojevi	60	60	100	300	500
Total Cr Ukupni Cr	100	100	200	500	750
Zn and compounds Zn i spojevi	200	200	300	700	1200

Table 3 – *Results of analysis of composite soil samples taken from the landfill (A1, A2) compared with the results obtained for the soil samples taken around the production plants (B1–B9), as well as LV of heavy metals in soil allocated for industrial and commercial purposes according to the Croatian Soil Monitoring Program*[23]

Tablica 3 – *Rezultati analize kompozitnih uzoraka tla s odlagališta (A1, A2) u usporedbi s rezultatima dobivenim za uzorke tla oko tvornice (B1–B9) kao i GV teških metala u tlu namijenjene područjima industrije i u komercijalne svrhe prema Programu trajnog motrenja tala Hrvatske*[23]

Elements Elementi	Metal content in soil (dry matter) / mg kg^{-1} Sadržaj metala u tlu (suha tvar) / mg kg^{-1}										
	A1	A2	B1	B2	B3	B4	B5	B6	B7	B8	B9	LV GV
Cd	19.33	17.72	0.88	0.17	0.90	0.82	2.43	3.29	4.09	0.73	3.27	50
Hg	0.034	0.667	0.262	0.069	0.449	0.114	0.295	0.330	0.265	0.085	0.593	50
Pb	24.73	81.62	102	26.22	69.99	59.38	145	172	340	50.05	355	1000
Ni	313	399	34.40	33.70	36.60	31.10	122	49.80	133	24.20	102	500
Cu	916	1018	31.89	25.35	39.36	51.91	318	81.34	197	19.06	145	500
Cr	756	766	37.40	46.20	44.40	88.90	462	84.70	262	35.70	142	750
Zn	78.01	296	417	115	355	621	2778	3067	10000	259	777	1200

centrations found in the samples taken from around the production facilities. Measured Cu concentrations at the landfill area were 916 mg kg^{-1} of dry matter in sample A1, and 1018 mg kg^{-1} of dry matter in A2, while concentrations in the samples from around the production facilities ranged from 19.06 mg kg^{-1} (B8) to 916 mg kg^{-1} of dry matter (B5).

The similar was found for Cr. Measured Cr concentrations for A1 amounted to 756 mg kg^{-1} and A2 766 mg kg^{-1}, while for samples from production facilities 35.70 mg kg^{-1} (B8) to 262 mg kg^{-1} of dry matter (B7).

For Zn the opposite situation was noticed. Measured Zn concentrations for A1 amounted 78.01 mg kg^{-1} and A2 296 mg kg^{-1}, while the Zn concentrations in samples from production facilities ranged from 115 mg kg^{-1} (B2) to 10 000 mg kg^{-1} of dry matter in sample B7 taken from the area near the plant for galvanization of welded pipes. Such a high concentration of Zn is the result of the direct pollution with Zn from the stack of the furnace system for hot galvanization of welded pipes.

The obtained results for heavy metal concentrations are presented in Table 3, and compared to the limit values for potentially unacceptable risk for soil used in industry according to the Croatian Soil Monitoring Program.[23] It could be concluded that the landfill is polluted with Cu and Cr, while the area around the production facilities is polluted with Zn.

Before comparing the heavy-metal concentrations in the composite soil samples from the landfill area with those outside battery limits, it is necessary to compare the results obtained for the reference samples with the LV in soil allocated for industrial and commercial usage (Table 4).

Values of heavy metals in reference samples shown in Table 4 are significantly lower than the LV of tested metals for industrially and commercially used soil according to the Croatian Soil Monitoring Program.[23]

For pollution assessment, a comparison of the heavy metal content in composite soil samples from the landfill with the values for potentially unacceptable risk for soils allocated for industry regulated by some EU member countries[25] is given in Table 5.

