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Influence of sludge-ash composts on some properties of reclaimed land

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Abstract: The study was conducted in the area of the impact of sulfur mine in Jeziórko. The aim of the study was to assess changes in pH, cation exchange capacity and content of available phosphorus, potassium and magnesium after 6 years of conducting remediation. In the experiment (plots with an area of 15 m^2) degraded soil was rehabilitating by post-floating lime and compost from sewage sludge, sewage sludge and ash from combined heat and power (CHP). Composts at a dose of dry matter 180 t · ha^{-1} (6%), were determined in accordance with Minister of the Environment Regulation from 2001, applied the following options: control (only native soil limed), compost from municipal sewage sludge, sewage sludge compost (80%) and ash (20%), compost from sewage sludge (70%) and ash (30%). The reclaimed plots were sown with mixture of rehabilitation grass. Single de-acidification, land fertilization and a further 6-year extensive (without fertilization) use had a different influence on the properties of the native soilless substratum. Irrespective of the reclamation manner, after six years land use in the upper layers, observed increase in the average content of available phosphorus, available potassium content does not changed significantly but recorded a tenfold decrease in the content of available magnesium.

Introduction

The process of sulfur extracting in Mine Jeziórko contributed to the violation of soil structure, very often on the devastation scale. Emitted pollutants ended up on the poor native soils with a light particle size, and low in humus and minerals, which was the cause of their rapid degradation and devastation (Kołodziej et al. 2004, Martyn et al. 2006). Degradation, and often environmental devastation, outlined the need for soil remediation and reconstruction works on soilless formations, and their essence consisted in shaping the properties of devastated land to the level that would determine the effective biological reclamation (Dulewski et al. 2000, Gołda 2000).

In the view of previous studies, sufficient quality wastes, especially organic ones, can be used for this purpose (Baran et al. 2006, Baran et al. 2008, Baran et al. 2007, Baran 2005, Gołda 2007, Jońca 2000, Warzybok 2000). Waste that is often used for reclamation is municipal sewage sludge. Its natural, especially agricultural use, is determined by favorable content of nutrients and organic matter (Baran 2005, Baran et al. 2007, Baran et al. 2008, Gasco et al. 2004). The factor that may limit the agricultural use of sewage sludge is its contamination with heavy metals and sanitary contamination (Harrison et al. 2006, Rozp. M.Ś. 2010).

In order to reduce the negative impact of sewage sludge on the environment, its stabilization is carried out by adding calcium carbonate or wastes with a high content of calcium, e.g. fly ash from power plants (Baran et al. 2006, Wysokiński et al. 2012).

The aim of this study was to evaluate changes in pH, cation exchange capacity, and the content of available phosphorus, potassium, and magnesium in soilless formation reclaimed using the compost made of sewage sludge as well as sewage sludge with 20 and 30% share of the ash from power plant after six years of remediation.

Material and methods

The vegetation experiment was founded in 2002 on the area devastated by the sulfur exploitation in the Sulfur Mine Jeziórko. The strongly acidic soilless formation with a particle size of weak loamy sand was treated with post-flotation lime at a dose of 300 t · ha^{-1} and mixed with a soil layer to a depth of 25 cm. Then the plots of 15 m^2 area were amended once with six-month composts made of municipal sewage sludge from Stalowa Wola and manufactured on the basis of sewage sludge with 20 and 30% addition of ash from the combustion of hard coal in a power plant "Stalowa Wola". Composts at a dry matter dose of 180 t · ha^{-1} (6%), set in accordance to the Regulation of Ministry of Environment from 2001, were used in the following variants:

- Soilless formation – control (native soil limed);
- Soilless formation + compost made of municipal sewage sludge;

- Soilless formation + compost made of sewage sludge (80%) and ash (20%);
- Soilless formation + compost made of sewage sludge (70%) and ash (30%).

Composts were mixed with a soil layer to a depth of 25 cm and a blend of reclamation grasses of the following composition was sown: meadow fescue (*Festuca pratensis*) – 41.2%, red fescue (*Festuca rubra*) – 19.2%, red clover (*Trifolium pratense*) – 6%, Italian ryegrass (*Lolium multiflorum*) – 12.4%, perennial ryegrass (*Lolium perenne*) – 14.7%, orchard grass (*Dactylis glomerata*) – 6.5%. In subsequent years of the experiment, no fertilization was applied. In October each year soil samples were collected from a depth of 0–20 cm and 20–40 cm, for laboratory analyses.

