The utilization of differently treated sewage sludges in agriculture.

Utilisation agricole de boues de station d'épuration issues de différents traitements.

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Abstract

The differently treated sewage sludges were used for pot and climabox experiments. Tested materials were liquid sludge (6.5 % of dry matter, 0.26% N in raw material), sludge after centrifugation (26.3% of dry matter, 0.84% N), composted sludge (23.5% of dry matter, 0.72% N), sludge after centrifugation with CaO (59.2% of dry matter, 0.83% N) and pelletized sludge with CaO (60% of dry matter, 0.64% N). The aim of our experiments was to evaluate the agronomical efficiency of differently treated sewage sludges and the uptake of heavy metals from treated soils by plants.

Keywords : sludge, agriculture, lime

Résumé

Différentes boues de station d'épuration précédemment traitées ont été utilisées lors d'essais en pots et d'une expérimentation en chambre de mesure climatisée Climabox. Les boues testées étaient, soit liquides (6.5% de matière sèche, 0.26% d'azote par rapport au produit brut), soit boues issues d'une centrifugation (26.3% MS, 0.84% N), soit boues compostées (23.5% MS, 0.72% N), soit boues après centrifugation avec ajout de CaO (59.2% MS, 0.83% N) et des boues pelletisées avec CaO (60% MS, 0.64% N). L'objectif de nos essais était d'évaluer l'efficacité agronomique de ces boues distinctement traitées et de déterminer l'absorption de métaux lourds par les plantes de sols amendés.

Mots-clés : boues, agriculture, chaux.

1. Introduction

At present 35 - 40% of produced sludges are utilized in agriculture in the Czech Republic. It is assumed this part of sludges will increase owing to decreased amount of landfilled ones. New legislative rules limit the direct application of sludges for agriculture, introducing both hygienic and environmental risks. These are reasons for a pretreatment of sludges before agricultural utilization. Possible methods are as follows: composting (at the temperature above 55°C for more than 21 days, with two overdigging), fermentation in the aerobic bioreactors (at the temperature above 65°C for more than 24 hours) or lime stabilization (minimal pH = 11.5 for 1 hour at least). Sludges used in agriculture must meet limits for heavy metals and contents of certain organic substances.

2. Materials and methods

Differently treated sewage sludges were used for pot and climabox experiments. Tested materials were liquid sludge (6.5 % of dry matter, 0.26% N in raw material), sludge after centrifugation (26.3% of dry matter, 0.84% N), composted sludge (23.5% of dry matter, 0.72% N), sludge after centrifugation with CaO (59.2% of dry matter, 0.83% N) and pelletized sludge with CaO (60% of dry matter, 0.64% N).

Pot experiments with ryegrass were carried out in the Mitscherlich´s pots with 5 kg of soil. Tested fertilizers were dosed to the each pot in the amount containing 2 g of nitrogen. During experiments acceptable nutrients in soil solutions were analyzed. Ryegrass yields and nitrogen contents were studied within three cuts. After the first cut soil samples were also analyzed. Nitrification and mineralization abilities and nitrate and ammonium forms of nitrogen contents were determined. Basal nitrification ability (BNA)(1) expresses the actual conditions of mineralization and nitrification processes in soil and it corresponds with the content of ammonium and slightly hydrolyzable organic nitrogen in soil which can be nitrified during a week aerobic incubation of soil wetted to 60 % of MVK (maximum water capacity) at 28 ^{o}C. Potential nitrification ability (PNA) expresses mineralization and nitrification processes in soil after slightly methabolizable nitrogen addition.

White mustard was cultivated in a climabox. The effect of applications of solid, composted and lime stabilized sludges on heavy metal contents in soils and plants and on plants growth were observed in this experiment. Tested sludges were added to 600 g of soil in the amount containing 120 and 240 mg of nitrogen. After 30 days ageing of this experiment the total content of heavy metals and their acceptable forms, which are extractable by 0.01*M* $CaCl_2$ or 0.005*M* DTPA, were determined in soils. Concentrations of total metals were also measured in plants.

Field trial has been taking place in Lukavec (euthric Cambisol, the potato production area) since 1996. Cultivated crops were potato and winter wheat in 1996 and 1997 respectively. Before potatoes these fertilizers were applicated: solid sludge, sludge + CaO pelletized and manure, in such amount so that the dose of nitrogen was 150 kg per ha. Concentrations of certain elements in tested fertilizers are shown in Table 1. Soil samples were taken from all variants of our experiment. Values of pH_{KCl}, pH_{H2O} and NO_3^-- N, NH_4^+- N concentrations were determined.

