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IMPACT OF UNCONTROLLED WASTE DUMPING ON SOIL CHEMICAL AND BIOCHEMICAL PROPERTIES

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Abstract: The study makes an attempt to assess the impact of uncontrolled waste dumps on soil chemical and biochemical properties. Investigations were carried out on five waste disposal sites situated in the south-eastern outskirts of the city of Lublin. The samples of soils collected from the adjacent arable land were used as reference material. In soils of four landfills, which were established relatively recently (four to five years ago); several times higher activity of the examined enzymes (dehydrogenases, acid phosphatase, basic phosphatase, urease, protease) than in the soils from the adjacent cultivated land was determined. Opposite trends were found in the case of a waste dump established 20 years ago. The determined lack of negative influence of the examined waste dumps on the soil chemical and biochemical properties of the adjacent arable land shows that the range of the contamination effect on the surrounding area was limited.

INTRODUCTION

Municipal wastes exert a steady negative influence on the natural environment. The functioning of ecosystems as well as man's health and well-being are particularly threatened by uncontrolled waste dumps which appear increasingly frequently in urban areas. The hazards are associated, among others, with the presence of dangerous refuse, i.e. household chemicals, expired pharmaceuticals, used bulbs and fluorescent lamps etc. [12]. Obviously, it is the topsoil that is the most exposed to the effect of toxic substances contained in wastes [15].

Biomonitoring employing methods based on biochemical tests allows for complex and comprehensive assessment of changes taking place in the soil environment under the influence of natural and anthropogenic factors [3, 5].

The objective of the undertaken investigations was to evaluate the effect of five uncontrolled waste dumps situated in the suburbs of Lublin on soil chemical and biochemical properties.

MATERIAL AND METHODS

The performed investigations comprised five uncontrolled waste landfill sites located in the outskirts of the city of Lublin in Felin district. Felin 1 is the waste dump which was established 20 years ago on which mainly car tyres, roofing paper, plastics, tar, bricks and construction debris were dumped. The remaining four dumps Felin 2, Felin 3, Felin 4 and Felin 5 appeared (four to five years ago) where household wastes, street garbage collected from waste bins, mainly food stuffs, paper, glass and metals were deposited.

Felin is situated in the south-eastern part of Lublin (51°15'N; 22°35'E) in the part of Lublin Upland deprived of ravines. According to the physiographic division of Chałybińska and Wilgata, this area constitutes part of the region of Giełczewski Highland. On the other hand, according to the geobotanical division of Poland, the discussed area is situated in the sub-district known as Świdnik Plateau which, in turn, is part of the Lublin District belonging to the region called Lublin Highland. The soils found here are typical grey brown podsolic soils (Haplic Luvisols) rated as class IIUR and 1st complex (very good wheat complex). The texture composition of these soils classifies them as dust-loam formations.

Pooled samples collected from the soil surface layers (0–25 cm) of the examined waste dumps as well as arable land adjacent to them (at the distance of 50–80 cm) on which wheat cv. Almari was cultivated were used to assess the extent of influence of the uncontrolled landfills on soil chemical and biochemical properties. The analyzed samples were means from 5 samples collected from each object.

The performed analyses comprised determinations of: organic carbon [ISO 14255], total nitrogen [ISO 13878], ammonia nitrogen and nitrate nitrogen [ISO 14255]. In addition, soil reaction – pH in H_2O and in 1 mol·dm^{-3} KCl [ISO 10390] – as well as the total content of heavy metals (Cu, Pb, Zn, Ni, Cr and Cd) by the method of atomic absorption spectrometry (AAS) following sample digestion in *aqua regia* (HCl : HNO_3 3 : 1) were determined.

Within the framework of biochemical analyses, the authors determined the activity of dehydrogenases with a TTC (triphenyltetrazole chloride) substrate [22], acid phosphatase (Pac) and basic phosphatase (Pal) [21], urease [24] and protease [14]. The activity of dehydrogenases was given in cm^3 H_2 necessary to reduce TTC to TFP (triphenylformozane), that of phosphatases – in mmols of PNP (p-nitrophenol) formed from sodium 4-nitrophenylphosphate, urease – in mg N-NH_4^+ developed from hydrolyzed urea, protease – in mg tyrosine from sodium caseinate.

