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Ecological Aspects of Sewage Sludge Utilization.

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ABSTRACT

The article discusses utilization of sewage sludge for fertilizing and phyto-amelioration as a solution to an important ecological problem of revegetation. Research results indicate the advisability of using sewage sludge along with sowing perennial grasses (alfalfa). The application of sewage sludge under perennial grasses significantly increased ameliorative properties of the latter. Under both fertilizer and ameliorative dosages, a decrease in soil density and increase in its porosity were observed. Nutrient content increased as follows: nitrate nitrogen – by 5.7 mg, phosphorus – by 4.1 mg, and potassium – by 15.2 mg (per 100 g of soil). After the application of sewage sludge, alfalfa herbage increased by 45–48 %. However, the fact that sewage sludge contains heavy metals hinders its extensive application. After the application of sewage sludge up to 100 t/ha, content of heavy metals increased in the first year of application, though staying within maximum permissible concentration. Over three years of application, content of heavy metals in blue alfalfa and hill mustard decreased 2–3 times, nearly reaching background content in soil. This fact emphasizes important phyto-ameliorative properties of perennial grasses, specifically alfalfa and hill mustard, in reutilization of sewage sludge.

Keywords: sewage sludge, phyto-amelioration, alfalfa, hill mustard, soil density, porosity, heavy metals.

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INTRODUCTION

In the context of modern agricultural system, we observe significant degradation of soil. Despite the considerable costs spent on growing crops, we also see a substantial reduction in yields [6].

Among the domestic and industrial waste, contaminating the environment, a special place is held by the sludge from aeration plants, with its annual output measured by millions of tons on a national scale [4, 5].

Today, a growing number of Russian cities face the problem of sewage sludge utilization. Its long-term storage requires additional substantial costs. One solution to this problem is using sludge as a fertilizer.

Current scarcity of fertilizers and degradation of soil calls for the application of unconventional sources of organic matter. Such approach will allow to gradually solve the existing situation, caused, on the one hand, by accumulation of huge amounts of organic matter, and on the other hand, by soil degradation.

However, the fact that sewage sludge contains heavy metals hinders its extensive application [1, 2, 3].

AIMS

The purpose of this work is to explore the possibilities of reutilization of sewage sludge from aeration plants and its environmental safety, when being applied for fertilizing and amelioration with the aim of phyto-ameliorative restoration of marginal lands.

MATERIALS AND METHODS

The experiment was performed on Southern black soil (humus content – 3.2 %) on the practice ground of the Saratov State Agrarian University. Experimental design involved the application of sewage sludge for cultivation of perennial grasses (alfalfa) at the following dosages: control w/o sewage sludge, 12.5 t/ha, 25 t/ha, 50 t/ha, and 100 t/ha. The experiment was performed in quadruplicate, on randomly located plots.

RESULTS

Sewage sludge, most effectively applied under perennial grasses, can be effectively used for biological amelioration of degraded Southern black soil of the Volga region along with any other local materials. An increase of crop and root residues and the application of sewage sludge with high content of organic matter significantly decreased soil density. In addition, sewage sludge decreased soil density by 0.12 g/cm^3, increased porosity at fertilizer dosages of 12.5 and 25 t/ha by an average of 1–2 %, at ameliorative dosages – by 3–4 % against background soil, and increased nutrient content under alfalfa as follows: nitrogen – by 5.7 mg, phosphorus – by 4.1 mg, and potassium – by 15.2 mg (per 100 g of soil).

The highest increase in yields of herbage from sewage sludge was observed in hill mustard due to better consumption of nutrients, specifically nitrogen. Hence, hill mustard herbage increased by 66–89 %, while alfalfa herbage increased by 45–48 %.

One of the reasons hindering extensive application of sewage sludge is the danger of depositing high amounts of heavy metals into the soil.

After the application of sewage sludge in our experiment, content of heavy metals in soil did increase, though stayed well within maximum permissible concentration.

