IMPACT OF MUNICIPAL LANDFILL ON THE NICKEL CONTENT IN SURROUNDING SOILS

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Matuszczak K., Bartkowiak A., Jaworska H., Różański S., 2016: Impact of municipal landfill on the nickel content in surrounding soils (*Oddziaływanie składowiska odpadów komunalnych na zawartość niklu w pobliskich glebach)*. Monitoring Środowiska Przyrodniczego, Vol. 18(1) s. 53-61.

Abstract: The location of municipal landfill may have negative impact on various elements of natural environment, such as soil, water, and air. The aim of this research was to determine the concentration of nickel in soil under the impact of landfill. 45 soil samples were collected for analysis from 3 different depths (0–15, 15–30, 30–50 cm). Material was collected from 4 different places – located 5, 10, 200 and 500 m away from the landfill. Material was also collected from the control site located 700 m from the landfill. The selected physicochemical properties of soils were determined: texture, soil pH, TOC. The total content of nickel in soil samples was determined after mineralization in a mixture of HF and $HClO_4$ according to Crock and Severson's method, while bioavailable forms of the metal after DTPA extraction by Lindsay and Norvell's method on SOLAR spectrometer. The total content of nickel ranged from 4.45 to 17.98 $mg{\cdot}kg^{-1}$. The highest content of this metal was observed in samples collected from sites located 500 m away from the landfill. The bioavailable form of nickel ranged from 0.27 to 1.78 $mg{\cdot}kg^{-1}$. Low content of total Ni prove low direct impact of the municipal landfill on soils of surrounding areas.

Key words: nickel, municipal landfill, total content, bioavailable forms
Słowa kluczowe: *nikiel, składowisko odpadów komunalnych, zawartość całkowita, formy przyswajalne*

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1. Introduction

The danger of increasing amount of waste is a consequence of society development and consumption growth (Arup Veltze 1999). Moreover the change of life style effect not only on the increase of waste amount, but also on their composition. For this reason arise the need for regulation of the waste management system taking into account environment protection (Arup Veltze 1999). Legal acts – concerning waste management and utilization, disposal and storage – are in Poland consistent with European Community Directive (Council Directive 75/442/EEC). Deposition on the landfill is the most common form of utilization municipal waste (Choma-Moryl 2004; Fajfer 2005). The landfills have been classified by Minister of the Environment as objects that can significantly effect on the environment conditions (Regulation No. 237, item. 2573). Due to the risks that the landfill may fulfill to the environment, these objects are constructed respectively to the three conditions: geotechnical, geoengineering and geohydrological (Regulation No. 126, item. 839). There are also three types of landfills: municipal landfill, hazardous, and different than hazardous (Sobik, 2007), from which investigated landfill is the first type.

Due to the risks which landfill may effect on the surroundings its location is very important. Improper positioning and the use of waste deposit site could influence on various components of the environment, such as soil, water, air. Such an element of anthropopressure may affect the continuous inflow of heavy metals into soil.

Municipal landfills due to their occupation of large areas and long term of exploitation, may be a potential risks to the environment.

Systematic monitoring provides early detection of potential leaching of hazardous substances along with heavy metals into the soils. Controlling the level of contaminants in surrounding soils, it may results an early detection of landfill influence. It is necessary then to take activities which are aimed on reduction of the magnifying problem of environment pollution, as well as on the restoration of proper indicators of soil (Szwalec, Mundała 2011).

Nickel is the metal which is worth noting in terms of environmental protection. It is not a microelement essential for the functioning of living organisms, however, numerous research have shown its presence in the adequate pattern of physiological processes in plants, animals and microorganisms (Trupschuch et al. 1995; Fu et al. 1996). Nickel is an element of high mobility in the environment. During to the weathering processes this metal is very mobile. Nickel cations can migrate along with the solutions for a long distance. Organic matter reveals high affinity in binding of nickel. As a result of sludge application, nickel contamination of soils in Great Britain was reported – 845 mg•kg^{-1} (Kabata-Pendias 2011). Anthropogenic origin Ni which is runon to the soils is easy absorbed by plant roots and transported to aboveground parts (Cachaney, Oliver 1996). Excess of nickel cations in plants could have inhibitory influence on metabolism, plant growing, and also for the photosynthesis process (Drążkiewicz 1994). There are, however, differences in the phytoaccumulation and phytotoxicity of nickel depending on its form in soil and on the plant species (Spiak 1996, 1997).