Fertilizer	N	P	K	Ca	Mg	Pb	Cd	Zn	Cu	Cr	Ni
	(% in dry matter)					(mg/kg of dry matter)					
Solid sludge	6.0	2.6	0.6	3.8	0.3	80.0	4.8	2619	354	69	29
Sludge+CaO	1.2	0.6	0.3	36.0	0.6	14.7	1.0	523	91	14	7
Manure	2.3	0.8	3.3	1.6	0.6	6.9	1.1	120	22	14	8

Table 1.
Concentrations of elements in tested fertilizers

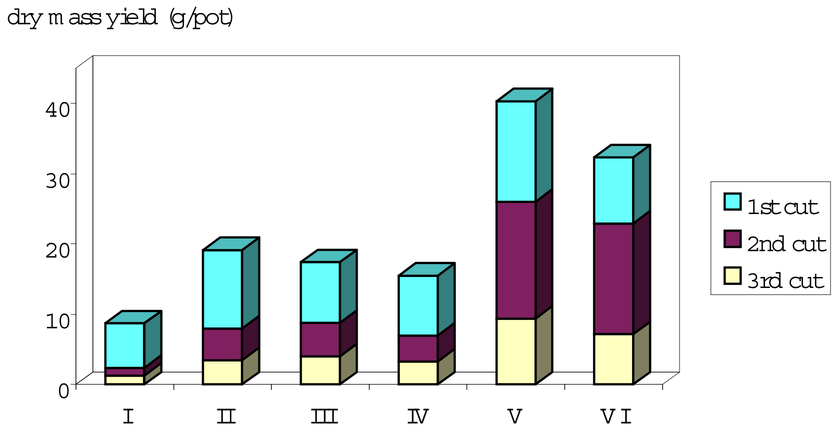
3. Results

The pot experiment results are showed in Figures 1 - 4. Liquid sludge contained the highest amounts of nitrate and ammonium nitrogen forms, which are easily utilizable by plants. Therefore the best seedling growth (the 1st - 4th week after emergention) was observed in this variant of our experiment. Vice versa the weakest one was found in the case of sludge with CaO, where the high pH value of fertilizer affected the observed process by the negative way. The following growth was fairly intensive in the variants containing sludges which support the highest yields of ryegrass in these cases (Fig. 1). The presence of alkaline lime stabilized sludge increased the intensity of mineralization and nitrification processes in soil and the consumption of nitrogen by plants (Fig. 2, 3). Pelletized sludge with lime affected gradual calcium releasing into soil solution by the positive way (Fig. 4).

In experiments both with ryegrass and with white mustard, sludges stabilized by lime retarded the germination and emergency of plant. Owing to the short vegetation season (30 days) in a climabox a weak seedling growth became evident in the total yield of the white mustard mass, that was more inferior in the sludge-CaO variant in comparison with solid or composted sludges. The higher yield and evener growth, the lower heavy metals concentration was found in plant. Concentrations of heavy metals in soils fertilized by sludges were unsignificantly increased only compared to the control variant without fertilizer. In the case of soil with lime stabilized sludge lower amounts of heavy metals extractable by DTPA solution were found.

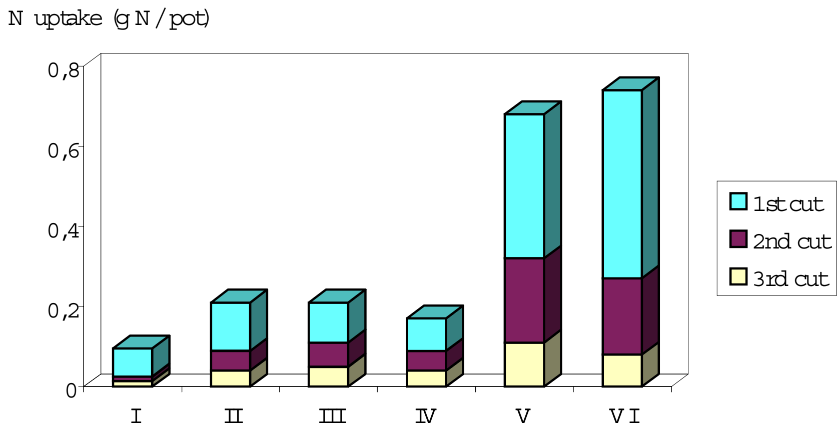
Both nutrients (N, P, K) and heavy metals concentration were decreased in finished product by the lime stabilization (Tab. 1). After mixing of sludge with CaO slaking of the latter ran thanks to water contained in sludge. Increasing of temperature of the reaction mixture, decreasing of the water content and strong increasing of pH (owing to $Ca(OH)_2$ forming) were observed consequently. Under these alkaline conditions mobile heavy metals cations (Cd^{2+}, Cu^{2+}, Ni^{2+}, Pb^{2+}, Zn^{2+}) form hydroxides which are only slightly soluble in water. After pelletizing the product is dried by air and influenced by the carbonatation process. By this process hydroxides in surface layers are transformed to carbonates soluble only in strongly acid solutions. Thus the protective cover arises on the surface of pellets. Following maturing of pellets (carbonatation carries on into internal layers) takes place after their defraying into dry soil. Therefore after the agricultural application of lime stabilized pelletized sludge heavy metal releasing to soil occurs only slowly and in the limited range reducing their transport into plants and a food chain.