All assays were prepared in three replications.

RESULTS AND DISCUSSION

Majority of the examined soils exhibited neutral reaction with the exception of soils from object F5, where the soil reaction was slightly acid (Tab. 1). Soil alkalization on urban areas is associated both with alkaline dust deposits and salinity [4]. Soils from the waste dumps were characterized by higher pH values than spoils from the arable land neighboring them. The observed differences ranged from: 0.2–0.5 pH units in H_2O and 0.3–0.4 pH units in 1 mol·dm^{-3} KCl (Tab. 1).

Table 1. Concentrations of: organic carbon, total nitrogen, ammonia and nitrate nitrogen, C:N ratio and pH in soils

Location, number and character of object		pH		C	N	C:N	$N-NH_4^+$	$N-NO_3^-$
		H_2O	KCl	[g·kg^{-1}]			[mg·kg^{-1}]	
Felin 1	waste dump	7.4	7.2	10.59	0.55	19.2	31.06	10.05
	arable land	7.2	6.8	11.42	0.87	13.1	54.29	28.16
Felin 2	waste dump	7.4	7.0	16.09	1.72	9.3	67.36	8.46
	arable land	7.1	6.6	6.36	0.69	9.2	53.72	24.59
Felin 3	waste dump	7.3	7.1	15.34	1.66	9.2	61.84	106.87
	arable land	7.1	6.8	8.35	0.82	10.2	53.22	27.09
Felin 4	waste dump	7.2	7.0	14.03	1.38	10.1	56.08	73.49
	arable land	7.0	6.7	9.45	0.93	10.1	50.09	28.31
Felin 5	waste dump	6.7	5.8	12.48	1.32	9.4	64.54	8.85
	arable land	6.2	5.5	8.32	0.81	10.2	50.21	32.06
$LSD_{0.05}$				2.32	0.24	2.6	4.94	16.08

In the case of objects F2 – F5, the content of organic carbon and total nitrogen in the soils collected from the waste dumps was by about 1.5 to 2.0 times higher in comparison with the adjacent arable land, which was associated with the supply of fresh organic matter contained in municipal wastes. The C : N ratio in the soils of these objects fluctuated from 9.2 to 10.2 (Tab. 1). In the case of the F1 object, the content of organic C and total nitrogen in the soil derived from the uncontrolled landfill was smaller than in the arable land. Following the increased supply of C of anthropogenic origin (among others, dusts of carbon black formed from rubbed out car tyres, tar particles), and very low content of the value of the C : N ratio in soils from the F1 object was significantly higher than in the soils from objects F2 – F5 and amounted to: 19.2 in the soil from the landfill and 13.1 – in the soil from the arable land (Tab. 1).

The content of nitrogen mineral forms, i.e. $N-NH_4^+$ and $N-NO_3^-$ ranged from 50.09 to 54.29 mg·kg^{-1} and from 24.59 to 32.6 mg·kg^{-1}, respectively in the examined arable soils, whereas in the soils from the landfills – from 31.06 to 67.36 mg·kg^{-1} and from 8.46 to 106.87 mg·kg^{-1} (Tab. 1). Statistically significant differences in the content of these constituents between individual inspection points were apparent only in the case of soils from the uncontrolled waste disposal sites. This could have been caused by considerable heterogeneity of the raw material and chemical composition of wastes deposited on landfills.

