

EFFECT OF SEWAGE SLUDGE AND FURNACE WASTE ON THE CONTENT OF SELECTED ELEMENTS IN THE SWARD OF LEGUME-GRASS MIXTURE

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Abstract

Industrial landfills resulting from operations of various industries, particularly power generation, create specific habitat conditions for flora. Among the waste which may be used for recultivation of dumping heaps there is sewage sludge, which contains a considerable amount of nutrients crucial for plants. This investigation aimed at identification of the effect of sewage sludge and furnace ashes on the content of selected elements in a mixture of grass and white clover recommended for furnace ash heap recultivation.

The experimental design comprised 6 treatments (each in four replications), which differed in a dose of the supplied sewage sludge and furnace ashes: 1) control (without waste admixture), 2) 200 t d.m. of sewage sludge, 3) 200 t d.m. of ash, 4) 150 t d.m. of sludge + 50 t d.m. of ash, 5) 50 t d.m. of ash + 150 t d.m. of ash, 6) 100 t d.m. of ash + 100 t d.m. of ash. The content of macroelements in plants depended on the treatment and ranged from 2.58-31.2 g Mg, 3.16-5.85 g Ca, 16.95-18.46 g K, 0.26-1.25 g Na and 2.27-3.37 g P kg⁻¹d.m. Plants grown exclusively on furnace ashes had the highest content of Mg, Ca and K, whereas the highest P and Na concentrations were noted in plants cultivated exclusively on sewage sludge.

While assessing the content of macroelements in the plant mixture in view of its fodder value, it was found that the content of Mg and K met the standards set for good quality feeds, the amounts of Ca and Na were below the optimum, whereas the P concentration was close to the optimum value.

Key words: sewage sludge, ash, Mg, Ca, K, Na, P, grass mixtures.

WPLYW OSADÓW ŚCIEKOWYCH I ODPADÓW PALENISKOWYCH NA ZAWARTOŚĆ WYBRANYCH PIERWIASTKÓW W RUNI MIESZANKI MOTYLKOWO-TRAWIASTEJ

Abstrakt

Składowiska przemysłowe będące efektem działalności różnych gałęzi przemysłu, zwłaszcza energetycznego, stanowią specyficzne warunki siedliskowe dla flory. Odpadem, który może być wykorzystany w rekultywacji hałd, może być osad ściekowy zawierający znaczną ilość składników pokarmowych niezbędnych dla roślin. Celem badań było poznanie wpływu osadów ściekowych i popiołów paleniskowych na zawartość wybranych pierwiastków w mieszance traw z koniczyną białą polecaną do rekultywacji hałd odpadów paleniskowych.

Schemat doświadczenia obejmował 6 obiektów (każdy w czterech powtórzeniach), różniących się dawką wprowadzonych osadów ściekowych i popiołów paleniskowych: 1) obiekt kontrolny (bez dodatku odpadów); 2) 200 t s.m. osadu ściekowego; 3) 200 t s.m. popiołu; 4) 150 t s.m. osadu + 50 t s.m. popiołu; 5) 50 t s.m. osadu + 150 t s.m. popiołu; 6) 100 t s.m. osadu + 100 t s.m. popiołu. Zawartość makroelementów w roślinach była uzależniona od obiektu i wynosiła: 2,58-3,12 g Mg, 3,16-5,85 g Ca, 16,95-18,46 g K, 0,26-1,25 g Na, 2,27-3,37 g P kg⁻¹ s.m. Najwyższą zawartość Mg, Ca i K stwierdzono u roślin uprawianych wyłącznie na popiele paleniskowym, natomiast najwyższą zawartość P i Na – u roślin uprawianych wyłącznie na osadzie ściekowym.

Oceniając zawartość makroelementów w mieszance pod względem wartości paszowej, stwierdzono, że zawartość Mg i K w mieszance roślin odpowiadała normom stawianym paszom dobrej jakości. Zawartość Ca i Na w roślinach kształtowała się poniżej wartości optymalnej, a zawartość P w roślinach była zbliżona do wartości optymalnej.

