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LEAD, NICKEL AND CHROMIUM CONTENT IN GRASS ON LAND RECLAIMED BY SEWAGE SLUDGE AND MINERAL WOOL GRODAN APPLICATION

ZAWARTOŚĆ OŁOWIU, NIKLU I CHROMU W TRAWIE UPRAWIANEJ NA GRUNCIE REKULTYWOWANYM PRZY WYKORZYSTANIU OSADU ŚCIEKOWEGO I WEŁNY MINERALNEJ GRODAN

Abstract: The objective of the present research was to analyze the impact of sewage sludge and post-use mineral wool applied to reclaim the devastated heavily acidified land, on heavy metal content in land reclamation grass seed mixture. The work presents the research findings from the three-year study period. There was analyzed grass obtained from the 1st cut as well as soil samples from 0–20 cm depth.

The experiment was set up on the post-sulfur mining land in Jeziorko. The 5 are-plots underwent the deacidification treatment with post-flotation lime followed by the employment of differentiated mineral wool doses (200, 400 and 800 $m^3 \cdot ha^{-1}$) along with a sewage sludge-amended dose. Ground in all the reclamation variants was characterized by a low content of lead, chromium and nickel.

A grass mixture from all the planting dates showed a natural level of the aforementioned trace elements. A grass Cr and Ni content was shown to be unaffected by sewage sludge and post-use mineral wool use for reclamation purposes. Mineral wool supplement implicated a proportional increase of a grass lead content.

Keywords: reclamation, lead, nickel, chromium, grass, ground, sewage sludge, mineral wool

Problems associated with the agricultural use of sewage sludge include primarily its bacterial and parasitic contamination with a concurrent wide range of toxic metals, in that heavy ones [1]. Sewage sludge application for non-industrial purposes, ground and land parameters as well as natural utilization of the sludge is governed by the stringent acts and regulations [2].

Mineral wool Grodan is produced from naturally occurring inorganic mineral material – magma rock. Rock wool is most widely used as a valuable growing substrate in the production of glasshouse crops but re-use of mineral wool slabs has remained

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a challenge [3]. That led to investigations on its application for devastated soil reclamation [4, 5].

Vegetation produced on sewage sludge-amended soil, especially for feedstuffs, should be examined for heavy metal contents. A few of them, like Cu and Zn (Ni and Cr to less extent) are recognized as essential micronutrients to maintain the life processes in plants/animals including human and animal health, whereas Pb and Cd affect plants most adversely.

The objective of the present study was to analyze the impact of sewage sludge and post-use mineral wool employed for reclamation of land devastated by heavy acidification, on heavy metal (Pb, Cd) content in a land reclamation grass seed mix.

Material and methods

The reclamation research was carried out on the post sulfur mining land in Jeziorko in 2004. The plots of 5-are area underwent the technical reclamation, i.e. deacidification process by post-flotation lime (100 $Mg \cdot ha^{-1}$) followed by the application of varied rock wool doses (200, 400, 800 $m^3 \cdot ha^{-1}$) along with a sewage sludge-amended dose (100 $Mg \cdot ha^{-1}$ d.m.). In spring prior to seed sowing, sewage sludge and mineral wool were applied integrated with ground (coarse sand) by means of a disk harrow and soil miller. The scheme of pre-sowing fertilizer dressing included P (single superphosphate), K (potassium sulfate) and 1/2 N (ammonium nitrate), while post-sowing 1/2 N after the 1st cut harvest.

The characteristics of materials used for reclamation process was presented in the paper by Baran et al [4]. Post-use mineral wool Grodan contained 35.5 mg $Pb \cdot kg^{-1}$, 18.5 mg $Cr \cdot kg^{-1}$ and 9.3 mg $Ni \cdot kg^{-1}$, while sewage sludge supplied by the treatment plant in Stalowa Wola comprised 29.2 mg $Pb \cdot kg^{-1}$, 26.7 mg $Cr \cdot kg^{-1}$ and 55.1 mg $Ni \cdot kg^{-1}$.

The schema of experiment is presented in Table 1. The plots were sown with a reclamation grass seed mix (Baran et al [5]).

