

Improving the efficiency of anaerobic disposal of organic waste

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Abstract. Experimental studies on the decontamination and stabilization of sludge sites sediment with calcium oxide treated with disinfectant. The results of the research discovered that the sewage sludge of Voronezh City is safe and can be used as organic fertilizer for growing agricultural plants. Determination of the content of macro-elements of mineral nutrition in the soil and the reaction of its environment showed that the application of organic fertilizers in the form of sludge increases the amount of nitrate nitrogen, exchangeable potassium, mobile phosphorus in the soil compared to the non-fertilized sample. Contemporaneously, the mass fraction of impurities of toxic elements in the soil decreases when the sewage sludge is used as an organic-lime fertilizer.

1 Introduction

Water management and municipal enterprises in Russia store more than a hundred million tons of organic sediments, not considering waste from livestock complexes. Sewage sludge is formed in the process of physico-chemical and biological treatment at domestic and industrial wastewater treatment plants. In most cases, the sewage sludge is fed to the silt sites for dewatering. Currently, most of the silt sites are overflowed and are often located in the residential territory of cities.

The volume and characteristics of sediments generated at sewage treatment plants can be categorized according to the following characteristics [1-5]:

- The amount of waste on grates with openings of 16 mm is 8 l/person per year - at a humidity of 80% and a volume weight of 750 kg/m³;
- Volume of sand retained by sand traps is 0.02–0.03 l/person/day, volume weight-1.5 t/m³, humidity-60%;
- Volume of floating sediments retained by fat traps or primary sedimentation tanks is 2 l/person per year at a humidity of 60% and a volume mass of 0.6 t/m³;
- Suspended pollution is retained by primary sedimentation tanks. The mechanical composition of sediments from primary sedimentation tanks is highly heterogeneous.

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- The size of individual particles ranges from 10 mm or more to particles of colloidal and molecular dispersion;
- The active sludge retained by the secondary settling tanks is a thin suspension and consists of 98% by weight of particles smaller than 1 mm. The humidity of activated sludge discharged from secondary settling tanks after the aeration tank is 99.2-99.6%, and 96-96.5% after biofilters;
 - Cake – the sediment after mechanical dewatering or dried on silt platforms.
 - Sediments contain toxic and carcinogenic substances, synthetic surfactants, and heavy metal salts. The content of these substances is determined by the presence of industrial wastewater impurities in domestic wastewater, bacteriological contamination (protozoa, bacteria, algae), parasites (helminth eggs). In the active sludge, in addition to aerobic bacteria, there are mold and yeast fungi, protozoa, and pathogenic bacteria. All this is the reason for the sanitary and epidemiological danger of sediments, which requires mandatory disinfection.

Since organic sediments belong to the fourth or fifth hazard class depending on the composition, the problem of their disposal is relevant. Environmental, economic and social parameters are important aspects of recycling [6].

Currently, the disposal of sediment is to bury it in landfills. Since urban wastewater sludge is a valuable organomineral product, its application for the cultivation of agricultural products is a promising tendency. The solid phase of sediments consists by more than 50% of organic substances, as well as nitrogen, phosphorus and potassium complexes. Organic and mineral substances increase the yield of cultivated plants when they are applied into the soil [7-10].

The use of sediments is restrained due to the risk of detection presence of pathogenic microorganisms and heavy metals in them, which is unacceptable when applied to the soil. According to sanitary and hygienic indicators, the safety of sewage sludge is determined by the presence of pathogenic microorganisms and helminth eggs [11,12]. Decontamination of sewage sludge can be carried out by adding lime, thiazone, ammonia, formaldehyde, urea and other chemicals. In addition to the decontamination effect, such a sediment can be applied into the soil as fertilizer, since the nutrients remain and positively affect the productivity of plants [13,14]. The residual content of thiazone formaldehyde and ammonia in the sediments prevents the development of microorganisms and maintains the stability of the sediments. However, these substances are toxic, requiring careful application and handling [15-18]. To prevent contamination of the soil and groundwater with nitrogen, it is necessary to consider the degree of its assimilation by plants, the proportion of it contained in the soil, and, depending on this, set the dose of applying the decontaminated sediment to the soil. The dose of sediments treated with other substances should also be determined taking into account their effect. [11,19,20].