Table 4 – *Heavy metal content in reference sample compared to the LV for soil allocated for industrial and commercial usage*[23]

Tablica 4 – *Sadržaj teških metala u referentnom uzorku u usporedbi s GV za tla namijenjenih područjima industrije i u komercijalne svrhe*[23]

Elements Elementi	Metal content in soil (dry matter) / mg kg^{-1} Sadržaj metala u tlu (suha tvar) / mg kg^{-1}	
	Reference sample Referentni uzorak	LV GV
Cd	<0.001	50
Hg	0.162	50
Pb	49.82	1000
Ni	34.14	500
Cu	21.09	500
Cr	57.84	750
Zn	284	1200

The comparison of heavy metal concentrations in composite soil samples from the landfill area with values (LV) representing a potentially unacceptable risk for soil allocated for industrial use regulated by some EU member countries shows that the measured concentrations of Hg, Pb and Zn were lower than LV regulated by Belgium, Finland, Italy, Poland and United Kingdom, *i.e.* all considered countries which have regulated LV for heavy metals.

Concentrations of Cd in the landfill soil samples marked as A1 and A2 were below the LV representing a potentially unacceptable risk for soil allocated for industrial use regulated by Belgium, Finland and United Kingdom, but higher than LV regulated by Italy and Poland. Therefore, from the point of view of Poland and Italy, the landfill area is considered polluted.

T a b l e 5 – *Comparison of heavy metal content in composite soil samples with values for potentially unacceptable risk for soil allocated for industry regulated by some EU member countries*[25]

T a b l i c a 5 – *Usporedba rezultata određivanja sadržaja teških metala kompozitnih uzoraka tla s vrijednostima za potencijalno neprihvatljiv rizik za tlo namijenjeno industriji u nekim zemljama EU*[25]

Elements Elementi	Landfill Odlagalište	Metal LV in soil (dry matter) / mg kg^{-1} GV metala u tlu (suha tvar) / mg kg^{-1}							
		Samples Uzorci	Reference sample Referentni uzorak	Belgium/ Brussels Belgija/Brisel	Belgium/ Wallonia Belgija/ Valonija	Finland Finska	Italy Italija	Poland Poljska	United Kingdom Ujedinjeno Kraljevstvo
Cd	A1	19.33	<0.001	30	50	20	15	13	1400
	A2	17.72							
Hg	A1	0.034	0.162	30	84	5	5	27	480
	A2	0.667							
Pb	A1	24.73	49.82	2500	1360	750	1000	600	750
	A2	81.62							
Ni	A1	313	34.14	700	500	150	500	285	–
	A2	399							
Cu	A1	916	21.09	800	500	200	600	600	–
	A2	1018							
Cr	A1	756	57.84	800	700	300	800	475	5000
	A2	766							
Zn	A1	78.01	284	3000	1300	400	1500	1650	–

The results obtained for Ni concentrations in the landfill soil classify this soil as polluted according to LV regulated by Finland and Poland, while compared to other observed EU countries, these concentrations were lower than regulated LV.

The landfill area is considered polluted with Cu because the measured concentrations exceeded the LV representing a potentially unacceptable risk for soil allocated for industry regulated by all observed EU countries.

Concentrations of Cr in the landfill soil samples were below LV for potentially unacceptable risk for soil allocated for industry regulated by Belgium (Brussels), Italy and United Kingdom, but higher than LV regulated by Belgium (Wallonia), Finland and Poland.

Conclusion

Soil pollution in the Republic of Croatia is defined only for agricultural land by the Ordinance on the Protection of Agricultural Land against Pollution,[24] while the quality of soil for industrial purposes is not regulated.

To evaluate the soil pollution level of the landfill area used for temporary storage of nonhazardous waste (10 02 02 – unprocessed slag; 10 02 10 – mill scales; 15 01 03 – wooden packaging; 16 11 04 – other linings and refractories from metallurgical processes; 17 01 07 – mixture of concrete, bricks, tiles and ceramics; 19 09 02 – sludge from water clarification; 19 09 03 – sludge from decarbonation; 20 01 01 – paper and cardboard; 20 01 39 – plastics; 20 03 07 – bulky waste) over many years of metallurgical production, a comparison was made of heavy metal concentrations from landfill soil samples with LV for potentially unacceptable risk for soil allocated for industry according to the Croatian Soil Monitoring Program[23] and regulated LV in some EU countries[25]. In addition, the results were compared with heavy metal concentrations in soil taken from around production facilities and a reference sample collected outside battery limits. According to the obtained results, the following conclusions may be drawn:

– The determined heavy metal content in composite samples A1 and A2 of landfill soil show that concentrations were mostly below the LV of pollutants for industrially and commercially used soils according to the Croatian Soil Monitoring Program. Exceptions were Cu and Cr concentrations which were higher than LV;

– The determined heavy metal concentrations in composite soil samples from the landfill area mainly correspond those determined in soil samples collected around the production facilities;

– Higher deviation in Cu and Cr concentrations were noticed in landfill soil samples, where the values exceeded concentrations in soil from around the production facilities;

– Zn concentrations in landfill soil are lower than the highest measured concentrations in the soil samples taken from an area nearby galvanization;

– Comparison heavy metal concentrations in composite soil samples from the landfill with values for potentially unacceptable risk for soil allocated for industrial use, regulated by some EU member countries, show that measured Hg, Pb and Zn concentrations were lower than LV regulated by Belgium, Finland, Italy, Poland and United Kingdom *i.e.* all considered countries which have regulated LV for heavy metals;

– Cd concentrations in landfill soil samples were below LV for potentially unacceptable risk for soil allocated for industrial use regulated by Belgium, Finland and United Kingdom, but higher than LV regulated by Italy and Poland; therefore, from the point of view of Poland and Italy, the landfill area is considered polluted;

– The determined Ni concentrations in the landfill soil classify this soil as polluted according to LV regulated by Finland and Poland, while in comparison to other observed EU countries, these concentrations were lower than the regulated LV;

– The landfill area is considered polluted with Cu because the measured concentrations exceed LV for potentially unacceptable risk for soil allocated for industry regulated by all observed EU countries;

– Cr concentrations in the landfill soil samples were below LV for potentially unacceptable risk for soil allocated for industry regulated by Belgium (Brussels), Italy and United Kingdom, but higher than LV regulated by Belgium (Wallonia), Finland and Poland;

– Comparison of the heavy metal concentrations with LV for potentially unacceptable risk for soil used in industry according to Croatian Soil Monitoring Program, has led to the conclusion that the landfill is polluted with Cu and Cr;

– Regarding the obtained results for the landfill and owner's decision on future usage of the examined area, certain measures in further treatment of soil have to be taken if required by law.

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SAŽETAK

Onečišćenje tla kao posljedica odlaganja neopasnog otpada iz procesa proizvodnje čelika

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Ispitano je tlo starog metalurškog odlagališta tvornice CMC Sisak d. o. o., koje je dugi niz godina bilo izloženo različitim utjecajima neštetnog metalurškog otpada. Sadržaj teških metala Cd, Cr, Cu, Hg, Ni, Pb i Zn u tlu određen je u uzorcima tla nakon njihove ekstrakcije metala zlatotopkom. Određivanje sadržaja svih navedenih metala osim žive provedeno je metodom optičke emisijske spektrometrije induktivno vezane plazme (ICP-OES), dok je sadržaj žive određen spektrometrijom atomske apsorpcije (AAS) primjenom hidridne tehnike.

Da bi se procijenila razina onečišćenja tla, napravljena je usporedba rezultata sadržaja teških metala u analiziranim uzorcima tla s propisanim vrijednostima za potencijalno neprihvatljiv rizik za tlo upotrebljavano u industriji prema Programu trajnog motrenja tla Republike Hrvatske kao i prema propisanim vrijednostima u nekim zemljama EU. Rezultati određivanja sadržaja teških metala u kompozitnim uzorcima tla uspoređivani su s njihovim koncentracijama u referentnom uzorku tla uzetom s prostora obližnjeg parka, izvan tvorničkog kruga. Dobiveni rezultati svrstavaju analizirano tlo s odlagališta kontaminiranim prema propisima svih promatranih zemalja EU-a s bakrom, Italije i Poljske s kadmijem i Belgije (Valonija), Finske i Poljske s kromom. Za buduću upotrebu tla u istu svrhu moraju se poduzeti odgovarajuće mjere.

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