Soil samples were subject to the following determinations:

- Acidity – potentiometry in H_2O and 1 mol · dm^{-3} KCl
- Hydrolytic acidity (H_h) – Kappen method in 1 mol · dm^{-3} CH_3COONa
- Alkaline cations (S) in extract of 0.5 mol · dm^{-3} ammonia chloride (pH 8.2)
- Organic carbon content – Tiurin method with Simakov modification
- Total nitrogen content – Kjeldahl method
- Total contents of P, K, Mg in mixture of concentrated nitric acid (V) and chloric acid (VII) (hyperchloric) mixed in 5:4 ratio – emission spectrometer ICP with inductively-coupled plasma
- Contents of available forms of phosphorus and potassium – Egner-Riehm method
- Content of available magnesium – Schachtschabel method.

This paper presents the properties of the native and reclaimed soil as well as after 1 and 6 years of experiment.

Results

Reclaimed soilless formation was a strongly acidified weak loamy sand (pH in 1 mol KCl was 4.7), poor sorption properties, as well as low in organic carbon and nitrogen (Table 1).

Municipal sewage sludge was characterized by the acidity close to neutral (pH in 1 mol KCl was 6.1). The sludge had favorable sorptive properties and high contents of carbon and nitrogen: 193.8 and 28.0 g · kg^{-1}, respectively. The C : N ratio was 6.9. The waste also met sanitary requirements.

The post-flotation lime is a waste with granulation of loam with alkaline reaction (pH in 1 mol KCl was 7.1). The content of alkaline cations amounted to 48.8 cmol (+) · kg^{-1}, and saturation of the sorption complex with these cations was high (99.35%) (Table 2).

The ash is a product of thermal transformation of the hard coal components, mainly kaolinite rocks. Features of ash determine its low specific density, low solubility of contained chemical components, and alkaline reaction (Table 1). The properties of tested ash are confirmed in the literature (Antonkiewicz 2007, Rosik-Dulewska 1998).

As a result of the combining the examined wastes and subjecting them to a process of composting, composts showing positive, yet diverse influence on the properties of the reclaimed soilless formation, were achieved. Similar results were obtained by Wysokiński and Kalembasa (2011).

Within upper layers (0–20 cm), after the soil reclamation, the pH in 1 mol KCl was in the range of 7.5–7.6. After six years of experiment, the pH value decreased by almost one unit and ranged from 6.5 to 6.7 (Table 2).

In the surface layer (0–20 cm) of native soilless formation, the organic carbon content was 5.6 g · kg^{-1} (Table 1). Composts used for the reclamation (made of sewage sludge and sewage-ash ones) contributed to the increased C_{org} content in the analyzed soilless formation compared to control (Table 2).

After six years of research, the content of organic carbon increased in control and soil reclaimed by compost made of sewage sludge. However, in objects reclaimed by compost made of sewage-ash with 20 and 30% ash addition there were observed similar contents.

In limed soilless formation (control), the N_{tot} content in 0–20 cm layer in the first year of the study was 0.20 g · kg^{-1}, which was lower than in the soil reclaimed by composts; it was connected with higher content of organic matter (Table 2). Soil

Table 1. Selected properties of sewage sludge, fly ash, post-flotation lime and soilless formation

Property	Unit	Sewage sludge	Fly ash	Post-flotation lime	Soilless formation
pH	H_20	6.3	7.9	7.3	5.4
pH	1 mol KCl	6.1	7.9	7.1	4.7
Hh	cmol(+) · kg^{-1}	4.50	0.8	4.5	4.2
S		50.04	122.1	48.8	2.02
T		54.54	122.9	54.3	6.22
N_{tot}	g · kg^{-1}	28.0			0.59
C_{org}		193.8			5.6
C:N		6.9			9.5
available P	mg · kg^{-1}	358.2	32.08	0.10	8.0
available K		604.0	135.0	28.6	2.38
available Mg		785.0	194.0	209	2.42

reclaimed by composts made of sewage sludge with 30% ash addition characterized highest total nitrogen content.