In the case of the F1 object, a significantly lower content of ammonia nitrogen was determined in the soil derived from the landfill than from the arable land, contrary to trends found in soils in objects F2 – F5 (Tab. 1), which was probably attributable to the presence of biodegradable municipal wastes deposited on these waste disposal sites. The quantity of nitrate nitrogen in the soils of F3 and F4 objects was several times higher in comparison with the soils of the adjacent arable land (Tab. 1). The recorded relatively low content of this compound in the soils of the F1, F2 and F5 objects (8.46–10.05 mg·kg^{-1}) could have been connected with the dissimilation reduction of nitrates(V) stimulated by the enzymes of the denitrification path when, in conditions of low oxygen concentration, microorganisms utilize NO_3^- as electron acceptors to secure energy from organic compounds. Several times lower content of nitrates(V) determined in the soils derived from these landfills, in comparison with the neighboring arable land, appears to confirm this suggestion. It is evident from other studies [8, 23] that, in conditions of low O_2 concentration, nitrates(V) utilizing reductases as the primary acceptor of electrons become active. But the main reason of a low concentration of $N\text{-}NO_3^-$ in the soils of the plots F1, F2, and F5 were the factors with negative influence on nitrification.

In light of the existing standards [18], the soils of the examined objects, derived both from waste dumps and arable land neighboring with them, were characterized by a natural content of the analyzed heavy metal (Tab. 2). Nevertheless, the determined quantities of these elements found in the soils from landfills were higher in comparison with the soils derived from the adjacent fields, which indicates a trend for the accumulation of heavy metals in places where wastes were deposited.

Table 2. Heavy metal content in examined soils

Location, number and character of object		Cu	Pb	Zn	Ni	Cr	Cd
		[mg·kg^{-1}]					
Felin 1	waste dump	10.1	10.9	46.0	10.8	15.3	0.16
	arable land	6.3	6.7	32.0	9.2	12.9	0.10
Felin 2	waste dump	6.3	7.9	39.2	15.3	20.9	0.33
	arable land	5.1	7.5	25.4	8.6	10.4	0.17
Felin 3	waste dump	13.5	16.8	47.2	14.2	16.8	0.42
	arable land	7.3	11.7	37.9	9.3	12.5	0.27
Felin 4	waste dump	22.9	9.4	37.6	9.2	12.5	0.35
	arable land	6.2	9.1	33.8	8.1	11.2	0.22
Felin 5	waste dump	5.5	11.5	35.7	6.8	6.8	0.31
	arable land	4.5	9.7	28.9	6.1	6.1	0.29

The activity of the examined soil enzymes varied significantly in relation to the object position and way of its utilization (Tab. 3). The soil from under the 20-year-old waste site (object F1) was characterized by the lowest enzymatic activity.

Table 3. Soil enzymatic activity (Dh – dehydrogenases in $cm^3\ H_2 \cdot kg^{-1} \cdot d^{-1}$, Pac – acid phosphatase and AFz – basic phosphatase in mmol $PNP \cdot kg^{-1} \cdot h^{-1}$, AU – urease in mg $N\text{-}NH_4^+ \cdot kg^{-1} \cdot h^{-1}$, AP – protease in mg $tyrosine \cdot g^{-1} \cdot h^{-1}$)

Location, number and character of object		Dh	Pac	AFz	AU	AP
Felin 1	waste dump	1.27	34.41	50.53	3.34	6.09
	arable land	2.97	68.31	127.29	20.54	15.72
Felin 2	waste dump	4.64	142.95	208.84	38.06	17.80
	arable land	2.39	67.58	106.41	10.09	9.12
Felin 3	waste dump	4.58	173.17	216.49	43.58	13.85
	arable land	2.04	85.58	106.90	25.52	7.53
Felin 4	waste dump	4.85	179.72	200.06	41.82	20.72
	arable land	2.09	84.63	108.26	18.19	11.38
Felin 5	waste dump	4.62	214.70	117.61	19.27	15.97
	arable land	2.05	105.97	46.06	6.43	9.02
$NIR_{0.05}$		1.33	12.62	14.18	2.89	2.74

In the case of soils from objects F2 – F5, the activity of all the examined enzymes was several times higher on landfills than in the arable land neighboring them. Opposite tendencies were observed in the case of object F1 (Tab. 3).