The aim of the study was to determine the impact of municipal landfill in Bydgoszcz on the basis of nickel content in soils of its close surroundings.

2. Materials and methods

Material included 45 soil samples collected from 3 depths: 0–15 cm, 15–30 cm and 30–50 cm, from research points located 5, 10, 200 and 500 m from the municipal landfill (53°06'27.2"N 18°12'57.2"E) and also from the control site (located 700 m from the landfill) toward the south-west according to wind rose. This landfill is located about 15 km from the center of Bydgoszcz. The landfill has an organized type. It means that the location has guided by hydrological and geological criteria in waste processing, defined by Ministry of Environment. These regulations are established to reduce the potential negative impact to the natural environment. In Bydgoszcz, there are several establishments engaged in the disposal of municipal waste. However investigated municipal landfill is one of the most modern in the city. This landfill has been functioning since 1 January 2008.

Soil Samples 1–9 – control samples, taken from **test site**.

Soil Samples 10–18 – **5 m** from the municipal landfill.

Soil Samples 19–27 – **10 m** from the municipal landfill .

Soil Samples 28–36 – **200 m** from the municipal landfill.

Soil Samples 37–45 – **500 m** from the municipal landfill.

In the research material selected physicochemical properties were determined: texture by laser diffraction method using a Mastersizer 2000 with the HydroμP,

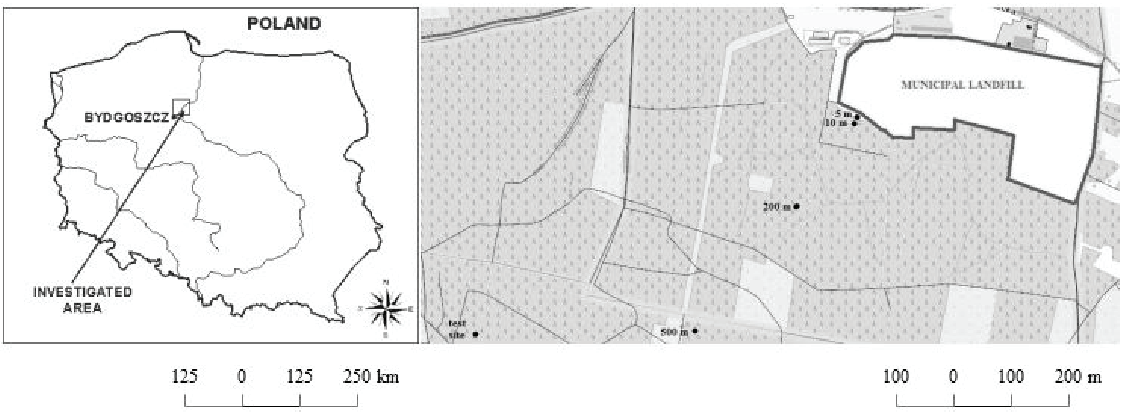


Fig. 1. Location of sampling points

Ryc. 1. Lokalizacja punktów poboru próbek glebowych soil pH in the extracts: H_2O and 1M KCl 1:2.5 ratio, content of total organic carbon (TOC) by Tiurin method. The total content of nickel was measured using atomic absorption spectroscopy method on SOLAR 969 (Unicam) after digestion in a mixture of HF and $HClO_4$ acids using Crock's and Severson's method (1980), and bioavailable forms in 1M diethylene triamine pentaacetic acid (DTPA) using Lindsay and Norvell's method (1978). All analysis were performed in three replicates and the verification of the results, based on the certified material Till-3.

To compare results from soils in close vicinity of landfill, samples from control site were analyzed, located 700 m away from the landfill (potentially not exposed to contamination).

On the basis of the analytical results contamination factor was calculated, assessing the impact of human activities on the soil (CF).

$CF = C_{0-1}/C_n$

where:

C_{0-1} – metal content

C_n – geochemical background (for Ni it is 4 $mg \cdot kg^{-1}$) (Czarnowska 1996)

where:

CF <1 – low contamination factor,

1 ≤ CF <3 – moderate contamination factor,

3 ≤ CF <6 – significant contamination factor,

CF ≥ 6 – very high contamination factor (Håkanson 1980).

The indicator of bioavailability was also calculated, which is the percentage of bioavailable form to the total content of nickel.