The application of sewage sludge at fertilizer dosages of 12.5 and 25 t/ha increased the content of cadmium in soil under alfalfa by 0.05 and 0.26 mg/kg respectively, as compared to the control. The application of sewage sludge at ameliorative dosages of 50 and 100 t/ha increased the content of this element by 0.43 and 1.14 mg/kg, or 2.2 and 4.1 times respectively. The content of lead increased by 17.5 and 39.2 % at fertilizer dosages and 2.5 and 5.3 time at ameliorative dosages. The content of copper under alfalfa increased by 12.5 %, 3.2, 3.4, and 4.1 times, according to the application dosages. The content of zinc increased by 45.8 %, 82.7 %, 2.2 and 2.8 times; while the content of mercury increased by 29.2 %, 50 %, 79.2 % and 2.4 times (Table 1).

Table 1: Content of heavy metals in soil under alfalfa, mg/kg

Experimental variants, sewage sludge dosages, t/ha	Lead	Cadmium	Copper	Zink	Mercury
Control (w/o sewage sludge)	12,0	0,37	15,2	32,3	0,024
12,5	14,1	0,42	17,1	47,1	0,031
25	16,7	0,63	49,0	59,0	0,036
50	30,2	0,80	52,3	71,1	0,043
100	63,7	1,51	62,3	89,4	0,058
MPC	130	2,0	132	220	2,1

After the application of sewage sludge up to 100 t/ha, content of heavy metals in soil under alfalfa increased as follows: lead – from 9.2 to 49.0 % of MPC, cadmium – from 18.5 to 75.5 % of MPC, copper – from 11.5 to 47.2 % of MPC, zinc – from 14.7 to 40.6 % of MPC, and mercury – from 1.1 to 2.8 % of MPC.

Content of heavy metals in soil under hill mustard also increased according to the sewage sludge application dosages. Lead content increased by 27.3 % and 2.4 times at fertilizer dosages, and 3.6 and 7.6 times – at ameliorative dosages. Content of other metals increased respectively: cadmium – by 63.9 % / 2.1 times, and 2.7 / 5.5 times; copper – by 22.0 % / 2.4, and 3.2 / 3.9 times; zinc – by 40.0 % / 51.4 %, and 75.0 % / 2.8 times. The content of lead in soil under alfalfa was considerably lower than under hill mustard. Deviations from control at different dosages were as follows: 12.5 t/ha – 0.2 mg/kg, 25 t/ha – 9.6 mg/kg, 50 t/ha – 9.9 mg/kg, 100 t/ha – 19.5 mg/kg. The same pattern was observed in the content of cadmium, with deviations of 0.17, 0.14, 0.16, and 0.48 mg/kg respectively.

On the contrary, content of zinc and copper was much lower under hill mustard. The content of copper under this crop was by 1.0, 16.7, 10.1, and 11.4 mg/kg less than under alfalfa. As for zinc, deviation was as follows: 7.9, 16.6, 22.1, and 12.3 mg/kg.

This speaks to the fact that blue alfa better removes lead and cadmium, while hill mustard better removes copper and zinc.

At ameliorative dosages, content of heavy metals in soil under alfalfa has been decreasing over the years. After the application of sewage sludge at a dose of 100 t/ha, deviation of lead content from control amounted to 59.7 mg/kg in the first year, and then decreased to 16.9 mg/kg or by 71.7 % in the third year.

At ameliorative dosage of 100 t/ha, cadmium content in soil under alfalfa, as compared to control, decreased from 1.69 mg/kg in the first year to 0.39 mg/kg or 5 times in the third year. The same goes for zinc – from 70.5 to 40.5 mg/kg or 1.7 times; copper – from 44.1 to 13.8 mg/kg or 3.2 times; mercury – from 0.042 to 0.020 mg/kg or 2 times; and arsenic – from 5.8 to 5.0 mg/kg or by 16 %.

Such rapid decrease in the content of heavy metals in soil and herbage emphasizes important phyto-sanitary properties of perennial grasses, which secure a high ecological level of soil after the application of sewage sludge.