The observed stimulation of the enzyme activity on waste dumps in the soils from objects F2 – F5 was connected with the abundance of the organic compounds contained in municipal wastes reactivating the circulation of nutrients. The presence of carbon substrates induces and stimulates enzyme biosynthesis by soil microorganisms [6]. It should be emphasized that fresh organic matter not only activates the metabolic activity of microorganisms but, equally importantly, exerts a positive impact on the decomposition rate of contaminants [11]. Numerous researchers reported elevated biological activities in soils from landfills of municipal wastes [7, 15, 17]. Niedźwiedzki *et al.* [15] claim that the biological balance in the soils from under landfills was disturbed following increased numbers of microorganisms which, in turn, led to the increased enzymatic activity and changes in soil metabolism. On the other hand, experiments conducted by Nowak *et al.* [16] dealing with the assessment of the effect of uncontrolled landfills established recently on the arable land of Gumnicka Plain on soil enzymatic activity carried out in laboratory conditions of model studies, revealed strong inactivation of dehydrogenases and phosphatases. Pot experiments, undoubtedly very valuable from the cognitive point of view, fail to reflect complex relationships between the activity of the soil biota and soil constituents which "buffer" the impact of external factors. Numerous researchers [among others, 2, 10] point to the defence mechanism which occurs in natural soils and protects microorganisms and enzymes against the influence of environmental stresses.

The weakening of the activity of the examined enzymes on object F1 in the soil from under the waste dump established 20 years ago (Tab. 3) could have been associated with the prolonged influence of contamination in the soil environment. It is worth mentioning here that numerous chemical compounds assume toxic or mutagenic properties following metabolic transformations taking place in living organisms [9]. Investigations carried out by Niedźwiedzki *et al.* [15] corroborate considerable differences in soil biological activities on and in the surroundings of uncontrolled waste dumping sites as well as observed variations in the degree of contamination of these soils. Ashford *et al.* [1] maintain that every site where municipal wastes are deposited results in the accumulation of toxic substances in the soil environment. Among factors which contributed to the weakening of the enzyme activity in the soil under the landfill of object F1 was, undoubtedly, the limited supply of fresh organic matter caused by the long-term deposition of wastes (covered with a thick, compact layer the soil surface) as well as a low proportion of humic substances in the total soil content of organic matter (as indicated by the determined wide value of the C : N ratio) restricting the accessibility of easily available C determining the development of soil bacteria manufacturing enzymes. The proportion of C of the microbiological biomass in the total content of soil organic C is an indicator of the relative substrate accessibility for enzymatic reactions [13].

Generally speaking, the soil enzymatic activity of arable lands adjacent to the examined waste dumps was at the level characteristic for soils of the undisturbed course of biological processes, which indicates that the scale of the impact of contamination caused by them on the surrounding land was limited. Studies conducted by Siuta *et al.* [20] revealed that increased numbers of microorganisms in the soils adjacent to municipal waste dumps appear only in the direct neighborhood of such sites which does not exceed several dozen meters. Also Quant and Sobociński [19] reported that the zone affected by waste dumps does not exceed 50 meters.

Simultaneously, it should be stressed that soil – as an open system into which various substances have unlimited access to – is exposed to continuous anthropopressure. This speaks in favor of continuing studies assessing the impact of gradual accumulation of contaminations in soils both under uncontrolled municipal waste dump sites and in their surroundings.

CONCLUSIONS

1. The observed increase of soil enzymatic activities in the majority of the examined landfills was associated with the supply to the soil environment of wastes of organic origin.
2. The determined high inactivation of the examined enzymes in the soil under the 20-year-old waste dump confirms a negative impact of the prolonged period of deposition of municipal wastes on soil biological properties.
3. The enzymatic activity of farmland soils neighboring the examined waste dumps did not differ significantly from the biological activity of soils of good quality.
4. The determined lack of the negative impact of the examined waste dumps on the chemical and biochemical properties of the soils from the adjacent farmland confirms that the area surrounding these sites which was affected by landfill contamination was limited.
5. The content of the analyzed heavy metals in the examined soils failed to exceed values considered as acceptable, although it was higher in the area of the waste sites than in the soils of the adjacent farmland. This may indicate a tendency for the accumulation of heavy metals in waste dump sites.
6. The performed investigations revealed that the determination of changes in the biochemical parameters in the soils from uncontrolled waste dumps as well as from the farmland in their surroundings provides reliable information about the condition of the soil environment. Studies in this area should be continued because they will make it possible to assess the ecological impact of the gradual accumulation of contaminants in soils surrounding uncontrolled sites of communal wastes.

