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**CHANGES IN VALUES
OF BASIC INDICATORS OF SOIL ACIDIFICATION
AS THE EFFECT OF APPLICATION OF SEWAGE SLUDGE
AND FLOTATION LIME**

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PODSTAWOWYCH WSKAŹNIKÓW ZAKWASZENIA GLEBY
W EFEKCIE STOSOWANIA OSADU ŚCIEKOWEGO
I WAPNA POFLOTACYJNEGO**

Abstract: The variability of selected factors of soil acidification: soil reaction (pH_{KCl}), exchange acidity and mobile aluminium were analyzed under the conditions of sewage sludge and flotation lime influence. The research was based on a two-year strict pot experiment, which was set up using complete randomization method, on soil material obtained from the vicinity of a sulphur mine. Prior to the experiment the soil was characterized by a very acidic reaction, an exchange acidity (Hex) value of $19.92 \text{ mmol}(+) \cdot \text{kg}^{-1}$, mobile aluminium content of $8.60 \text{ mmol}(+) \cdot \text{kg}^{-1}$, and moreover, by a low content of available phosphorus and potassium, very low content of available magnesium and high content of S-SO₄. The results obtained show that applied experimental factors (sewage sludge, flotation lime) positively influenced the changes in the analyzed soil properties. Under the influence of liming, the value of soil pH was changed distinctly and, in consequence, the soil reaction was changed from very acidic to acidic or slightly acidic. Moreover, soil liming caused a decrease in the values of exchange acidity and mobile aluminium in the examined soil. The influence of sewage sludge on the analyzed soil properties, in most objects, was also beneficial but less distinct than in the case of flotation lime.

Keywords: soil acidification, sewage sludge, flotation lime, soil reaction, exchange acidity, mobile aluminium

The extraction of sulphur by underground melting method causes the considerable changes in the environment, including chemical degradation of soils situated around

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sulphur mines [1–3]. One of the many negative effects of environment transformation is undoubtedly strong acidification of soils from these territories and that is why the basic task to improve soil environment is neutralization of acidic reaction [4]. Because of that fact waste substances, including flotation lime, found application in the restoration of the territories of former mines [5]. Moreover, organic sewage sludge has been proposed as useful in the process of soil structure restoration [6, 7]. The additional advantage of this method is high fertilization value [8].

The performed studies were aimed to analyse the effect of the flotation lime and sewage sludge on the selected indicators of acidification of soil, reaction (pH), exchange acidity (Hex) and mobile aluminium, obtained from the vicinity of a former sulphur mine ‘Jeziórko’.

Material and methods

The experiments were conducted based on the results of a two-year strict pot experiment carried out in the period 2004–2005. The experiment was performed using complete randomization method on soil material obtained from a vicinity of a former sulphur mine. Prior to the experiment the soil with the granulometric composition of light loamy sand was characterized by the following properties: $\text{pH}_{\text{KCl}} = 3.57$, Hex – $19.92 \text{ mmol}(+) \cdot \text{kg}^{-1}$, mobile aluminium content – $8.60 \text{ mmol}(+) \cdot \text{kg}^{-1}$, as well as by a low content of available phosphorus and potassium, a very low content of available magnesium and high content of S-SO₄. Two variable factors were used in the experiment: a dose of sewage sludge and a dose of flotation lime. Both factors were applied on three levels, according to the following pattern:

- | | | |
|------------------------------------|------------------------------------|------------------------------------|
| 1. Ss ₀ Ca ₀ | 4. Ss ₁ Ca ₀ | 7. Ss ₂ Ca ₀ |
| 2. Ss ₀ Ca ₁ | 5. Ss ₁ Ca ₁ | 8. Ss ₂ Ca ₁ |
| 3. Ss ₀ Ca ₂ | 6. Ss ₁ Ca ₂ | 9. Ss ₂ Ca ₂ |

where:

Ss₀ – without sewage sludge application;

Ss₁ – sewage sludge applied in the amount of $10 \text{ g} \cdot \text{kg}^{-1}$ soil;

Ss₂ – sewage sludge applied in the amount of $20 \text{ g} \cdot \text{kg}^{-1}$ soil;

Ca₀ – no liming;

Ca₁ – flotation lime in the amount of $3.096 \text{ g} \cdot \text{kg}^{-1}$ soil;

Ca₂ – flotation lime in the amount of $6.192 \text{ g} \cdot \text{kg}^{-1}$ soil.

The lower sewage sludge dose constituted 1 % of soil mass in the pot, whereas the higher one – 2 %. Under the field conditions, taking into considerations the mass of 20 cm of soil layer in the area of 1 ha, these doses corresponded to 30 Mg (Ss₁) and 60 Mg · ha⁻¹ (Ss₂). The lime doses were calculated on the base of hydrolytic acidity (Hh), taking 0.75 Hh for the lower dose and 1.5 for the higher one.