The effect of pelletized sludge with lime was also verified by a field trial, in comparison with solid sludge, manure and soil without fertilizer. Pellets successive disintegration and nutrients releasing to soil solution took place after their application and defraying to soil. The latter improved physical and chemical properties of soil including the pH regulation in the following period (Fig. 5). Results obtained were similar to ones in the pot experiments: soil with this sludge had the higher mineralization and nitrification ability, nitrogen bonded in organic compounds both in soil and sludge was released more intensively, and therefore yields obtained for potatos and wheat were the highest of all tested variants (Fig. 6-8).



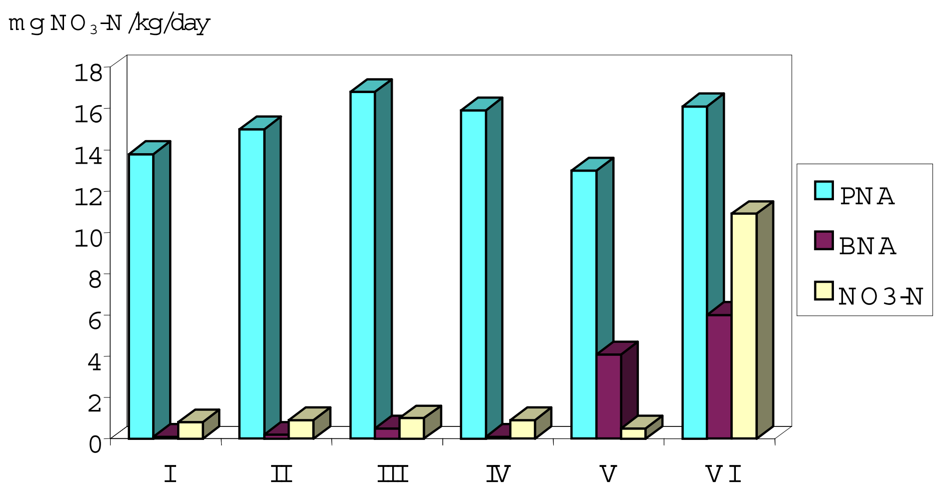
I - Control. II - Liquid sludge. III - Solid sludge. IV - Composted sludge. V - Sludge + CaO. VI - Sludge + CaO pelletized.

Figure 1
Yield of ryegrass



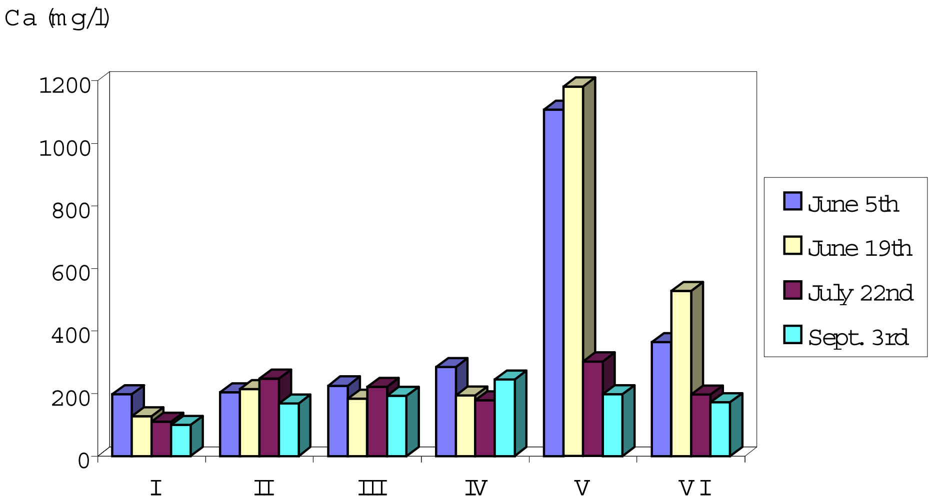
I - Control. II - Liquid sludge. III - Solid sludge. IV - Composted sludge. V - Sludge + CaO. VI - Sludge + CaO pelletized.