REFERENCES

[1] Ashford S.A., C. Visvanathan, N. Hausain, C. Chomsurin: *Design and construction of engineered municipal solid waste landfills in Thailand*, Waste Management, **18**, 462–470 (2000).

[2] Badura L.: *Metale ciężkie w ekosystemach lądowych, a ekotoksykologia*, [in:] Drobnoustroje w środowisku, występowanie, aktywność, znaczenie, Kat. Mikrobiologii AR Kraków, 13–26 (1997).

[3] Baran S., E.J. Bielińska, P. Oleszczuk, E. Baranowska: *Aktywność dehydrogenaz jako wskaźnik zmian zawartości WWA w glebie użyźnionej osadem ściekowym*, Archives of Environmental Protection – Archiwum Ochrony Środowiska, **29**, 4, 97–105 (2003).

[4] Czarnowska K.: *Gleby i rośliny w środowisku miejskim*, Zesz. Probl. Post. Nauk Roln., **418**, 111–115 (1995).

[5] Domżał H., E.J. Bielińska (red.): *Ocena przeobrażeń środowiska glebowego i stabilności ekosystemów leśnych w obszarze oddziaływania Zakładów Azotowych „Puławy" S.A.*, Acta Agrophysica **145**, Rozprawy i Monografie (2) (2007).

[6] Fierer N., J.P. Schimel, P. Holden: *Variations in microbial community composition through two soil depth profiles*, Soil Biol. Biochem., **35**, 167–176 (2003).

[7] Frączak K.: *Oddziaływanie składowiska odpadów komunalnych w Tarnowie Krzyżu na liczebność grzybów w środowisku glebowym ze szczególnym uwzględnieniem grzybów toksynotwórczych*, Acta Agraria et Silvestria, ser. Agraria, **42**, 87–95 (2004).

[8] Granli T., O. Bockman: *Nitrous oxide from agriculture*, Norw. J. Agricul. Sci., Suppl., 12 (1994).

[9] Hübner H.: *Ekologiczne biomonitorowanie człowieka*, [in:] A. Kurnatowska (red.), Ekologia, jej związki z różnymi dziedzinami wiedzy, Wydawnictwo Naukowe PWN, Warszawa – Łódź 2002, pp. 321–331.

[10] Januszek K.: *Aktywność enzymatyczna wybranych gleb leśnych Polski południowej w świetle badań polowych i laboratoryjnych*, Zesz. Nauk. AR Kraków, Seria Rozprawy, **250** (1999).

[11] Kanchikerimath M., D. Singh: *Soil organic matter and biological properties after 26 years of maize – wheat – cowpea cropping as affected by manure and fertilization in a Cambisol in semiarid region of India*, Agriculture, Ecosystems and Environment, **86**, 2, 155–162 (2001).

[12] Kuczyńska I.: *Rola składowiska w gospodarce odpadami*, [in:] Konferencja Naukowo-Techniczna Składowiska odpadów komunalnych źródłem gazu, Czarna, 17–19 października 2007, PL-UA Center Landfill Gas Control, Instytut Nafty i Gazu, 2007, pp. 121–127.

[13] Kurek E.: *Związki przyczynowo-skutkowe aktywności mikrobiologicznej i zakwaszenia gleb*, Zesz. Probl. Post. Nauk Roln., **482**, 307–316 (2002).

[14] Ladd N., J.H.A. Butler: *Short-term assays of soil proteolytic enzyme activities using proteins and dipeptide derivatives as substrates*, Soil Biol. Biochem., **4**, 19–30 (1972).