Sorption properties of soils are very important feature determining the level of fertilization, abundance in available nutrients, as well as the ability to retain contaminants (Gruszczyński 2010).

Use of post-flotation lime for de-acidification of the soilless formation (control) increased its sorption capacity from 6.25 to 22.6 cmol(+) · kg^{-1} (Table 1–2). The addition of tested composts increased – yet also differentiated – the sorption capacity of reclaimed soilless formation. Its highest value was reported in the surface layer of the formation with addition of the sewage sludge compost, while the lowest under conditions of applying the compost made of sewage sludge with 20% addition of ash. Sorption capacity in 20–40 cm layer was in general lower, and its differentiation did not show a clear direction. After six years of the experiment, an increased sorption capacity was observed, but to a large extent this was due to the increase in hydrogen ions concentration. In the surface layer of soil reclaimed with composts, the percentage of hydrogen ions in sorption capacity was greater from after 6 years of use in comparison to the baseline (Figure 1). Only in the soil reclaimed with compost made of sewage sludge with 20 and 30% addition of ash from the power plant, smaller saturation of sorption complex with hydrogen ions was observed in 20–40 cm layer.

The total phosphorus content in reclaimed soil during the first year of the study ranged from 0.20 to 0.38 g · kg^{-1} (Table 3). The process of reclamation and the soil layer (0–20 and 20–40 cm) did not differentiate univocally this feature. After 6 years of use, there was a significant increase in the total phosphorus content in 0–20 cm layer of soil reclaimed with the compost made of sewage sludge with the addition of ash from power plant. Regardless of the reclamation method, the

Table 2. Reaction and sorption properties of soil reclaimed by compost and post-flotation lime

Reclamation variants	depth (cm)	pH_{KCl}		C_{org}		N_{tot}		T			
				g·kg^{-1}				H		T	
								cmol(+)·kg^{-1}			
		I	II	I	II	I	II	I	II	I	II
Post-flotation Lime (control)	0–20	7.6	6.5	2.5	3.1	0.2	0.3	11.0	12.7	22.6	26.4
	20–40	7.3	6.5	1.6	2.1	0.2	0.2	15.1	15.0	24.0	27.5
Compost made of municipal sewage slugde (100%)	0–20	7.5	6.6	1.2	13.0	1.0	1.0	9.0	12.7	24.3	25.3
	20–40	7.4	6.6	3.6	3.2	0.3	0.4	5.0	12.0	14.2	24.4
Compost: sewage sludge (80%) and ash (20%)	0–20	7.6	6.7	13.6	13.3	1.0	1.0	7.5	12.7	19.5	24.9
	20–40	7.6	6.6	3.4	2.4	0.2	0.3	13.5	13.5	20.8	25.8
Compost: sewage sludge (70%) and ash (30%)	0–20	7.6	6.7	13.2	13.5	1.4	1.2	7.4	12.0	21.8	24.5
	20–40	7.5	6.7	5.4	4.9	0.3	0.5	14.1	11.2	25.1	23.5