Table 1

The schema of experiment

Reclamation variants
Post flotation lime + NPK 80; 40; 60 (control)
Post flotation lime + sewage sludge (control)
Post flotation lime + sewage sludge + wool 200 $m^3 \cdot ha^{-1}$
Post flotation lime + sewage sludge + wool 400 $m^3 \cdot ha^{-1}$
Post flotation lime + sewage sludge + wool 800 $m^3 \cdot ha^{-1}$
Post flotation lime + wool 200 $m^3 \cdot ha^{-1}$
Post flotation lime + wool 400 $m^3 \cdot ha^{-1}$
Post flotation lime + wool 800 $m^3 \cdot ha^{-1}$
Post flotation lime + wool 200 $m^3 \cdot ha^{-1}$ + NPK (80; 40; 60)
Post flotation lime + wool 400 $m^3 \cdot ha^{-1}$ + NPK (80; 40; 60)
Post flotation lime + wool 800 $m^3 \cdot ha^{-1}$ + NPK (80; 40; 60)

For the laboratory examinations, ground samples were collected from the topsoil (0–20 cm) after the soil was prepared for grass seed mix sowing and then, at late vegetation season (October) for three following years. The ground samples were collected in 3 replications (from random squares of 1 m^2 area). In the successive research periods, three cuts of grass were harvested (late spring, summer, autumn). The present study analyzes the results of the first cuts of grass. Having dried the grass, it was mineralized in concentrated acid mixture – HNO_3 and $HClO_4$ for the determination of Pb, Cr and Ni in the extract [6]. The ground samples taken were subjected to mineralization procedure in a mixture of concentrated acids HNO_3 and $HClO_4$ followed by determination of total contents of Pb, Cr and Ni in the ground and plants. The samples were measured using the ICP-AES inductively coupled plasma atomic emission spectrometer, Leeman Labs, model PS 950.

For the analyzed elements, there was calculated a bioaccumulation index (from the ratio between Pb, Cr and Ni content in plant biomass and their soil contents).

Results

Sewage sludge and mineral wool have changed a lead content in the reclaimed ground only to a small extent as compared with control I and II (Table 2). Pb content in 0–10 cm layer of the initial ground averaged 8.4 mg $\cdot$ kg^{-1}. Mean content of the element in ground, subject to an object, was found within 8.1–16.2 mg $\cdot$ kg^{-1} range. In all the fertilizer variants, a lead content increased with the rock wool dose elevation. The ground treated with differentiated doses of mineral wool and NPK showed the highest average lead content. The exception was made by the reclamation variants of lime + wool + NPK, where the ground displayed a higher lead content at the application of wool dose 200 $m^3 \cdot ha^{-1}$ as compared with a 400 $m^3 \cdot ha^{-1}$ dose. The observed differences were most likely to arise from ununiformity of the substrate structure.

Table 2

Content of lead in ground and mix of the grass from experiment
(average values from 3 years of the researches)

Reclamation variants	Ground	Mix of the grass	Bioaccumulation coefficient
	[mg · kg^{-1} d.m.]		
Control: post flotation lime + NPK	8.1	0.90	0.11
Control: post flotation lime + sewage sludge	8.5	0.93	0.11
Post flotation lime + sewage sludge + wool 200 $m^3 \cdot ha^{-1}$	9.0	0.49	0.05
Post flotation lime + sewage sludge + wool 400 $m^3 \cdot ha^{-1}$	10.7	0.40	0.04
Post flotation lime + sewage sludge + wool 800 $m^3 \cdot ha^{-1}$	12.9	1.18	0.09
Post flotation lime + wool 200 $m^3 \cdot ha^{-1}$	9.8	1.53	0.16
Post flotation lime + wool 400 $m^3 \cdot ha^{-1}$	9.7	1.51	0.15
Post flotation lime + wool 800 $m^3 \cdot ha^{-1}$	16.2	1.32	0.08
Post flotation lime + wool 200 $m^3 \cdot ha^{-1}$ + NPK (80; 40; 60)	13.5	0.51	0.04
Post flotation lime + wool 400 $m^3 \cdot ha^{-1}$ + NPK (80; 40; 60)	13.0	1.26	0.10
Post flotation lime + wool 800 $m^3 \cdot ha^{-1}$ + NPK (80; 40; 60)	15.1	1.01	0.07

A chromium content in 0–10 cm layer of the initial ground reached 13.6 mg · kg^{-1} .