Sewage sludge used in the experiment had been hygienized and stabilized and had a pH_{KCl} value of 8.30. The flotation lime applied in the experiment contained $429.14 \text{ g CaO} \cdot \text{kg}^{-1}$.

In the first year of the experiment barley, ‘Cwał’ variety, was cultivated on the analysed soil and in the second year – spring rape, ‘Mozart 00’ variety. The plants were

cultivated in 8 replications. The harvesting of overground parts of plants took place in the phase of heading (oat) or flowering (rape) and in the phase of full maturity (oat, rape). In all the phases the harvesting of plants was carried out in four replications. All experiment objects were also constantly fertilized with NPK and a microelement solution, in the amounts adjusted to the plants' nutritional needs. The following parameters were determined in the soil material obtained prior to the experiment and in the second year of the experiment, after the rape harvest in the flowering and full maturity phase: pH in 1 mol · dm⁻³ KCl solution determined potentiometrically with a glass electrode and exchange acidity and mobile aluminium – determined using Sokolow method in the extract of 1 mol KCl · dm⁻³.

Results and discussion

The sewage sludge and flotation lime used in the experiment favourably affected the changes in the values of analysed indicators of soil acidification (Table 1).

Table 1

The effect of sewage sludge and flotation lime application on the value of selected indicators of soil acidification

Object	Determination	Reaction	Exchange acidity (Hex)	Mobile aluminium
		pH _{KCl}	[mmol(+) · kg ⁻¹]	
Soil after rape harvest in the flowering phase				
	Ss ₀ Ca ₀	3.62	14.70	4.70
	Ss ₀ Ca ₁	4.66	3.10	0.80
	Ss ₀ Ca ₂	5.62	1.90	0.50
	Ss ₁ Ca ₀	3.72	11.90	4.80
	Ss ₁ Ca ₁	4.60	2.70	0.70
	Ss ₁ Ca ₂	5.78	2.20	0.60
	Ss ₂ Ca ₀	3.81	10.80	4.10
	Ss ₂ Ca ₁	4.68	3.10	0.90
	Ss ₂ Ca ₂	5.65	1.40	0.10
Soil after rape harvest in the full maturity phase				
	Ss ₀ Ca ₀	3.68	13.70	5.60
	Ss ₀ Ca ₁	4.35	3.70	1.30
	Ss ₀ Ca ₂	5.46	1.40	0.40
	Ss ₁ Ca ₀	3.77	12.50	5.50
	Ss ₁ Ca ₁	4.51	2.60	0.80
	Ss ₁ Ca ₂	5.54	1.60	0.70
	Ss ₂ Ca ₀	3.82	10.50	4.20
	Ss ₂ Ca ₁	4.60	2.20	0.40
	Ss ₂ Ca ₂	5.63	1.60	0.40
	Before the experiment	3.57	19.92	8.60

Explanation: Ss – sewage sludge; Ca – liming.

The soil reaction is an indicator which correlates with the content of basic cations in the soil, thus supplying of them with the flotation lime aims to stabilization and optimization of soil reaction. As the effect of many-year sulphur contamination of soil, unfavourable changes in the saturation of sorption complex occur [9], which leads to the decrease of soil pH value. The procedure of soil liming affects its reaction and leads to the increase of pH value [10, 11]. In the performed experiment de-acidifying properties of liming were observed in the all experimental objects, in which this procedure was applied. The values of pH_{KCl} of soil in liming objects place in the range of 4.35–5.65 in comparison with the values in the objects without liming, which fluctuated from 3.62 to 3.82. The lower dose of liming caused the change of soil reaction from very acidic to acidic, whereas the higher one to slightly acidic. It was reflected in the pH values, which amounted to 4.35–4.68 in the objects with the lower dose of liming and 5.46–5.78 with the higher one.

Accompanying the change in soil reaction, the values of exchange soil acidity and mobile aluminium were also improved in the effect of liming. In both cases a considerable decrease of values of analysed acidification indicators was observed. Similarly as in the case of pH value, the favourable effect took place in all the experimental objects. The liming applied in the lower dose caused on the average four-times decrease of exchange acidity in comparison with the values from control objects. The higher dose of flotation lime resulted in 7.5-time decrease in exchange soil acidity value when compared with not-limed objects.

Studies by other authors [11, 12] indicate that liming is the most effective method to lower the concentration of mobile aluminium ions. In the performed experiment, in the effect of application of this procedure, the content of mobile aluminium decreased to trace amounts, similarly as reported by other authors [13–15]. In the objects where lime was applied in the amount of $3.096 \text{ g} \cdot \text{kg}^{-1}$ of soil, these values ranged from 0.4 to $1.3 \text{ mmol}(+) \cdot \text{kg}^{-1}$ and decreased 6.5-times on average in comparison with values from the objects with no liming. The soil which was limed with the higher dose of flotation lime was characterized with the content of mobile aluminium in the range of 0.1–0.7 $\text{mmol}(+) \cdot \text{kg}^{-1}$. In this case the average decrease was 15-times when compared with the values from Ca_0 objects. The highest, 41-times decrease in the content of mobile aluminium was observed in the objects Os_2Ca_2 , in the soil samples, taken in the phase of rape flowering.

