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# THE POSSIBILITIES OF RECLAMATION OF SOILS ACIDIFIED AT SLUDGE UTILIZATION*

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A b s t r a c t. The general properties (reaction, organic matter content, sorptive characteristics) were investigated in a light soil fertilized with sludge, in vegetative pot experiments, meant for plants cultivation in crop rotation and monoculture. It was found that various sludge doses and species of plants cultivated in rotation and monoculture exerted a cosiderable influence on the analysed properties of light soil.

K e y w o r d s: acidified soils, sludge utilization, soil reclamation

## INTRODUCTION

Natural defect or caused by the influence of anthropogenic factors, applies to great majority of Polish soils area and concerns the organic matter content and soil acidification [7].

In the light soils, acid from their nature, a negative balance of organic matter is observed that brings about a significant decrease of their sorptive capacites [1,4]. As a result, these soils undergo quite intensive washing off processes that in turn shake the ion equilibrium and induce regular acidification. Owing to these processes, there is an onward degradation of soils as well as water-courses and water basins contamination.

Despite many years or even annual fertilization of the soils with organic fertilizers, there was no expected humus growth, that pointed to agromelioration application [5,8].

Regarding the serious necessity in this respect and limits in organic fertilizers amount, it is evident that some nonconventional organic substances should be used [2,3,6,7,9].

Hence, the objective of the present experiments was to estimate the changes in reaction, sorptive properties and organic matter content in light soil fertilized with sludge.

## MATRIALS AND METHODS

The vegetative experiment was conducted in 11 $dm^3$ pots, applying loose sand from $A_1$ horizon of podzolic soil as substrate with various: 1 %, 2.5 %, 5 %, 10 %, 20 %, 40 % additives of smudge sludge coming from a municipal-industrial sewage-treatment plant in Końskie.

In the pots there were the following plants cultivated in the sequence: maize, broad bean, oil radish employing complementary mineral fertilization in g per pot:

| | | | |
|---|---|---|---|
| maize | N-0.6 | P-0.4 | K-0.65 |
| broad bean | N-0.2 | P-0.5 | K-0.80 |
| oil radish | N-0.4 | P-0.5 | K-0.65. |

The control was made by the pots with soil only and soil fertilized with manure 30 t/ha.

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On the above mentioned substrates for three years' time there were cultivated in the monoculture buckwheat, broad bean, spring barley and orchard grass, at NPK application in g per pot:

| | | | |
|---|---|---|---|
| buckwheat | N-0.30 | P-0.25 | K-0.35 |
| spring barley | N-0.40 | P-0.35 | K-0.30 |
| orchard grass | N-0.75 | P-0.50 | K-0.60. |

In the soil samples coming from the experiments the following factors were determined:

- granulometric composition after Cassagrande's method modified by Prószyński,
- electrometric reaction,
- basic cations and hydrolytic acidity according to Kappen's method,
- organic matter by means of mineralization in 500 °C,
- total carbon after Tiurin.

The obtained results were worked out statistically with variance analysis and correlation coefficients calculation.

## RESULTS

The soil of loose sand granulometric composition employed in the experiment showed an acid reaction, a low content of organic matter and poor saturation with basic cations (Table 1).

**Table 1.** Some soil and sludge properties applied in the experiment

| Specification | C total (%) | pH | | Hydrolytic acidity mmol $H^+$/100 g | Basic cation saturation (%) |
|---|---|---|---|---|---|
| | | $H_2O$ | KCl | | |
| Soil | 0.84 | 5.9 | 5.1 | 3.7 | 21.3 |
| Sludge | 15.70 | 6.4 | 6.2 | 2.4 | 95.5 |

The studied sludge, however, demonstrated a high content of organic matter, a slightly acid reaction and the optimum level of basic cation saturation (Table 1) at considerable (except potassium) macroelement content and mean concentration of heavy metals [1,3,9].

Sludge additive in the examined soil caused the changes in its general properties.

### pH changes in a light soil fertilized with sludge

Sludge additive decreased a hydrolytic acidity value and as statistically proved, the influence of the applied doses was conditioned by its greater span, for example 1 % and 5 %, 2.5 % and 10 % (Table 2).

At plants cultivation in rotation, hydrolytic acidity significantly increased (by 21.8 %) in the combinations of lower sludge doses.

In the soil for monoculture cultivation, only broad bean exerted a significant impact on acidification (Table 3). While the investigated plants went like following: broad bean>buck wheat> spring barley-orchard grass.

Hydrolytic acidity stands in a significant but negative dependance with the rest soil properties and the correlation values grow together with the time going by from sludge employment (Table 4).

Not such an evident impact was exerted by sludge upon exchangeable acidity and even less on the active one.

Plant cultivation in rotation gave rise to significant acidification measured by exchangeable acidity whereas explicitly less influence was recorded for active acidity (Table 2).

Acidification intensity diminished together with the growth of sludge in the substrate.

The plant species cultivated in monoculture significantly differentiated the exchangeable acidity, while in case of active acidity, the differences were not so clear (Table 3).