Słowa kluczowe: osady komunalne, popiół, Mg, Ca, K, Na, P, mieszanka traw.

INTRODUCTION

Industrial waste landfills resulting from operations of various industries, particularly power generation, create specific habitat conditions for flora (CABAŁA, JARZĄBEK 1999, GOS 1999), including such unique features as the lack of humus and high alkalinity (pH 8.1-12.5), which make it difficult for plants to take up nutrients (MACIAK et al. 1976a,b). Ashes contain considerable amounts of Ca, Mg, Fe, Mn, B or Na and smaller quantities of P and K whereas nitrogen occurs in heterocyclic compounds unavailable to plants. Ashes also contain remains of unburnt coal (BEREŚNIEWICZ, NOWOSIELSKI 1977). Because of these specific properties, heaps of furnace ash must be managed immediately. Various recultivation measures are undertaken to facilitate biological management of landfills (GILEWSKA, PRZYBYŁA 2001). During initial recultivation of an ash landfill, it is recommended to fertilize the top layer of the heap and mix it with ashes. Municipal sewage sludge containing large amounts of nutrients crucial for plants may be the type of waste used for heap recultivation (CZEKAŁA 1999, MAZUR 1996). Sewage sludge used for biological recultivation of furnace waste heaps will solve the problem of their

management and at the same time will allow plants used for the recultivation to utilize the applied nutrients (KALEMBASA et al. 1987). However, it should be mentioned that beside many valuable macroelements, sewage sludge may also contain high concentrations of heavy metals, which disqualifies it as a substance useful for soilless area recultivation (ANTONKIEWICZ 2008, KALEMBASA, KALEMBASA 1997).

The research aimed at identification of the effect of sewage sludge and furnace ashes on the content of selected elements in the sward of a legume-grass mixture.

MATERIAL AND METHODS

The research was conducted in 2002-2005 as a field experiment located at the EMPOŚ Municipal and Industrial Sewage Treatment Plant in Oświęcim. A one-factor field experiment was conducted in a randomized block design on 8 m² plots. Sewage sludge and furnace ashes were tested in the field experiment, in which the experimental design comprised 6 treatments (each in four replications) different in a dose of the applied sewage sludge and furnace ashes (Table 1). Ash, sludge and their mixtures were applied once on the soil surface (without ploughing), two weeks prior to sowing a plant mixture.

Table 1

Design of the field experiment

No object	Combination	Doses (t ha ⁻¹ d.m.)	
		sludge	ash
1	control	-	-
2	sludge	200	-
3	ash	-	200
4	3/4 sludge+1/4 ash	150	50
5	1/4 sludge+3/4 ash	50	150
6	sludge + ash 1:1	100	100

Field experiment I was set up on soil of the grain size distribution of medium loam. The topsoil (0-20 cm) contained 42% sand, 7% coarse silt, 10% fine silt, 11% coarse silty clay, 12% fine silty clay and 18% colloidal clay. The soil on which the field experiment was set up had neutral pH (pH_{KCl}), whereas furnace ash pH was alkaline and municipal sewage sludge had a slightly acidic reaction (Table 2). The soil contained 8.24 g C and 0.67 g N kg⁻¹d.m. Organic carbon and total nitrogen content assessed in the

sewage sludge was respectively over 26- and 41-fold higher than in the soil, as well as over three- and two-fold higher than in the furnace ash (Table 2).

A mixture composed of the following grasses and legumes was sown for the experiment: red fescue (*Festuca rubra* L.) cv. Brudzyńska (40%), tall fescue (*Festuca arundinacea* Schreb.) cv. Skarpa (15%), Kentucky bluegrass (*Poa pratensis* L.) cv. Skiz (20%), birdsfoot (*Lotus corniculatus* L.) cv. Skrzyszowicka (10%) and white clover (*Trifolium repens* Haifa) (15%).