The effect of sewage sludge, applied in the experiment, on the change of analysed soil acidification indicators was less explicit and less unambiguous than in the case of flotation lime. Supplying organic matter to the soil does not usually cause considerable changes in soil reaction [16]. In the performed experiment soil pH values from the objects where sewage sludge was applied insignificantly increased. The average increase of pH values caused by application of sewage sludge was about 1.5 % in comparison with control objects. This tendency occurred both for lower and higher doses of sewage sludge. The increase of soil pH value in the effect of application of sewage sludge was also observed by other authors [17, 18].

The values of exchange acidity were favourably affected by application of sewage sludge. In most of objects where sewage sludge was applied in lower dose, the values of

exchange acidity were lower of about 17 % in comparison with control objects and of about 29 % when higher dose of sewage sludge was applied. The inconsiderable increase of exchange acidity value in comparison with the values from objects with no sewage sludge was observed in the objects Ss_1Ca_2 , in the soil samples taken from under plants harvested both in the phase of flowering and full maturity and in the objects Ss_2Ca_2 in the soil samples taken from under plants harvested in the phase of full maturity. The increase of exchange acidity value caused by the application of living-farming-industrial sewage sludge was also observed by Grzywnowicz and Strutyński [19].

The sewage sludge caused the favorable change of the content of mobile aluminium in soil to a lesser degree than liming. The highest 5-times decrease of the content of mobile aluminium in the test soil in comparison with the control objects was observed in the combination Ss_2Ca_2 , in the soil samples taken from under plants harvested in the phase of flowering and about 3-times in the objects Ss_2Ca_1 with the single dose of lime. In the other objects lower decrease in the content of mobile aluminium in soil was observed and in some objects – even insignificant increase in the value of this indicator. Generally, it may be concluded, that the lowest content of mobile aluminium was observed in soil samples in the series both limed and fertilized with sewage sludge. It is an evidence for the favorable cooperation of both experimental factors on the content of mobile aluminium in soil.

Conclusions

1. The applied waste substances, both flotation lime and sewage sludge, have positively affected the analysed indicators of soil acidification.
2. The application of flotation lime has contributed to a change of soil reaction from very acidic to acidic and slightly acidic which is optimal for the growth of some cultivated plants.
3. The effect of flotation lime has also resulted in a substantial decrease in the exchange acidity of the analysed soil and in the soil content of mobile aluminium.
4. The sewage sludge has affected the changes in the values of analysed soil acidification indicators to a lesser extent than flotation lime.

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ZMIANY WARTOŚCI PODSTAWOWYCH WSKAŹNIKÓW ZAKWASZENIA GLEBY W EFEKCIE STOSOWANIA OSADU ŚCIEKOWEGO I WAPNA POFLOTACYJNEGO

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Abstrakt: Przeanalizowano wpływ osadu ściekowego oraz wapna poflotacyjnego na zmiany w wartościach wybranych wskaźników zakwaszenia gleby: odczynu (pH), kwasowości wymiennej (w) i glinu ruchomego. Badania prowadzono w ścisłym dwuletnim doświadczeniu wazonowym, które założono metodą kompletnej randomizacji, na glebie pochodzącej z okolic kopalni siarki. Gleba przed doświadczeniem charakteryzowała się bardzo kwaśnym odczynem (pH_{KCl}), wartością kwasowości wymiennej wynoszącą $19,92 \text{ mmol}(+) \cdot \text{kg}^{-1}$ oraz zawartością glinu ruchomego $- 8,60 \text{ mmol}(+) \cdot \text{kg}^{-1}$, a ponadto małą zawartością przyswajalnego fosforu i potasu, bardzo małą zawartością przyswajalnego magnezu oraz dużą zawartością S-SO₄. Uzyskane wyniki wskazują, że zastosowane w doświadczeniu czynniki zmienne (wapno poflotacyjne, osad ściekowy) korzystnie wpłynęły na zmiany analizowanych właściwości gleby. Pod wpływem wapnowania wyraźnemu podwyższeniu uległa wartość pH gleby, w wyniku czego odczyn z bardzo kwaśnego zmienił się w kwaśny lub lekko kwaśny. Ponadto wapnowanie spowodowało zmniejszenie wartości kwasowości wymiennej i zawartości glinu ruchomego w badanej glebie. Wpływ osadu ściekowego na analizowane właściwości glebowe był również w większości obiektów korzystny, jednakże zmiany ich wartości wywołane tym czynnikiem były mniej widoczne.

Słowa kluczowe: zakwaszenie gleby, osad ściekowy, wapno poflotacyjne, odczyn gleby, kwasowość wymienna, glin ruchomy