I – the beginning of research; II – 6 years after the creation of the experience

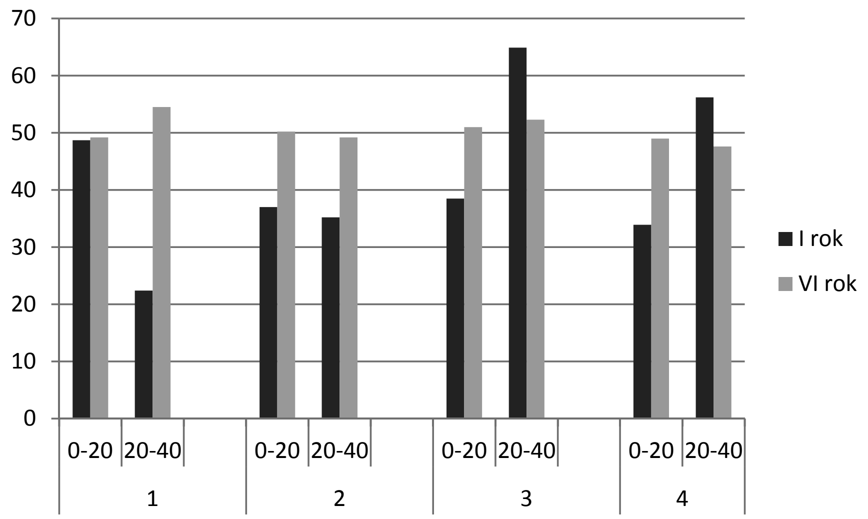

Fig. 1. Percentage contribution of hydrogen ions in sorption capacity in the first year of the study and after six years. Explanations: 1 – soil-less substrate + post-flotation lime (control), 2 – soil-less substrate + sludge compost, 3 – soil-less substrate + compost of sludge (80%) and ash (20%), 4 – soil-less substrate + sludge compost (70%) and ash (30%), 0–20 and 20–40 cm – depth of soil sampling

Table 3. The total content of P, K, Mg in soils reclaimed by composts and post-flotation lime

Reclamation variants	Depth (cm)	P		K		Mg	
		g·kg^{-1}					
		I	II	I	II	I	II
Post-flotation Lime (control)	0–20	0.20	0.31	0.41	0.61	0.40	0.36
	20–40	0.23	0.16	0.43	0.75	0.43	0.37
Compost made of municipal sewage sludge (100%)	0–20	0.33	0.14	0.46	0.10	0.61	0.45
	20–40	0.28	0.11	0.46	0.12	0.46	0.38
Compost: sewage sludge (80%) and ash (20%)	0–20	0.25	0.94	0.49	0.55	0.52	0.53
	20–40	0.20	0.19	0.42	0.56	0.40	0.35
Compost: sewage sludge (70%) and ash (30%)	0–20	0.38	0.73	0.48	0.62	0.63	0.65
	20–40	0.27	0.49	0.45	0.53	0.45	0.42
Mean	0–20	0.29	0.53	0.46	0.47	0.54	0.50
	20–40	0.24	0.24	0.44	0.49	0.43	0.38

average content of this element in the layer of 0–20 cm in the first year of the experiment was 0.29 g · kg^{-1}, while in the sixth year -0.53 g · kg^{-1}. The average phosphorus content in 20–40 cm layer after six years of utilization has not changed.

The soilless formation was characterized by low content of available phosphorus (8.0 mg · kg^{-1}). At the beginning of the experiment, the phosphorus content was significantly higher than in the devastated native soil, although little differentiated between reclamation methods and soil layers (0–20 and 20–40 cm) (Table 4). The content of this element in the reclaimed soil ranged from 22.4 to 35.4 mg · kg^{-1}, which showed a low abundance (Fertilizer recommendations 1990). After six years of the research, available phosphorus content in top layer 0–20 cm ranged from 27.2 to 47.4 mg · kg^{-1}. The soilless formation reclaimed using sewage sludge compost with 20% ash addition after six years of research was characterized by the highest content of available phosphorus compared to other combination.

The percentage of available in the total phosphorus forms in 0–20 cm layer in the first year of the study ranged from 7.6 to 13.8%, with average of 9.8%, while in the sixth year, it was within a wider range from 4.5 to 26.3%, averaging to 9.5% (Figure 2). The highest solubility of phosphorus in the first year of the study was recorded in the control soil, whereas after six years – in the soil ground reclaimed with sewage sludge compost. Deeper levels (20–40 cm), regardless of the reclamation method, were characterized by a higher percentage of available in the total content of phosphorus both referring to the 0–20 cm layer and to the first year of experiment. Czekała et al. (2010) reported that both the rate and frequency of sewage sludge application had no significant effect on the content of phosphorus available in the soil.