Table 3

Content of chromium in ground and mix of the grass from experiment
(average values from 3 years of the researches)

Reclamation variants	Ground	Mix of the grass	Bioaccumulation coefficient
	[mg · kg^{-1} d.m.]		
Control: post flotation lime + NPK	12.7	1.8	0.14
Control: post flotation lime + sewage sludge	11.8	2.2	0.19
Post flotation lime + sewage sludge + wool 200 m^3 · ha^{-1}	14.3	2.3	0.16
Post flotation lime + sewage sludge + wool 400 m^3 · ha^{-1}	18.5	2.2	0.12
Post flotation lime + sewage sludge + wool 800 m^3 · ha^{-1}	24.5	2.1	0.08
Post flotation lime + wool 200 m^3 · ha^{-1}	18.1	2.1	0.12
Post flotation lime + wool 400 m^3 · ha^{-1}	21.8	2.1	0.10
Post flotation lime + wool 800 m^3 · ha^{-1}	30.5	1.9	0.06
Post flotation lime + wool 200 m^3 · ha^{-1} + NPK (80; 40; 60)	22.1	1.8	0.08
Post flotation lime + wool 400 m^3 · ha^{-1} + NPK (80; 40; 60)	24.6	2.0	0.08
Post flotation lime + wool 800 m^3 · ha^{-1} + NPK (80; 40; 60)	36.4	2.0	0.05

A mean Cr level determined from three-year study period of each reclamation variants was in the range between 11.8–36.4 mg · kg^{-1}. A chromium content in all the reclamation variants was shown to rise with increasing mineral wool doses, while in the ground a combination of lime + wool 800 m^3 · ha^{-1}+ NPK, a Cr content showed an over three-fold increase as against control I and II.

Prior to experiment, the initial ground was characterized by a low Ni level – 4.55 mg · kg^{-1}. Its mean content determined in the experimental plot ground ranged within 6.7–14.8 mg · kg^{-1}.

Considering all the fertilizer variants, the highest Ni amount was detected in the ground with the highest mineral wool dose. Alike, the ground under lime + wool + NPK combination was reported to have a higher Ni level compared with control and other fertilizer variants.

A mean lead content in a grass mixture from the plot was found between 0.40 and 1.53 mg · kg^{-1} d.m. (Table 2). The lowest Pb content was established in grass on the plots with sewage sludge and varied mineral wool dressing. In this fertilizer variant, Pb content grew with a rising wool dose. The highest lead content was recorded in grass obtained from the mineral wool-amended plots.

A chromium level in a grass mixture from the plots under study appeared to be slightly differentiated. Waste applied for the reclamation of devastated ground did not affect a Cr content in the grass analyzed (Table 3). A Cr level in the grass mix ranged between 1.8 and 2.3 mg · kg^{-1} d.m., similar values were found in plants from the experimental plots.

Table 4

Content of nickel in ground and mix of the grass from experiment
(average values from 3 years of the researches)

Reclamation variants	Ground	Mi of the grass	Bioaccumulation coefficient
	$[mg \cdot kg^{-1}$ d.m.]		
Control: post flotation lime + NPK	6.7	3.3	0.49
Control: post flotation lime + sewage sludge	7.3	3.1	0.42
Post flotation lime + sewage sludge + wool 200 $m^3 \cdot ha^{-1}$	7.3	2.7	0.37
Post flotation lime + sewage sludge + wool 400 $m^3 \cdot ha^{-1}$	9.5	2.8	0.29
Post flotation lime + sewage sludge + wool 800 $m^3 \cdot ha^{-1}$	11.7	3.0	0.26
Post flotation lime + wool 200 $m^3 \cdot ha^{-1}$	7.3	2.2	0.30
Post flotation lime + wool 400 $m^3 \cdot ha^{-1}$	8.8	2.0	0.23
Post flotation lime + wool 800 $m^3 \cdot ha^{-1}$	14.8	2.3	0.15
Post flotation lime + wool 200 $m^3 \cdot ha^{-1}$ + NPK (80; 40; 60)	11.4	2.2	0.19
Post flotation lime + wool 400 $m^3 \cdot ha^{-1}$ + NPK (80; 40; 60)	10.4	2.0	0.19
Post flotation lime + wool 800 $m^3 \cdot ha^{-1}$ + NPK (80; 40; 60)	13.7	2.3	0.17

A mean nickel content in the analyzed grass was in the 2.0–3.3 $mg \cdot kg^{-1}$ d.m. (Table 4). Alike a Cr content, a grass Ni level was not affected by post-use mineral wool Grodan or sewage sludge applied for land reclamation.

A bioaccumulation index calculated for lead in the grass mix under study was very low and ranged between 0.04 and 0.16. The highest values were detected in grass from the plots, which beside the liming were dressed with varied doses of post-use mineral wool (200 and 400 $m^3 \cdot ha^{-1}$).Wool at the dose of 800 $m^3 \cdot ha^{-1}$ applied in all the reclamation variants has declined this metal bioaccumulation in grass.