In the studied period of time a significant acidification increment was found determined on the basis of all acidity categories resulting from basic cations washing off (Table 2) and transformation of sludge organic matter [1,4,9,11].

### Changes in basic cation saturation in light soil fertilized with sludge

A low level of soil saturation with basic cations was typical of these soils after sludge use, though it augmented proportionally to its dose

**T a b l e 2.** The changes of properties of soil fertilized with sludge from the sewage-treatment plant in Końskie

| Treatment | Sludge dose (%) | $pH_{H_2O}$ | | | $pH_{KCl}$ | | | Hydrolytic acidity (mmol $H^+$/100 g) | | | Basic cation saturation (%) | | | C total (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | $\bar{x}$ | 1 | 2 | $\bar{x}$ | 1 | 2 | $\bar{x}$ | 1 | 2 | $\bar{x}$ | 1 | 2 | $\bar{x}$ |
| Soil | - | 5.9 | 5.3 | 5.6 | 5.1 | 4.8 | 4.9 | 3.7 | 4.6 | 4.2 | 21.3 | 0.0 | 10.7 | 0.53 | 0.52 | 0.52 |
| Soil+manure | - | 6.1 | 5.4 | 5.7 | 5.7 | 4.9 | 5.3 | 3.3 | 4.3 | 3.8 | 26.7 | 0.0 | 13.4 | 0.63 | 0.54 | 0.58 |
| Soil+sludge | 1.0 | 6.0 | 5.8 | 5.9 | 5.4 | 4.9 | 5.2 | 3.5 | 4.3 | 3.9 | 23.9 | 0.0 | 12.0 | 0.63 | 0.62 | 0.62 |
| | 2.5 | 6.0 | 5.8 | 5.9 | 5.4 | 4.9 | 5.2 | 3.4 | 4.2 | 3.8 | 26.2 | 0.0 | 13.1 | 0.64 | 0.61 | 0.62 |
| | 5.0 | 6.0 | 5.9 | 5.9 | 5.5 | 5.0 | 5.3 | 3.3 | 4.1 | 3.7 | 32.7 | 8.9 | 20.8 | 0.78 | 0.64 | 0.71 |
| | 10.0 | 6.0 | 6.0 | 6.0 | 5.5 | 5.1 | 5.3 | 3.2 | 4.0 | 3.6 | 36.0 | 20.1 | 28.0 | 0.93 | 0.70 | 0.81 |
| | 20.0 | 6.0 | 6.1 | 6.1 | 5.8 | 5.1 | 5.5 | 3.1 | 3.6 | 3.4 | 49.1 | 41.9 | 45.5 | 1.07 | 0.81 | 0.94 |
| | 40.0 | 6.0 | 6.2 | 6.1 | 5.9 | 5.9 | 5.9 | 2.8 | 3.3 | 3.0 | 66.7 | 56.6 | 61.6 | 1.20 | 0.99 | 1.10 |
| Mean | - | 6.0 | 5.8 | - | 5.6 | 5.2 | - | 3.2 | 3.8 | - | 41.3 | 23.9 | - | 0.80 | 0.68 | - |
| Treatment | | | 0.08 | | | 0.10 | | | 0.15 | | | | 1.00 | | 0.07 | |
| LSD: date | | | 0.02 | | | 0.03 | | | 0.04 | | | | 0.29 | | 0.02 | |
| interaction | | | 0.13 | | | 0.17 | | | 0.24 | | | | 1.61 | | 1.11 | |

**Table 3.** The variance analyses of general properties of soils under monoculture plant cultivation

| Variation source | Basic cation saturation (%) | pH | | Hydrolytic acidity (mmol $H^+$/100 g) | C total (%) |
|---|---|---|---|---|---|
| | | $H_2O$ | KCl | | |
| Buckweat | 29.20 | 6.00 | 5.20 | 3.50 | 0.77 |
| Broad bean | 11.50 | 5.80 | 4.90 | 4.00 | 0.82 |
| Spring barley | 29.30 | 6.30 | 5.40 | 3.30 | 0.87 |
| Orchard grass | 26.60 | 6.40 | 5.80 | 3.30 | 0.77 |
| LSD | 8.37 | 0.24 | 0.14 | 0.40 | 0.23 |

**Table 4.** The correlations between the properties of soil fertilized with sludge

| | | Hydrolytic acidity | Sorptive capacity | C total |
|---|---|---|---|---|
| Exchangeable cations | 1 | -0.8241 | 0.9993 | 0.8990 |
| | 2 | -0.9428 | 0.9988 | 0.9704 |
| Hydrolytic acidity | 1 | | -0.8000 | -0.9152 |
| | 2 | | -0.9256 | -0.9629 |
| Sorptive capacity | 1 | | | 0.8602 |
| | 2 | | | 0.9504 |

1-the beginning of experiment, 2-the end of the experiment.

and the increments were significant (Table 2). Having employed the highest examined dose (40 %), the feature takes values that correlate to very good quality soils. It was recorded a constant decline of basic cation contents in the soil fertilized with sludge and modified, among other, by the system of plant cultivation.