Table 4. The content of available P, K, Mg in the soil-less substrate reclaimed by compost and post-flotation lime

Reclamation variants	depth (cm)	P		K		Mg	
		mg·kg^{-1}					
		I	II	I	II	I	II
Post-flotation Lime (control)	0–20	26.6	30.1	15.1	20.0	11.3	2.4
	20–40	22.4	41.6	21.6	10.0	14.6	0
Compost made of municipal sewage sludge (100%)	0–20	25.0	27.2	19.5	20.0	77.7	0
	20–40	35.4	25.1	21.6	15.0	46.4	0
Compost: sewage sludge (80%) and ash (20%)	0–20	24.3	47.4	15.4	15.0	43.9	6.8
	20–40	27.6	46.9	18.5	10.0	21.9	4.0
Compost: sewage sludge (70%) and ash (30%)	0–20	32.3	32.9	16.5	15.0	64.3	7.5
	20–40	24.8	38.1	20.9	10.0	32.5	6.0
Mean	**0–20**	**27.1**	**34.4**	**16.6**	**17.5**	**49.3**	**4.6**
	20–40	**27.5**	**37.9**	**20.6**	**11.2**	**28.8**	**2.9**

I – the beginning of research; II – 6 years after the creation of the experience

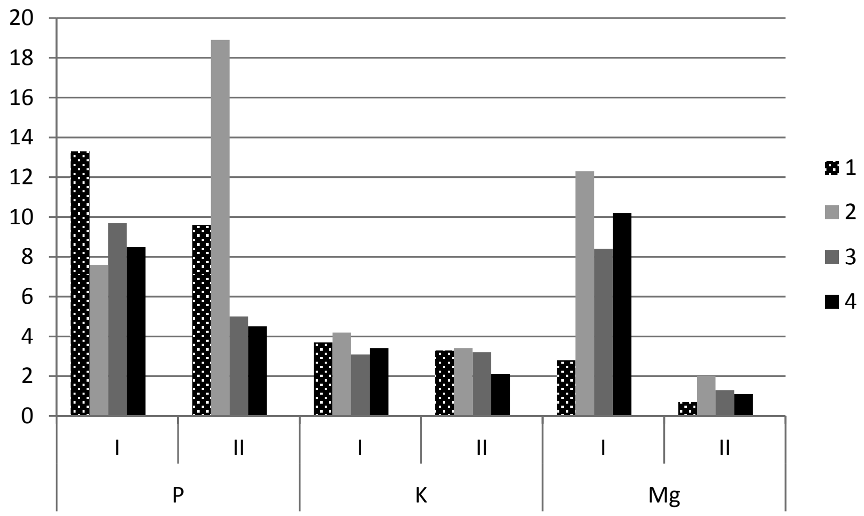

Fig. 2. Percentage content of available form P, K, Mg at a total content in the 0–20 cm layer of reclaimed soil. Explanations: 1 – soil-less substrate + post-flotation lime (control), 2 – soil-less substrate + sludge compost, 3 – soil-less substrate + compost of sludge (80%) and ash (20%), 4 – soil-less substrate + sludge compost (70%) and ash (30%), 0–20 and 20–40 cm – depth of soil sampling; I – the beginning of the experience, II – after 6 years

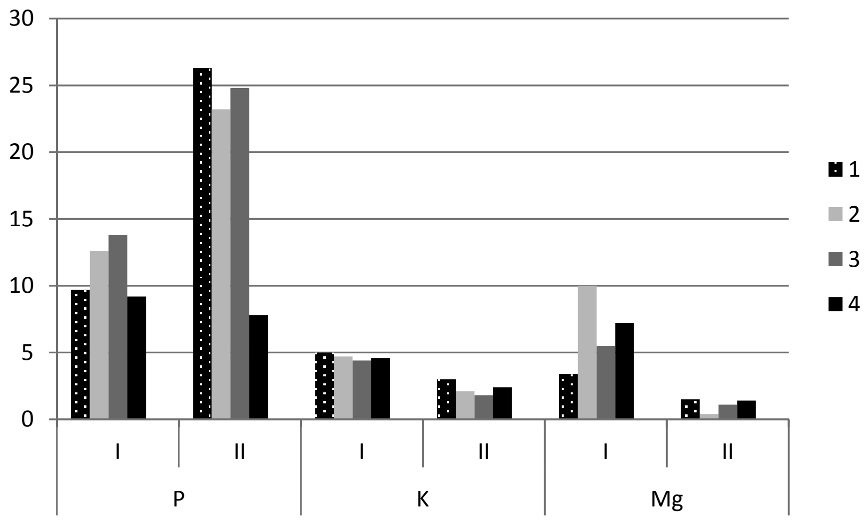

Fig. 3. Percentage content of available form P, K, Mg at a total content in the 20–40 cm layer of reclaimed soil. Explanations: 1 – soil-less substrate + post-flotation lime (control), 2 – soil-less substrate + sludge compost, 3 – soil-less substrate + compost of sludge (80%) and ash (20%), 4 – soil-less substrate + sludge compost (70%) and ash (30%), 0–20 and 20–40 cm – depth of soil sampling, I – the beginning of the experience, II – after 6 years