Pearson correlation coefficient ($p < 0.05$) were calculated between total content of nickel, its available forms and analysed soil properties. Correlation was performed in the STATISTICA 12.0 for WINDOWS Pl software.

3. Results and discussion

The texture of analysed soils was course – sands and loamy sands (USDA). The content of sand separates ranged from 73.17 to 95.18%, silt from 4.7 to 24.66% and clay from 0.11 to 2.61%. Texture had dominant impact on pollutants migration from the landfill. The highest content of clay separates (from 2.15 to 2.61%) were characterized the soil samples collected from points located 500 m away from the municipal landfill.

The investigated soils were characterized by similar values of the selected physicochemical properties regardless of the distance from the place of sampling. In the analysed samples pH in H_2O ranged from 4.6 to 6.2 pH, while pH in KCl from 3.9 to 5.8 pH (Table 1). The TOC content ranged from 0.42 to 19.46 $g \cdot kg^{-1}$. The hi-

Table 1. Physicochemical properties of studied soils
Tabela 1. Fizykochemiczne właściwości badanych gleb

Number and location *Liczba i lokalizacja*	Sampling depth *Głębokość próbkowania* [cm]	Selected properties of soils/*Wybrane właściwości gleb*		
		pH H_2O	pH 1M KCl	TOC [$g \cdot kg^{-1}$]
1–9 – 700 m from the landfill – control	0–15	4.7	3.9	19.46
	15–30	4.6	4.1	13.58
	30–50	4.7	4.3	7.86
10–18 – 5 m from the landfill	0–15	5.0	4.4	12.00
	15–30	5.0	4.5	5.76
	30–50	5.0	4.5	5.18
19–27 – 10 m from the landfill	0–15	4.7	4.1	0.96
	15–30	4.8	4.4	0.64
	30–50	5.1	4.6	0.42
28–36 – 200 m from the landfill	0–15	4.6	4.0	9.36
	15–30	4.6	4.4	3.00
	30–50	4.7	4.5	1.12
37–45 – 500 m from the landfill	0–15	6.1	5.4	12.18
	15–30	6.0	5.7	10.72
	30–50	6.2	5.8	6.18

ghest content of TOC was found in the surface horizons (0–15 cm) in all test points independently on the distance from the municipal landfill. The highest concentration of TOC in the samples collected from the control site was noticed, and the lowest was observed in samples collected 10 m away from the municipal landfill. Higher organic carbon concentration in soil samples taken 200 m and 500 m away from the municipal landfill and from the control site was related with inflow of fresh organic substances from litter (Brogowski, Chojnacki 2013). In point located 10 m away from the landfill, concentration of organic carbon was the lowest. It was connected with lack of humus horizon, which was probably removed as a result of cleanup works.

In the investigated soils the total content of nickel ranged from 4.45 to 17.98 mg·kg^{-1} (Table 2). The lowest concentration of this metal was found in the samples from the control site (4.45 mg·kg^{-1}), while the highest concentration was observed in soil samples collected 500 m away from the municipal landfill (17.98 mg·kg^{-1}). These values were higher in the topsoil of most soils, which may be a result of the chemical affinity of nickel to create connections with the organic substances in the form of mobile chelates (Håkanson 1980). Kabata-Pendias (2011) as well as Ruszkowska and Wojcieska-Wyskupajtys (1996) confirm a high capacity of organic matter for nickel. The amount of this element in soils results mostly its content in the parent material and content of iron and clay minerals (Czarnowska 1996). Nickel most frequently accompanies rock-forming magnesium-iron silicates (Smolińska, Król 2011). Łęcki and Troć (2005) determined the average concentration of nickel for sandy soils as 8.69 mg·kg^{-1}. Studies conducted by Murphy and Parth (2011) have shown that the content of nickel in the adjacent area to the hazardous waste landfill ranged from 12.5 to 131.9 mg·kg^{-1}. Kassassi's analysis (2008) showed that the concentration of nickel in soils in the surroundings of landfill ranged from 5.63 to 63.75 mg·kg^{-1}. In the analyzed soil samples the total content of Ni was similar to the geochemical background value (Kabata-Pendias 2011), and it did not exceed the limit for uncontaminated soils (Regulation No. 165, item. 1359).

The content of DTPA extracted Ni forms (bioavailable forms) in the investigated soils ranged from 0.27 to 1.78 mg·kg^{-1}. The lowest content of bioavailable forms of Ni was observed in the samples from the control site, while the highest in soil samples collected at the distance of 500 m away from the municipal landfill (Table 3).