Rotation plant cultivation caused a significant decrease (45.5 %) of soil saturation with basic cations, the most evident at lower sludge doses (Table 2) due to the mineralization of the organic matter introduced to the soil together with sludge.

In the monoculture plant cultivation some significant influence upon a reduced number of basic cations in soil was exerted only by broad bean compared to other plants (Table 3).

Concerning soil running out of basic cations, the studied plats line up like that: broad bean>buckwheat - orchard grass>spring barley.

It should be emphasized that soil depletion of basic cations at the monoculture plant cultivation was positively less as against rotation system cultivation (Table 5).

**Table 5.** The changes of general properties of soil fertilized with sludge under rotation and monoculture cultivation

| Specification | C total (%) | | | Basic cation saturation (%) | | | Hydrolytic acidity | | |
|---|---|---|---|---|---|---|---|---|---|
| | Quantitative changes | Relative changes | | Mean loss | Relative loss | | Quantitative changes (mmol $H^+$/100 g) | Relative changes (%) | |
| | | from initial content | in relation to rotation | | from initial content | in relation to rotation | | from initial content | in relation to rotation |
| Rotation cultivation (maize, broad bean, oil radish) | -0.15 | -0.17 | 100.0 | -17.8 | -45.5 | 100.0 | +0.7 | +21.8 | 100.0 |
| Monoculture cultivation: | | | | | | | | | |
| buckwheat | -0.02 | -2.4 | 13.3 | -3.4 | -9.7 | 19.1 | +0.1 | +3.0 | 14.3 |
| broad bean | +0.08 | +9.6 | 153.3 | -9.8 | -27.8 | 55.1 | +0.6 | +18.2 | 85.7 |
| spring barley | +0.05 | +6.0 | 133.3 | -1.9 | -5.4 | 10.7 | -0.1 | -3.0 | 12.5 |
| orchard grass | -0.03 | -3.6 | 20.0 | -3.4 | -3.7 | 19.1 | -0.1 | -3.0 | 12.5 |

**Changes in organic matter content in light soil fertilized with sludge**

Sludge additive into light soil poor in organic matter, results in the growth of organic matter content (Tables 2,3,5). However, from sludge application time the organic matter content undergoes quantitative changes.

Rotation crop cultivation brought about a rise of carbon content in soil significant already from a dose 1 % in relation to soil and 5 % regarding the combinations with manure. Some significant carbon increments among the combinations with sludge were noted at sludge additives in soil higher then 5 %. Ever since sludge use, diminution of the introduced organic matter was recorded proportional to a sludge dose.

The changes in organic matter content in monoculture plant cultivation proved to be insignificant (Table 3) while compared to rotation cultivation, they are explicitly differentiated (Table 5).

Regarding buckwheat and orchard grass cultivation, the mineralization process of organic matter was far less (by 80.0-86.7 %) as against rotation. Monoculture cultivation of broad bean and spring barley, compared to rotation one, caused a positive balance in the organic matter content.

Concerning the mineralization rate of organic matter, the plants go as follows: orchard grass> buckwheat>spring barley> broad bean.

Organic carbon content shows some significant, positive relation with sodium cations and sorptive capacity whereas negative ones with hydrolytic acidity (Table 4). From the time of sludge application, this coefficient has increased and this fact is connected with mineralization and humification processes [1,4].

CONCLUSIONS

1. Sludge additive in light soil brings about a proportional to the applied dose improvement of reaction, organic matter and basic cation content. The improvement is stable at higher ameriolative content of sludge in the substrate.

2. A factor that modifies the mentioned properties are species of cultivated plants.

- Rotation plant cultivation caused a significant acidification, still different from changes in reaction in the monoculture plant cultivation. The plants cultivated in monoculture can be lined up like that regarding their acidification: broad bean>buckwheat >spring barley - orchard grass.
- Soil saturation with basic cations decreased by 45.5 % in rotation plant cultivation while in monoculture was clearly lower; significant for broad bean only. The cultivated plants according to monoculture system can be lined up concerning soil depletion of basic cations: broad bean>buckwheat - orchard grass> spring barley.
- Rotation plant cultivation resulted in a serious loss (by 45.5 %) of organic matter. Monoculture cultivation of buckwheat and orchard grass limited the process of organic matter mineralization by 80.0-86.7 % compared to rotation cultivation. The positive balance was noted for broad bean and barley cultivation (33.3-53.3 %).

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## MOŻLIWOŚĆ REKULTYWACJI GLEB ZAKWASZONYCH PRZY WYKORZYSTANIU OSADÓW ŚCIEKOWYCH

W wegetacyjnych doświadczeniach wazonowych, pod uprawą roślin w zmianowaniu i monokulturze, badano zmiany ogólnych właściwości (odczyn, zawartość substancji organicznej, właściwości sorpcyjne) w glebie lekkiej użyźnionej osadem ściekowym. Stwierdzono ewidentny wpływ różnych dawek osadu oraz gatunków roślin uprawianych w zmianowaniu i monokulturze na analizowane właściwości gleby lekkiej.

S ł o w a k l u c z o w e: gleby zakwaszone, wykorzystanie osadów ściekowych, rekultywacja gleb.