[15] Niedźwiecki E., A. Nowak, J. Nowak, D. Kłódka, E. Meller, B. Smolik: *Oddziaływanie niekontrolowanych wysypisk odpadów na właściwości chemiczne oraz aktywność mikrobiologiczną gleby*, Zesz. Probl. Post. Nauk Roln., **501**, 325–334 (2004).

[16] Nowak J., D. Kłódka, B. Smolik: *Ocena oddziaływania niekontrolowanych wysypisk odpadów na aktywność enzymów glebowych i roślinnych w doświadczeniu wazonowym z pszenicą*, Zesz. Probl. Post. Nauk Roln., **501**, 335–341 (2004).

[17] Pascual J.A., C. Garcia, T. Hernandez: *Lasting microbiological and biochemical effects of the addition of municipal solid use waste to an arid soil*, Biol. Fertil. Soil, **30**, 1–6 (1999).

[18] PIOŚ: *Podstawy oceny chemicznego zanieczyszczenia gleb – metale ciężkie, siarka i WWA*, Państwowa Inspekcja Ochrony Środowiska, Instytut Uprawy Nawożenia i Gleboznawstwa, Biblioteka Monitoringu Środowiska, Warszawa 1995.

[19] Quant B., Z. Sobociński: *Strefa oddziaływania składowisk odpadów – dylematy rzeczoznawcy*, [in:] Metody badań powietrza, wody i gleby wokół składowisk odpadów, Materiały Ogólnopolskiego Sympozjum, Kraków 1996, pp. 43–51.

[20] Siuta J., G. Wasiak, B. Litwin: *Zasady tworzenia stref ochronnych wokół wysypisk odpadów komunalnych*, Wydawnictwo IKŚ, Warszawa 1980.

[21] Tabatabai M.A., J.M. Bremner: *Use of p-nitrophenyl phosphate for assay of soil phosphatase activity*, Soil Biol. Biochem., **1**, 301–307 (1969).

[22] Thalmann A.: *Zur Methodik der Bestimmung der Dehydrogenase Aktivität in Boden mittels Triphenyltetrazoliumchlorid (TTC)*, Landwirtsch. Forsch., **21**, 249–258 (1968).

[23] Włodarczyk T.: *Emisja i absorpcja N_2O na tle emisji CO_2 w glebach brunatnych w zróżnicowanych warunkach oksydoredukcyjnych*, Acta Agrophysica, 28, (2000).

[24] Zantua M.I., J.M. Bremner: *Comparison of methods of assaying urease activity in soils*, Soil Biol. Biochem., **7**, 291–295 (1975).

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WPŁYW NIEKONTROLOWANYCH WYSYPISK ODPADÓW NA WŁAŚCIWOŚCI CHEMICZNE I BIOCHEMICZNE GLEBY

W pracy podjęto próbę oceny oddziaływania niekontrolowanych wysypisk odpadów na właściwości chemiczne i biochemiczne gleby. Badaniami objęto pięć niekontrolowanych wysypisk odpadów zlokalizowanych na południowo-wschodnim obrzeżu Lublina. Odniesieniem były próbki glebowe pobrane z pól uprawnych znajdujących się w sąsiedztwie badanych wysypisk. W glebach na czterech wysypiskach, które pojawiły się stosunkowo niedawno (przed czterema – pięcioma laty), stwierdzono kilkakrotnie większą aktywność badanych enzymów (dehydrogenaz, fosfatazy kwaśnej, fosfatazy alkalicznej, ureazy i proteazy) niż w glebie z pól uprawnych. Przeciwne tendencje zanotowano w przypadku składowiska odpadów powstałego przed dwudziestu laty. Stwierdzony brak ujemnego oddziaływania badanych wysypisk odpadów na właściwości chemiczne i biochemiczne gleb sąsiadujących z nimi użytków rolnych świadczy, że zasięg oddziaływania zanieczyszczeń wokół wysypisk był ograniczony.