Table 2

Characteristics of materials used for the field experiment

Parameter		Unit	Sludge	Soil	Ash
			content		
pH	(H ₂ O)	pH	6.32	7.20	8.72
	(KCl 1 mol dm ⁻³)		5.88	6.81	8.46
	(CaCl ₂ 0.1 mol dm ⁻³)		6.22	6.91	8.47
Grain size distribution		-	-	gs*	pgmp**
Dry weight		%	19.63	-	76.12
Organic carbon		g kg ⁻³ d.m.	217.0	8.24	26.1
Total nitrogen			27.51	0.67	1.91
Total phosphorus			13.70	0.265	0.96
Magnesium			0.447	0.219	0.502
Calcium			2.662	0.407	1.030
Potassium			0.080	0.174	0.090
Sodium			0.074	0.038	0.131

* medium loam, ** strong loamy silt sand

After the harvest, the plant mixture was dried in a dryer with a forced air flow at 70°C and the dry weight yield was determined. Samples of plant material were dry-mineralized in a muffle furnace at 450°C and the content of Mg, Ca, K, Na and P was determined with the ICP-AES method. The paper presents the mean weighed average content of macroelements for the years 2002-2005. The concentrations of P, Mg, Ca, Na and heavy metals approximating the total in the soil (substratum) were determined after incineration of the organic matter and its digestion in a mixture of HClO₄ and HNO₃ (3:2) acids. As in the plant material, the content of elements in the soil filtrates was determined using the ICP-AES method (OSTROWSKA et al. 1991).

RESULTS AND DISCUSSION

The soil on which the experiment was set up met the standards for heavy metal concentrations, i.e. Cd, Pb, Cu, Ni, Zn and Cr, established for application of sewage sludge as a land recultivation measure for agricultural and non-agricultural purposes (*Rozporządzenie...* 2002). Sewage sludge used for the experiment met the requirements concerning heavy metal content for use in agriculture and for land recultivation for arable and non-arable purposes (*Rozporządzenie...* 2002). The content of Mg, C and Na in furnace ash used for the experiment was much higher than their soil concentrations (Table 2).

The effect of sewage sludge and furnace ashes on the crop yield of the grass-legume mixture was also presented in a monograph by ANTONKIEWICZ (2009).

A significant effect of sewage sludge and furnace ash and their mixtures on the plant mixture crop yield was found in the present field experiment. Analysis of the average yield for the investigated period showed the highest value for treatment 4, where 150 t d.m. of sludge and 50 t d.m. of ash were used per 1 ha. An increase in the plant mixture yield from this treatment was over 160% in comparison with the control. Sewage sludge applied in a dose of 200 t ha⁻¹ d.m. (treatment 2) also produced a large increase (over 130% vs. the control) in the plant mixture yield. Ash and sludge mixed in a 1:1 weight ratio (100 t d.m. of sludge per 1 ha of waste; treatment 6) also led to a significant increase in yield, which was almost 100% higher in comparison with the control. High fertilizer value of sewage sludge was depressed when a large amount of ash was added, as in the combination consisting of 50 t d.m. of sludge and 150 t d.m. of ash (treatment 5). The yield obtained from this treatment was significantly higher in comparison with the control. Furnace ash used separately in a dose of 200 t ha⁻¹ d.m. significantly diminished the crop yield, which corresponded to 60% of the yield obtained from the control (Table 3).

Our analysis of the chemical composition of the legume-grass sward revealed that the application of either type of waste and their mixtures led to a markedly diversified content of macroelements. The biggest differences occurred in the content of Na and Ca in the sward, while the smallest ones were found for the content of Mg. Depending on the treatment, the content of macroelements in the legume-grass sward ranged from 2.58-31.2 g Mg, 3.16-5.85 g Ca, 16.95-18.46 g K, 0.26-1.25 g Na and 2.27-3.37 g P kg⁻¹d.m. (Figure 1). The highest concentrations of calcium and potassium were determined in plants grown in the treatment where ash was used separately in a dose of 200 t d.m. ha⁻¹, while the highest content of phosphorus and sodium accumulated in plants in the treatment where sludge alone was applied, also in a dose of 200 t d.m. ha⁻¹.