2 Materials and methods

The amount of sediment added to the soil can be found by the formula below [11]:

$$D_{hm} = \frac{(0.8 \cdot MPC - A) \cdot 3000}{C_{hm}} \quad (1)$$

where D_{hm} is the allowable rate of sediment, t/ha of dry matter;

MPC - maximum permissible concentration of heavy metal in the soil, mg/kg;

A - actual content of heavy metal in the soil, mg/kg;

C_{hm} - heavy metal content in the sediment, mg/kg of dry matter;

3000 - weight of the arable soil layer in terms of dry matter, t/ha.

The content of heavy metals in the sewage sludge depends on the enterprises that discharge water to the treatment facilities. Such indicators will differ for each city. The MPC value of heavy metals in wastewater sludge is strictly regulated. Table 1 shows the MPC values for different countries and Russia according to regulatory data [11,12,20].

Table 1. MPC value of heavy metals in wastewater sludge

TM	MPC of HM in sediment (mg/kg of dry matter)								
	Russia	EEC Directives	Finland	France	Sweden	Holland	Switzerland	Austria	Germany
As	20	-	-	-	-	-	-	-	-
Co	-	-	100	200	-	-	80-150	100	-
Cr	1200	750	1000	200	1000	500	900-1500	500	1200
Cu	1500	1000	3000	1500	3000	500	900-1500	500	1200
Cd	30	20	30	15	15	10	25-40	10	20
Ni	400	300	500	-	-	100	150-300	200	200
Hg	15	16	25	8	8	10	8-15	10	25
Zn	4000	2500	5000	3000	10000	-	2500-4000	2000	3000
Mn	2000	-	3000	500	-	-	-	-	-
Pb	1000	750	1200	300	300	500	900-1500	500	1200

Analyzing this table, we can conclude that the Russian standards correspond to generally accepted international ones. In terms of arsenic content, they are higher than in the above countries.

Experimental studies on improving the efficiency of anaerobic stabilization of organic waste generated at a sewage treatment plant were carried out using lime in a decanter centrifuge. The general view of the installation is shown in Fig.1. The installation consists of a lime feed hopper (pos. 2), a screw mixer of sludge with lime (pos. 3). The sediment was previously dewatered on filter presses. Quicklime from the silo goes through the lime feed screw to the screw mixer, where the lime is mixed and dosed with the sediment. The discharge of the treated sludge is carried out in an automated mode.

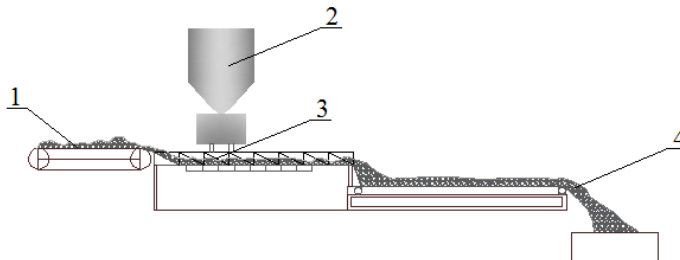


Fig. 1. Scheme of treatment of dehydrated sludge:

1-dehydrated sludge; 2-lime feed; 3-screw mixer of sludge with lime; 4-discharge of treated sludge.

Studies on the use of a decontaminating agent were carried out at the wastewater treatment facilities of Voronezh City. The treatment of organic waste was carried out with calcium oxide treated with an ovicidal preparation. The decontaminating reagent is SE-1 (ROSUN) - white or grey powder with a moisture content of 0.5%, a volume density of at least 0.9

g/cm³, and a water solubility of up to 20 g/l. It is a strong oxidizing agent that provides, in addition to affecting pollutants, a decontaminating effect. The composition of the reagent includes the following substances:

- Potassium monopersulfate (double salt up to 18-24%);
- Sodium chloride (1-5%);
- Active oxygen (7-9%).