The available phosphorus content was negatively correlated with the acidity, while positively with the total phosphorus and potassium contents (Table 5).

The total potassium content in the reclaimed soil of the experiment was not very differentiated, both between the remediation methods and the depth of soil sampling (0.41–0.46 $g \cdot kg^{-1}$) (Table 3). Six-year use without fertilization diversified the content (0.10–0.75 $g \cdot kg^{-1}$), although the average of all variants was similar to the content in the year of experiment foundation (0.46 $g \cdot kg^{-1}$ – year of experiment start and 0.47 $g \cdot kg^{-1}$ – VI year). In six years of research, the smallest total potassium content compared to other combination was recorded in the soil reclaimed using sewage sludge compost in both analyzed layers.

The soilless formation was characterized by low (2.38 $mg \cdot kg^{-1}$) available potassium content (Fertilizer recommendations 1990). The soil reclaimed with sewage sludge compost and sewage sludge with different ash proportions was distinguished by similar content of the component (very low), but higher than the native soil (Table 4). In the deeper layer (20–40 cm), a higher content of available potassium than in the surface (0–20 cm) was determined. After 6 years of experiment, a similar potassium content in the surface layer as compared to the first year of study, as well as smaller in deeper layers, was found. Baran et al. (2006), when applied sewage sludge and used mineral wool for the reclamation of the soil devastated by the sulfur industry, reported their very positive influence on the content of available forms of potassium, magnesium, and phosphorus.

The percentage of available potassium forms in its total content in 0–20 cm layer, did not exceed 4% in both years (Figure 2). At deeper layer (20–40 cm), the solubility was significantly higher at the beginning than after 6 years of soil reclamation (4.7 and 2.3%) (Figure 3).

The simple correlation coefficient showed only a significant positive impact of the exchangeable acidity on the potassium content in the reclaimed soil (Table 5).

Table 5. Simple correlation coefficients

Property	available P	available K	available Mg
pH in KCl	-0.5319**	0.4554*	0.7523**
Kh			-0.6950**
T			-0.5027**
Corg			
Ntot.			
P tot.	0.4656*		
K tot.	0.5337*		
Mg tot.			0.6222**

For pH, Kh and T at the significance level $\alpha_{0.10} = 0.4259$; $\alpha_{0.05} = 0.4973$
For Corg and Norg at the significance level $\alpha_{0.10} = 0.6215$; $\alpha_{0.05} = 0.7067$

Total content of magnesium in the first year of the study ranged 0.40–0.63 $g \cdot kg^{-1}$ (Table 3). The 0–20 cm soil layer, to which compost was applied, was characterized by a higher magnesium content as compared with the control and deeper layers. The six-year use without fertilization contributed to the reduction of this element concentration in the control and soil reclaimed using sewage sludge compost. The sewage sludge compost with different ash proportions applied for reclamation, stabilized magnesium content in the soil.

The control soil treated only with post-flotation lime, was the poorest in available magnesium. Applying tested composts to the soilless formations greatly increased and diversified the available magnesium content in the first year of study. This effect can be lined up as follows: sewage sludge compost > sewage sludge compost (70%) plus ash (30%) > sewage sludge compost (80%) plus ash (20%) > post-flotation lime (control). The surface layers were much richer in this component than deeper ones. The abundance of reclaimed soil in available magnesium ranged from very low to high (Fertilizer recommendations 1990). After 6 years of use, the available magnesium was the most deficit element within the reclaimed soilless formation. Taking into account the fact that since the experiment foundation in 2002, no fertilizers were applied, such a very low abundance can be understood. Only traces of magnesium were found in the soilless formation reclaimed with sewage sludge compost. In the first year of study, the percentage of available magnesium in its total content was in the range from 2.8 to 12.3%, while in the sixth year, it ranged from 0 to 1.4%; in the surface layers, the ratio was higher than in the deeper ones (Figures 2 and 3). The control soil was characterized by the lowest magnesium solubility.