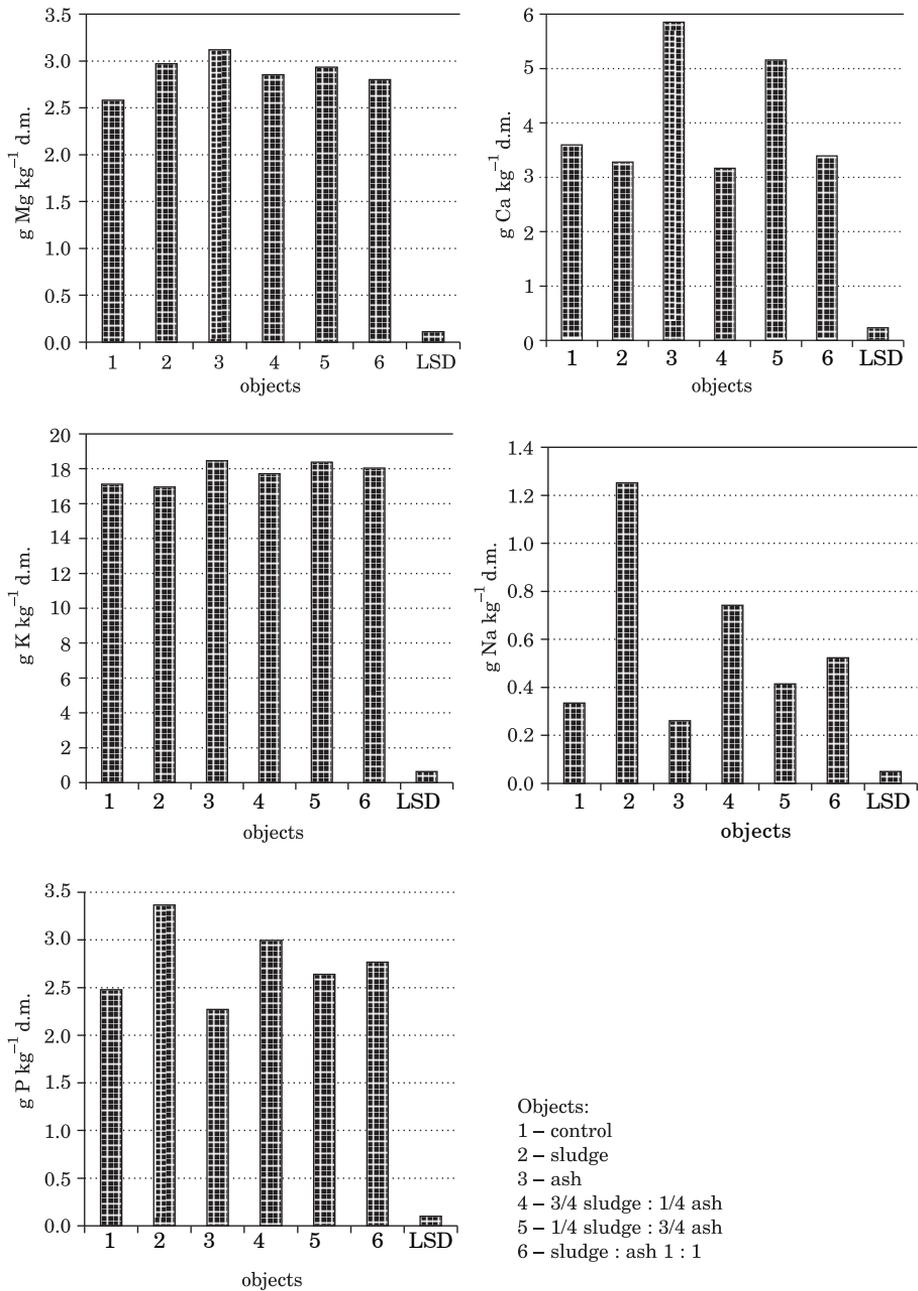


Fig. 1. Content of macronutrients in the sward of legume-grass

Table 3

Yield of plant mixture (t d.m. ha ⁻¹)						
No object	Combination*	Year of vegetation				Average
		2002	2003	2004	2005	
1	control	0.49	4.39	4.33	4.06	3.32
2	sludge	2.45	10.22	9.41	8.56	7.66
3	ash	0.15	2.65	2.60	2.35	1.94
4	PO 3/4:1/4	2.78	11.81	10.56	9.83	8.74
5	PP 1/4:3/4	0.80	6.86	6.79	6.31	5.19
6	PO 1:1	2.26	8.21	8.20	7.73	6.60
V, %		76.10	47.07	43.71	43.70	46.72
LSD($\alpha=0.05$)		0.17	0.42	0.25	0.25	0.302

* For experimental design see Table 1

Furnace waste used without admixtures in an amount of 200 t kg⁻¹ caused a marked increase in the content of magnesium, calcium and potassium in the grass and legume mixture as compared to the control.

Moreover, the applied municipal sewage sludge and ash-sludge mixtures significantly raised the magnesium content in plants. CIEĆKO and NOWAK (1984) confirmed the results demonstrating that the biomass obtained from plants cultivated on furnace ashes was more abundant in magnesium. On the other hand, the contribution of ash in the ash-sludge mixture clearly increased the levels of calcium and potassium in the mixture of grasses and legumes. Concentrations of calcium and potassium in the sward were significantly higher in the treatments fertilized with ashes and ash-sludge mixtures than in the control. KALEMBASA and WYSOKIŃSKI (2002) reported similar results from a pot experiment, in which higher content of calcium was noted in plants cultivated on sludge-ash mixtures than in plants grown on sludge.

Furnace ash applied in the experiment caused an evident decline in the sodium and phosphorus content in the sward versus the control and sewage sludge treatment. The significantly highest sodium concentration in the mixture of grasses and legumes was determined in the object enriched with a dose of 200 t ha⁻¹ d.m of sewage sludge. Also, the ash-sludge mixtures proved to be a rich source of sodium for the grass and legume mixture recommended for recultivation of post-industrial areas. The results are in accord with the research conducted by other authors (NOWAK et al. 1993), where alkalization of soil environment did not limit the potassium uptake by plants.