Figure 2
Amount of nitrogen taken up by plants.



I - Control. II - Liquid sludge. III - Solid sludge. IV - Composted sludge. V - Sludge + CaO. VI - Sludge + CaO pelletized.

Figure 3
Nitrate content in soil and nitrification ability of soil.



I - Control. II - Liquid sludge. III - Solid sludge. IV - Composted sludge. V - Sludge + CaO. VI - Sludge + CaO pellets.

Figure 4
Calcium content in soil solution.

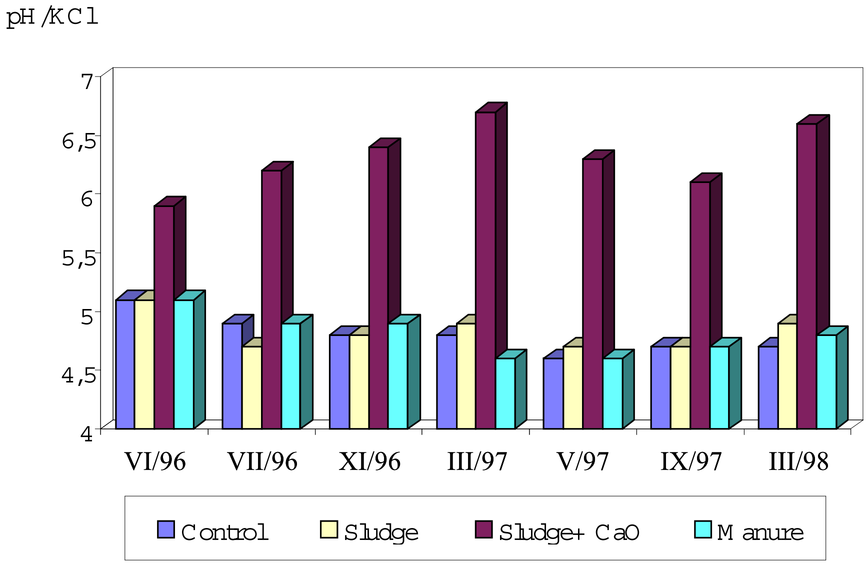


Figure 5
Soil pH/KCl reaction after application of fertilizers.

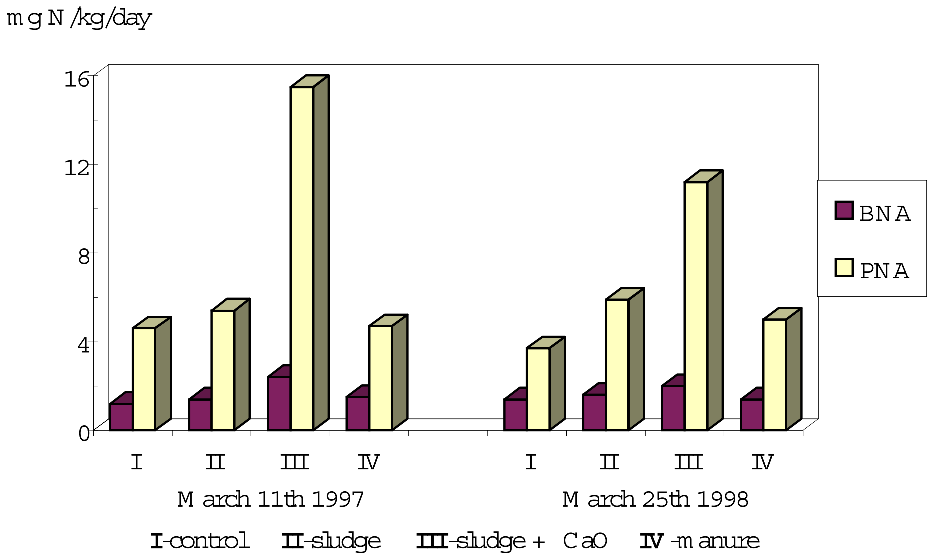


Figure 6
Nitrification ability of soil.