Table 2. The total content of nickel in soil samples
Tabela 2. Zawartość całkowita niklu w próbkach glebowych

Number and location *Liczba i lokalizacja*	Sampling depth *Głębokość próbkowania* [cm]	The total content of nickel/*Zawartość całkowita niklu* [mg·kg^{-1}]			
		minimum	mean	maximum	Standard deviation *Standardowe odchylenia*
1–9 – control sample	0–15	5.95	6.81	7.30	0.746
	15–30	4.45	7.03	8.65	2.255
	30–50	6.50	7.03	7.70	0.611
10–18 – 5 m from the landfill	0–15	8.65	9.55	10.95	1.229
	15–30	8.10	8.92	9.45	0.718
	30–50	8.38	8.97	9.60	0.614
19–27 – 10 m from the landfill	0–15	10.13	11.21	12.70	1.335
	15–30	9.73	10.72	12.43	1.486
	30–50	11.23	11.90	12.30	0.588
28–36 – 200 m from the landfil	0–15	11.35	12.44	13.53	1.229
	15–30	12.70	12.98	13.25	0.718
	30–50	13.25	13.87	14.30	0.614
37–45 – 500 m from the landfill	0–15	15.40	16.44	17.30	0.963
	15–30	14.60	16.18	17.43	1.440
	30–50	14.73	16.63	17.98	1.693

Table 3. The content of bioavailable form of nickel in soil samples
Tabela 3. Zawartość form biodostępnych niklu w próbkach glebowych

Number and location *Liczba i lokalizacja*	Sampling depth *Głębokość próbkowania* [cm]	Bioavailable forms of nickel/*Biodostępne formy niklu* [mg·kg^{-1}]			
		minimum	mean	maximum	Standard deviation *Standardowe odchylenie*
1–9 – control samples	0–15	0.27	0.44	0.74	0.144
	15–30	0.32	0.43	0.53	0.154
	30–50	0.45	0.52	0.63	0.172
10–18 – 5 m from the landfill	0–15	0.70	0.75	0.78	0.252
	15–30	0.50	0.73	1.00	0.092
	30–50	0.60	0.67	0.77	0.049
19–27 – 10 m from the landfill	0–15	0.69	0.92	1.15	0.145
	15–30	0.88	1.02	1.17	0.073
	30–50	0.91	0.98	1.06	0.129
28–36 – 200 m from the landfill	0–15	1.12	1.29	1.51	0.146
	15–30	1.16	1.33	1.44	0.203
	30–50	1.26	1.43	1.66	0.145
37–45 – 500 m from the landfill	0–15	1.33	1.51	1.60	0.078
	15–30	1.60	1.65	1.74	0.036
	30–50	1.68	1.71	1.78	0.047

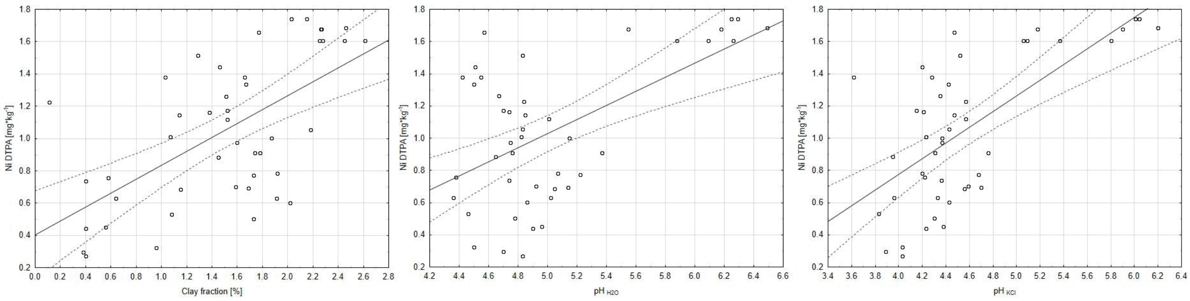
Analysis of bioavailable forms of nickel in soils is important because of their potential uptake by plants determined by the concentration of mobile forms in soils. Toxic impact of nickel for plants may be observed in disorder of photosynthesis, in the process of nitrogen binding and in transpiration (Panwar et al. 2002).