It should also be noted that the application of sewage sludge in the experiment did not raise the content of heavy metals in soil and herbage above maximum permissible concentration, even at ameliorative dosages. At the highest dose of 100 t/ha, content of heavy metals in soil under alfalfa was 1.3–8.7 times below MPC, and 2.4–33.3 times below MPC in this crop's herbage.

At fertilizer dosages (12.5–25 t/ha), content of heavy metals increased as follows: cadmium – by 70–113.9 %, lead – by 39.2–139 %, zinc – by 51.4–82.7 %, and copper – 2.4–3.2 times. At ameliorative dosage of 100 t/ha, content of cadmium increased 4.1–5.5 times, lead – 5.3–7.6 times, zinc – 2.7–2.8 times, and copper –

3.8–4.1 times. At fertilizer dosages, content of heavy metals in herbage increased as follows: cadmium – by 43.8–53.8 %, lead – by 28.6–139 %, zinc – by 24.3–42.8 %, and copper – by 24.3–84.2 %. At ameliorative dosages, content of cadmium in herbage increased 2.0–2.4 times, lead – 1.7–3.5 times, zinc – 2.2–2.3 times, and copper – 2.3–3.1 times. Despite the increase of heavy metals in soil and herbage, their content stayed well within maximum permissible concentration. At the highest dose of 100 t/ha, content of heavy metals in soil under blue alfalfa was 1.3–8.7 times below MPC, and 2.4–33.3 times below MPC in this crop's herbage.

The growth of perennial grasses over three years has been decreasing the content of heavy metals both in soil and crops' herbage. By the end of the third year, blue alfalfa decreased the content of heavy metals in soil as follows: cadmium – 2.6 times, lead – 7 times, zinc – 1.7 times, and copper – 3.3 times. Content of cadmium in its herbage decreased by 40 %, lead – by 35 %, copper – by 45 %, and zinc – by 31 %. This emphasizes important phyto-sanitary properties of perennial grasses, especially alfalfa, in reutilization of sewage sludge.

Alfalfa's herbage on control contained 2.1 mg/kg of lead. Deviations across the variants were 0.3, 0.6, 0.8, and 1.4 mg/kg. Content of cadmium in control amounted to 0.080 mg/kg, while its deviations were 0.21, 0.43, 0.80, and 0.110 mg/kg. Content of lead amounted to 0.70, 1.21, 1.67, 2.05, and 2.47 mg/kg respectively, which is 3.0, 2.0, 1.64, 1.41, and 1.42 times less than that of alfalfa; while content of cadmium amounted to 0.073, 0.090, 0.105, 0.120, and 0.147 mg/kg, or 1.1, 1.12, 1.17, 1.33, and 1.29 times less.

Table 2: Content of heavy metals in alfalfa herbage, mg/kg

Experimental variants, sewage sludge dosages, t/ha	Lead	Cadmium	Copper	Zink	Mercury	Arsenic
Control (w/o sewage sludge)	2,1	0,080	1,70	11,5	0,008	0,021
12,5	2,4	0,101	1,93	12,7	0,011	0,023
25	2,7	0,123	2,70	14,3	0,012	0,027
50	2,9	0,160	3,25	19,1	0,012	0,029
100	3,5	0,190	3,90	27,0	0,013	0,030
MPC	5,0	0,400	30,0	100	0,100	1,000

CONCLUSIONS

In view of the above, it is recommended to apply sewage sludge with increased concentration of lead and cadmium under leguminous crops, such as alfalfa, while that with increased concentration of copper and zinc – under non-leguminous crops, such as hill mustard. The analysis of the content of heavy metals in soil and herbage indicated that over the years it goes down to a background level.

Such rapid decrease in the content of heavy metals in soil and herbage emphasizes important phyto-sanitary properties of perennial grasses, which secure a high ecological level of soil after the application of sewage sludge.

It should also be noted that the application of sewage sludge in the experiment did not raise the content of heavy metals in soil and herbage above maximum permissible concentration, even at ameliorative dosages. At the highest dose of 100 t/ha, content of heavy metals in soil under alfalfa was 1.3–8.7 times below MPC, and 2.4–33.3 times below MPC in this crop's herbage.

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