The content of available magnesium was significantly and positively correlated with exchangeable acidity and total magnesium content, whereas negatively with hydrolytic acidity and sorption capacity (Table 5).

Conclusions

1. The reclaimed soilless formation formed as a result of multivariate acidic degradation within the area of the Sulfur Mine Jeziórko, had negative chemical, physicochemical, and biological properties, making it unsuitable for the development of natural management.
2. A one-time soil improvement (de-acidification and fertilization) and a further six-year extensive utilization (without fertilization) exerted a different influence on the properties of the native soilless formation.
   - Regardless of the reclamation method, the upper layers of soil showed a decrease in pH by a unit, as well as an increase in the percentage of hydrogen ions in the sorption capacity.
   - After six years of use, in the soil reclaimed with the sewage sludge compost with addition of ash from the power plant, an increase in total phosphorus content and total potassium stability was observed in 0–20 cm layer. However, the magnesium content was not differentiated.
   - Regardless the reclamation method, after six years of soil use, the average content of available phosphorus increased, available potassium content did not change much, while content of available magnesium decreased about 10 times in the upper layers.

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References

[1] Antonkiewicz, J. (2007). Effect of ash-and-sludge and ash-and-peat blends on yield of grass-birdsfoot trefoil mixture and levels of selected elements in mixture, *Acta Scientiarum Polonorum, Formatio Circumiectus*, 6 (3), pp. 61–72. (in Polish)

[2] Baran, S., Wójcikowska-Kapusta, A. & Żukowska, G. (2006). Assessment of sewage sludge and mineral wool Grodan usefulness in reclamation of devastated soil based on phosphorus, potassium and magnesium available forms content, *Roczniki Gleboznawcze LVII*, 1–2, pp. 21–31. (in Polish)

[3] Baran, S., Wójcikowska-Kapusta, A., Żukowska, G. & Milczarek, T. (2008). Influence of the addition of compost from sewage sludge and sludge-ashes on sorption properties of the soil-less ground formation, *Zeszyty Problemowe Postępów Nauk Rolniczych,* 533, pp. 49–58. (in Polish)

[4] Baran, S. & Jońca, M. (2007). The possibility of restoration and rehabilitation of soils occurring in the areas devastated by the Sulphur Mine Jeziórko using municipal sewage sludge from Krosno wastewater treatment plants, *Report*, Agricultural University of Lublin, Lublin 2007. (in Polish)

[5] Baran, S. (2005). The possibility of restoration and rehabilitation of soils occurring in the areas devastated by the Sulphur Mine Jeziórko using municipal sewage sludge from Jasło wastewater treatment plants, *Report,* Lublin--Jeziórko 2005. (in Polish)

[6] Czekała, J., Mocek, A. & Owczarzak, W. (2010). Effect of long-term sewage sludge applicationon soil chemical indices, *Ecological Chemistry and Engineering A*., 17, 4–5, pp. 385–393.

[7] Dulewski, J. & Wtorek, L. (2000). Problems in restoration of lands degraded by coal mining to recovery them the utility value [In:] Protection and land reclamation, *Ecological Engineering*, 1, pp. 14–22. (in Polish)

[8] Gasco, G., Martinez-Inigo, M. & Lobo, M. (2004). Soil organic matter transformation after a sewage sludge application, *Electronic Journal of Environmental Agricultural and Food Chemistry*, 3, pp. 716–722.

[9] Gołda, T. (2000). The basic conditions of post-mining land reclamation devastated by Sulphur Mine Jeziorko, *Ecological Engineering*, 1, pp. 31–37. (in Polish)

[10] Gołda, T. (2007). The use sulphur ore post-flotation sludge in the reclamation of post-exploitation areas in borehole sulphur mining, *Inżynieria Ekologiczna,* 19, pp. 79–88. (in Polish)

[11] Gruszczyński, S., (2010). The Bayesian model of the interdependencies between soil sorption features, *Archives of Environmental Protection,* 36, 2, pp. 25–34.