In the analyzed soils bioavailable forms of nickel content was lower than results given by Kabata-Pendias (2011) for the soils of Poland. Weng et al. (2004) stated that the mobility of nickel is determined by the pH of soil. Higher acidity leads to the mobilisation of the nickel complexes in soil solution and also to an increase of bioavailability of this element (Szatanik-Kloc 2004). In the soils of acid reaction its solubility increases considerably. However, its susceptibility for the formations with organic substance also results a high mobility of nickel in neutral or alkaline reaction. Besides, a lower content of organic matter is less important in limiting the bioavailability of nickel, as compared with acid soil. Soil liming is, therefore, a factor limiting the phytoavailability of nickel (Jaworska et al. 2013). According to Panwear (2002), Weng et al. (2004), Ronney et al. (2007), Jaworska et al. (2013) texture (clay separates percentage) is the factor which has the most significant influence on the concentration and the mobility of nickel. The soils containing more silt and clay separates usually show a higher content of that element (Właśniewski 2002). However, the correlation between Ni content, organic matter, and the acidity was low in these soils. Warda (1997) draws attention to the fact that an important factor modifying the uptake of nickel by plants is not only the soil type, but mostly the plant species.

Calculated correlation coefficients confirmed the significant relation between the content of bioavailable forms of nickel and the content of the clay ($r = 0.618$ at $p<0.05$) (Fig. 2a), pH_{H2O} ($r = 0.571$ at $p<0.05$) (Fig. 2b) and pH_{KCl} ($r = 0.665$ at $p<0.05$) (Fig. 2c).

Tkaczyk and Bednarek (2007) in their studies stated that the correlations between the content of nickel forms and selected physicochemical properties of soils (texture, pH, organic carbon content, $CaCO_3$, EC) are statically insignificant.

The contamination factor (CF) is based on the value of soil geochemical background. According to the standard developed by Håkanson (1980), the examined soil from the control site were characterized by a low contamination factor of analyzed heavy metal (Table 4),



a b c

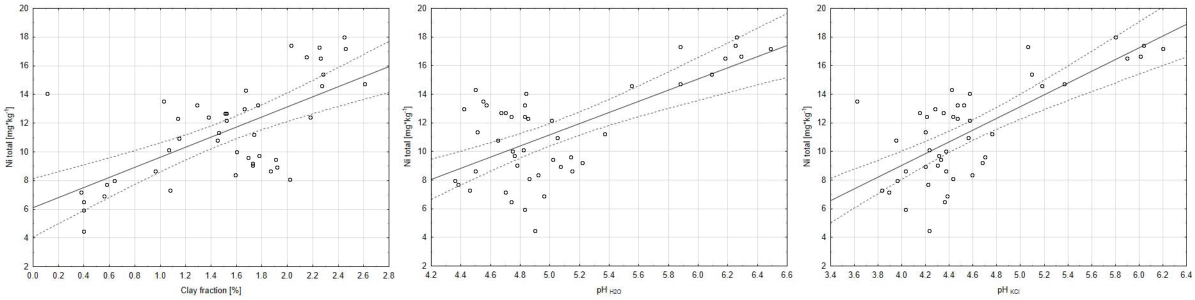
Fig. 2. Correlation between Ni DTPA and clay (a), pH_{H2O} (b) and pHK_{Cl} (c)
Ryc. 2. Wykres rozrzutu pomiędzy Ni DTPA a frakcją iłu (a), pH_{H2O} (b) oraz pH_{KCl} (c)

Table 4. Contamination factor (CF) and the indicator of bioavailability of nickel (%) in soil samples
Tabela 4. Współczynnik zanieczyszczenia i wskaźnik biodostępności niklu (%) w próbkach glebowych

Number and location *Liczba i lokalizacja*	Sampling depth *Głębokość próbkowania* [cm]	Contamination factor *Współczynnik zanieczysz-czenia* (CF)	Indicator of bioavailability of nickel *Wskaźnik biodostępności niklu* (%)
1–9 – control samples	0–15	1.70	6.46
	15–30	1.76	6.12
	30–50	1.76	7.39
10–18 – 5 m from the landfill	0–15	2.39	7.85
	15–30	2.23	8.18
	30–50	2.24	7.47
19–27 – 10 m from the landfill	0–15	2.80	8.21
	15–30	2.68	9.51
	30–50	2.98	8.24
28–36 – 200 m from the landfill	0–15	3.11	10.37
	15–30	3.25	10.25
	30–50	3.47	10.31
37–45 – 500 m from the landfill	0–15	4.11	9.18
	15–30	4.05	10.19
	30–50	4.16	10.28