Fertilization with ash-sludge mixtures led to a significant increase in phosphorus concentrations in sward of the legume-grass mixture in compar-

ison with the control. Notably, the highest phosphorus content was found in plants grown in treatments fertilized only with sludge, in contrast to the control and ash-sludge mixtures. Moreover, the data shown in Figure 1 suggest that the content of phosphorus in plants decreases as a result of admixing ashes from black coal incineration to sludge as compared to fertilization with sludge alone. The results are supported by the research of KALEMBASA and WYSOKIŃSKI (2002), demonstrating that furnace ash admixture to sewage sludge decreases phosphorus content in plants. Although ashes sometimes contain large amounts of phosphorus, in an alkaline environment this component is almost completely retarded by calcium ions (MACIAK et al. 1976b).

The following concentrations of macroelements are regarded as optimal for fodder plants: 2.0 g Mg, 7.0 g Ca, 17-20 g K, 1.5-2.5 g Na and 3.0 g P kg⁻¹d.m. The municipal sewage sludge and furnace ashes applied in this experiment fully covered the plant requirements for magnesium, whereas the Ca and Na content in grass and legume mixture was below the optimum value. Potassium in plants cultivated on a substrate enriched with the above two types of waste corresponded to the optimum value, while the phosphorus content in the grass-legume mixture was close to the optimum.

CONCLUSIONS

1. Municipal sewage sludge, furnace ash and their mixtures applied in the experiment led to a significant increase in the content of Mg, Ca, K, Na and P.

2. The highest content of Mg, Ca and K was determined in the grass and legume mixture cultivated exclusively on ash, whereas the highest P and Na concentrations were found in the mixture cultivated on sewage sludge.

3. The Mg and K content in the grass-legume mixture met the standards for good quality feeds, whereas Ca, Na and P concentrations remained below the optimum value and the P content was close to the optimum.

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