A bioaccumulation index for Cr and Ni in the investigated grass mixture was differentiated but generally, low. The highest values were noted in grass from the control plots, while the lowest from those with the highest mineral wool dose.

Discussion

Sewage sludge and post-use mineral wool Grodan used for the reclamation of land devastated by heavy acidification showed a low Pb, Cr and Ni content. Kuziemska and Kalembasa [7] reported similar Ni levels and tenfold higher Pb levels in the sewage sludge collected from the Siedlce and Sokolow Podlaski region.

Alike, the reclaimed ground also contained small amount of the metals studied. Sewage sludge did not affect these element levels. Only slightly elevated contents of Pb, Ni and Cr were detected in the ground reclaimed with the highest doses of post-use mineral wool.

Contents of Pb and Ni determined in the first cut of the reclaimed grass mix reported it as favourable for forage use [8] with the heavy metal contents most frequently recorded in grasses [9, 10]. Similarly, a Cr level was characteristic of the grasses from the Lublin region [11].

The present studies have not revealed any impact of the waste used in reclamation efforts on Cr and Ni accumulation in a grass mixture. However, there was noted a Pb content increase in the grass on the ground reclaimed by varied post-use mineral wool doses. Alike, in the investigations of Kuziemska and Kalembasa [7] sewage sludge applied did not increase Ni content in the tested plants as compared with those cultivated on manure. Czyzyk [12] in his studies found that Pb, Cr and Ni content in grasses from meadows irrigated with various sewages was dependent on a sewage type and amount of metals it contained. Meadow irrigation by sewages from non--industrialized cities did not cause a significant trace element growth in grasses. Grygierzec et al [10] noted that a grass nickel content was subject to a type of fertilizer dressing applied.

A bioaccumulation index for Pb, Cr and Ni has evidenced low and mean metal accumulation rate in grass mix [13]. Post-use mineral wool used for reclamation at 800 $m^3 \cdot ha^{-1}$ doses has reduced bioaccumulation of Pb, Cr and Ni in grass.

Conclusion

1. Ground reclaimed under all the fertilizer combinations showed a low Pb, Cr and Ni content.
2. Sewage sludge used in reclamation activities had no impact on the studies element contents, but their content increased with growing doses of post-use mineral wool doses.
3. Grass mixture from all the cuts was characterized by a natural content of the discussed heavy metals.
4. Sewage sludge and post-use mineral wool applied for reclamation did not affect chromium or nickel content in grass mix; mineral wool supplement increased proportionally lead accumulation in grass.

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ZAWARTOŚĆ OŁOWIU, NIKLU I CHROMU W TRAWIE UPRAWIANEJ NA GRUNCIE REKULTYWOWANYM PRZY WYKORZYSTANIU OSADU ŚCIEKOWEGO I WEŁNY MINERALNEJ GRODAN

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Abstrakt: Celem niniejszych badań była analiza wpływu osadu ściekowego i poużytkowej wełny mineralnej, zastosowanych do rekultywacji zdewastowanego przez silne zakwaszenie gruntu, na zawartość metali ciężkich w rekultywacyjnej mieszance traw. W pracy przedstawiono wyniki z trzech lat badań. Analizowano trawę z pierwszego pokosu, jak również glebę pobraną z głębokości 0–20 cm.

Doświadczenie założono na terenie byłej kopalni siarki w Jeziórku. Na poletkach o powierzchni 5 arów, po wcześniejszym odkwaszeniu wapnem poflotacyjnym, stosowano zróżnicowane dawki wełny mineralnej (200, 400 i 800 $m^3 \cdot ha^{-1}$), na tle melioracyjnej dawki osadu ściekowego.

Rekultywowany grunt we wszystkich kombinacjach nawozowych charakteryzował się małą zawartością ołowiu, chromu i niklu.

W mieszance traw ze wszystkich pokosów stwierdzono naturalną zawartość omawianych metali ciężkich. Zastosowane do rekultywacji osady ściekowe i poużytkowa wełna mineralna nie miały wpływu na zawartość w niej chromu i niklu. Wzrastające dodatki wełny mineralnej zwiększały proporcjonalnie zawartość ołowiu w trawie.

Słowa kluczowe: rekultywacja, ołów, nikiel, chrom, trawa, grunt, osad ściekowy, wełna mineralna