[12] Harrison, E.Z., Oakes, S.R., Hysell, M. & Hay, A. (2006). Organic chemicals in sewage sludges, *Science of The Total Environment*, 367, pp. 481–497.

[13] Jońca, M. (2000). Application of sewage sludge in reclamation of Sulphur Mine Jeziórko land, *Ecological Engineering*, 1, pp. 27–30. (in Polish)

[14] Kołodziej, B. & Słowińska-Jurkiewicz, A. (2004). Results of soil cover reclamation on the area after Jeziorko sulphur mine, *Roczniki Gleboznawcze* LV, 2, pp. 231–237. (in Polish)

[15] Martyn, W. & Jońca, M. (2006). Chemical properties of soils that remained for 35 years under central sulphur storage dump in KiZPS „Siarkopol" in Tarnobrzeg, *Acta Agophysica,* 8(3), pp. 689–698. (in Polish)

[16] Rosik-Dulewska, Cz. (1998). Environment hazard caused by the redusting from transportation of energetic industry dusts, *Archiwum Ochrony Środowiska,* 24(3), pp. 129–145. (in Polish)

[17] Rozporządzenie Ministra Środowiska z dnia 13 lipca 2010 w sprawie komunalnych osadów ściekowych. Dz.U. 2010.137.924.

[18] Warzybok, W. (2000). Reclamation of mining land of Sulfur Mines Jeziorko, *Ecological Engineering*, 1, pp. 23–26. (in Polish)

[19] Wysokiński, A. & Kalembasa, S. (2011). The influence of mineral and organic additives to the sewage sludge and composting process of those mixtures on their selected properties, *Inżynieria Ekologiczna*, 27, pp. 240–249. (in Polish)

[20] Wysokiński, A. & Kalembasa, S. (2012). The influence of the addition of CaO and ashes from power station to sewage sludge as well as the composting of these mixtures on the content of nickel and chromium in fractions separated by sequential method, *Ochrona Środowiska i Zasobów Naturalnych*, 53, pp. 7–18. (in Polish)

[21] Fertilizer recommendations. (1990). Vol. I. Numbers limit for valuation content in soils of macro- and micronutrients, Ed. IUNG, Puławy, P(44), pp. 26, Puławy 1990. (in Polish)

Wpływ kompostów osadowo-popiołowych na niektóre właściwości rekultywowanego gruntu

Badania prowadzono w obszarze oddziaływania kopalni siarki w Jeziórku. Celem badań była ocena zmian odczynu, pojemności sorpcyjnej i zawartości przyswajalnych form fosforu, potasu i magnezu po 6 latach od przeprowadzenia rekultywacji. W doświadczeniu (poletka o powierzchni 15 m^2) przeprowadzono rekultywację zdegradowanego gruntu wapnem poflotacyjnym, oraz kompostami: z osadu ściekowego, osadu ściekowego i popiołu z elektrociepłowni. Komposty w dawce suchej masy 180 t · ha^{-1} (6%), ustalonej w oparciu o rozporządzenie MŚ z 2001 roku, zastosowano w wariantach: kontrola (grunt rodzimy tylko zwapnowany); kompost z komunalnego osadu ściekowego; kompost z osadu ściekowego (80%) i popiołu (20%); kompost z osadu ściekowego (70%) i popiołu (30%). Na zrekultywowanych poletkach zasiano mieszankę traw rekultywacyjnych. Jednorazowe odkwaszenie i nawożenie gruntu i dalsze 6-letnie ekstensywne (bez nawożenia) użytkowanie wywarły zróżnicowany wpływ na kształtowanie właściwości rodzimego utworu bezglebowego. Bez względu na sposób rekultywacji, po sześciu latach użytkowania gruntu, w wierzchnich warstwach, zwiększyła się średnia zawartość przyswajalnego fosforu, zawartość przyswajalnego potasu nie uległa znacznym zmianom natomiast około 10-krotnie zmniejszyła się zawartość przyswajalnego magnezu.