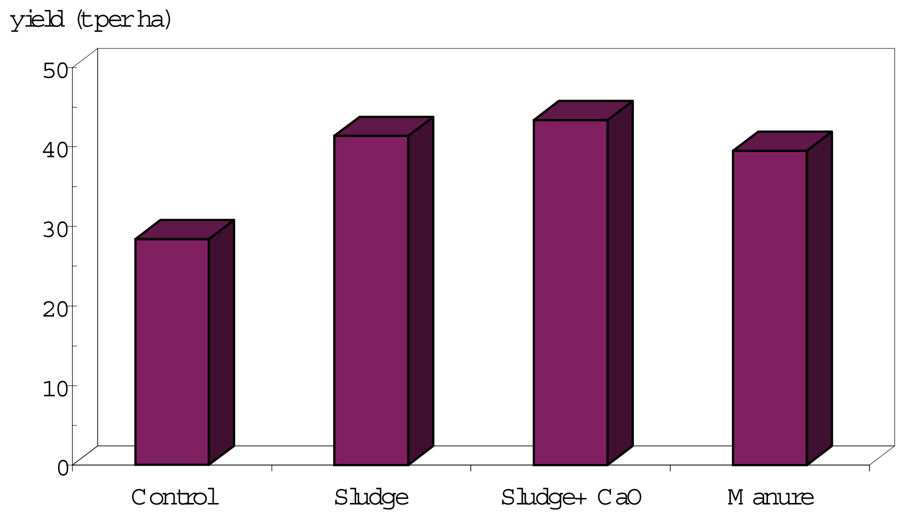


Figure 7
Yield of potato bulbs (1996).

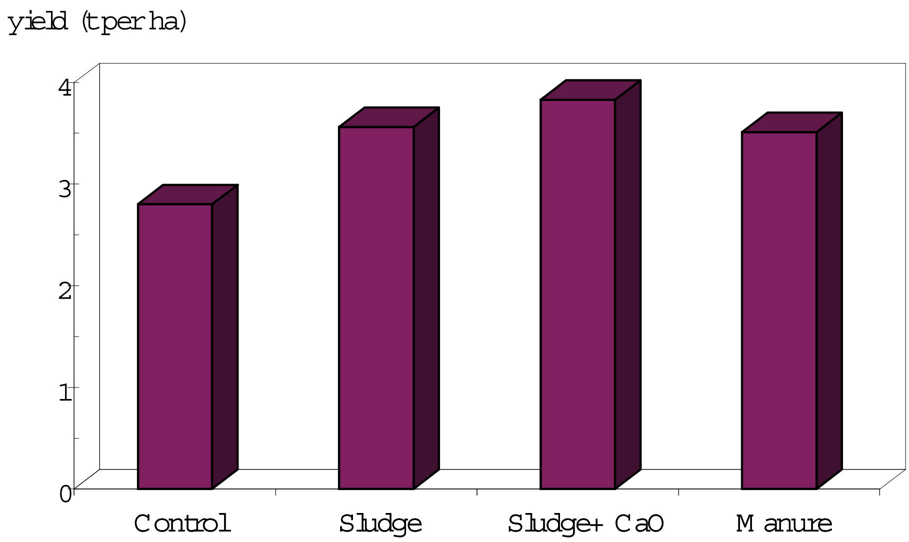


Figure 8
Yield of wheat corn (1997).

4. Conclusions

4.1. Direct agricultural application of sludges from sewage disposal plants introduce both hygienic and environmental risks. The accumulation of hazardous substances accumulation and the local infection sources can come due to heterogenity of this material

4.2. Different methods of sludge treatment exist to hygienize ones. In the Czech Republic are convenient as follows: composting (at the temperature above 55°C for more than 21 days, with two overdigging), fermentation in the aerobic bioreactors (at the temperature above 65°C for more than 24 hours) or lime stabilization (minimal pH = 11.5 for 1 hour at least). Reaction conditions above named are in accordance with requirements for the regular fermentation processes course, i. e. the correct utilization of raw materials, carbon/nitrogen ratio, humidity, aeration etc.

4.3. The pathogenic micro-organisms in sludge are diminished by the lime biosolidization. Furthermore decreasing of heavy metals concentrations and their mobility carries out. The latter is caused by forming of slightly soluble hydroxides and carbonates. Hence the heavy metal transport in the food chain is restricted under correctly utilized dose and date of the lime stabilized sludge application.

4.4. Lime stabilized sludges must be applicated to soil 3 - 4 weeks before sowing or planting at least. The releasing of calcium as well as other nutrients take place more slowly from pelletized product than from lime stabilized sludge without a following treatment.

4.5. The highest yields of cultivated plants were found after the lime stabilized sludge application in comparison with differently treatment sludges, both in pot and field trials. Soil with this sludge had the higher mineralization and nitrification ability, nitrogen bonded in organic compounds, both in soil and sludge, was released more intensively. The consumption of nitrogen by plants was also higher in this variant.