points located 5, 10 and 200 m away from the municipal landfill were characterized by moderate contamination factor. Points located 500 m away from the landfill were characterized by significant contamination factor (Table 4). It can be assumed that increasing CF was connected with concentration of organic matter. The highest content of organic matter in place located 500 m away from the landfill is related with high concentration of Ni. Content of metals are defined by ability to creative with the organic elements in soil complex and chelate compounds. Steadiness of chelates depends of the soil pH and type of metal ions. Create organometallic complexes in soil is very important. It prevents before leaching of heavy metals toxic ions from soil and also partly their detoxification and limit the absorption by plants (Gustafsson et al., 2003). These dependences in the analyzed results did not confirm the correlation analysis carried out. Statistical calculations of the results showed a significant positive correlation coefficient between the content of total nickel and the content of clay ($r = 0.654$ at $p<0.05$) (Fig. 3a), pH_{H2O} ($r = 0.661$ at $p<0.05$) (Fig. 3b) and pH_{KCl} ($r = 0.727$ at $p<0.05$) (Fig. 3c).

The indicator of Ni bioavailability ranged from 6.12 to 10.37% (Table 4). The percentage of bioavailable forms in total concentration of nickel in tested samples is low. The results obtained were similar to those



a b c

Fig. 3. Correlation between Ni total and clay (a), pH_{H2O} (b) and pH_{KCl} (c)
Ryc. 3. Wykres rozrzutu pomiędzy zawartością całkowitą niklu a frakcją iłu (a), pH_{H2O} (b) oraz pH_{KCl}

obtained by Dąbkowska-Naskręt et al. (1997) in soils under the influence of cement industry, and Bartkowiak (2012) in agricultural alluvial soils.

4. Conclusions

The total content of nickel ranged from 4.45 to 17.98 mg·kg^{-1} what allows to identify analysed soils as uncontaminated by this metal. Low concentrations of total Ni suggest the lack of a direct impact of the municipal landfill in the Bydgoszcz city on soils of surrounding areas.

On the basis of the total content of Ni the investigated soils were classified as uncontaminated soils by nickel. The contents of nickel extracted using DTPA ranged from 0.27 to 1.78 mg·kg^{-1} can be considered as below-toxicity level. Moreover, the studied soil samples were characterized by a moderate or significant contamination factor, in reference to the geochemical background.

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ODDZIAŁYWANIE SKŁADOWISKA ODPADÓW KOMUNALNYCH NA ZAWARTOŚĆ NIKLU W POBLISKICH GLEBACH

Streszczenie

Składowisko odpadów komunalnych może wywierać negatywny wpływ na różne elementy środowiska naturalnego, takie jak: gleba, woda i powietrze. Celem badań było określenie koncentracji niklu w glebach w zasięgu oddziaływania składowiska odpadów. Do analiz pobrano 45 próbek glebowych z trzech różnych głębokości (0–15, 15–30, 30–50 cm). Materiał do badań pozyskano z czterech miejsc położonych w odległości 5 m, 10 m, 200 m, 500 m od obiektu. Materiał pobrano również z punktu kontrolnego zlokalizowanego 700 m od składowiska. Określono wybrane fizykochemiczne właściwości gleb: skład granulometryczny, pH gleby, zawartość węgla organicznego. Całkowitą zawartość niklu w próbkach glebowych oznaczano w roztworach po mineralizacji w mieszaninie kwasów HF i $HClO_4$ według Crocka i Seversona, natomiast form biodostępnych badanego metalu po ekstrakcji roztworem DTPA według Lindsaya i Norvella na spektrometrze SOLAR. Całkowita zawartość niklu mieściła się w przedziale od 4,45 do 17,98 $mg \cdot kg^{-1}$. Najwyższą koncentrację badanego metalu zaobserwowano w próbkach pochodzących z miejsc położonych 500 m od składowiska odpadów. Zawartości form przyswajalnych niklu mieściły się w przedziale od 0,27 do 1,78 $mg \cdot kg^{-1}$. Niska całkowita zawartość Ni wykazuje niski, bezpośredni wpływ składowiska odpadów komunalnych na okoliczne glebach.