There is a safety passport for the reagent, which includes all 17 items required for the corresponding document in the Russian Federation. According to the safety data sheet, the product undergoes biological oxidation and does not biologically accumulate. The decontaminating effect of the reagent is also provided by its pronounced oxidizing ability. The mechanism of the bactericidal effect is in blocking the transfer of ribonucleic acid and destroying the genetic system. When dissolved in water, active oxygen, hydroxyl free radical, hydrogen peroxide, and hypochlorous acid are formed. All components act simultaneously on organic substances of technogenic and natural origin and inorganic substances with variable valence.

With the application of a decontaminating reagent in an amount not exceeding 2% by weight, it can be used for decontamination, stabilization and deodorization of both urban treatment facilities and local treatment facilities of industrial enterprises sewage sludge in combination with other treatment technologies.

With the application of a decontaminating reagent in an amount not exceeding 1.5% by weight, in addition to previously listed sediments, it can be used for decontamination, stabilization and deodorization of the effluents of livestock and poultry complexes. The main parameters of the applied reagent should contain at least 80% of the active CaO, the fractional composition of the grains should not be more than 200 microns, the bulk density should not be less than 700 kg/m³. If these parameters are reached, the reaction temperature with water is 70-85⁰C, with a reaction time of 3-15 minutes.

The experimental studies on determination of the toxic elements content in the treated sediment were conducted at the Left-bank wastewater treatment facilities in Voronezh (LOS, LLC).

3 Results and discussion

During the sewage sludge decontamination experiments the problems with the reaction of lime arised. Absolutely dehydrated sediment did not fully reacted with lime, thus, the expected decontamination effect was not achieved. Therefore, the required moistness of the sediment was set. Experiments were conducted with raw sludge and a raw sludge and excess activated sludge mixture. Sediment, excess activated sludge, and CaO were mixed in different proportions in order to get the generalized studies results. Various samples data are shown in the following table.

Table 2. Samples of sludge from wastewater treatment plants

Sample	Content in the sample, %		
	raw sludge	excess active sludge	CaO
№1	100	-	5
№2	100	-	7
№3	30	70	3
№4	10	90	5
№5	30	70	5

The most optimal option for applying treated sediment to the soil is sample No. 5. The amount of sediment applied was determined by the formula (1), taking into account the heavy metals content in the soil and sediment

For dewatered sludge (30% crude sludge, 70% excess activated sludge) of treatment facilities, the application dose calculated for 60 kg of active substance per ha in terms of nitrogen content was 4.45 t/ha, while for treated with CaO with 5% of decontaminating additive it was 3.78 t/ha. The sediment was applied under the main tillage.

Studies conducted at treatment facilities show that the mass fraction of toxic elements in the sludge after treatment is not significant. The determination of heavy metals in samples was conducted in the State Center of Agrochemical Service "Voronezhsky". The mass fraction of heavy metal impurities in the dewatered sludge treated with CaO and the normative content are presented in Table 3.

Table 3. Research parameters of sewage sludge

Parameter	Regulatory requirements	Sludge	CaO treated Sludge
1	2	3	4
H ₂ O, %	<<82	36,4	63,6
pH	5,5-8,5	6,4	12,2
Organic fraction in dry matter, %	40-60	72,9	66,1
Nitrogen fraction, %	1-3	1,84	2,6
P ₂ O ₅ , %	1-4	1,14	1,4
K ₂ O, %	0,2-0,7	0,1	0,13
Hg, mg/kg	15	0,45	0,41
Cr, mg/kg	<1200	48,3	20,7
Pb, mg/kg	<1000	114,9	97,1
Ni, mg/kg	<400	27,2	20,4
As, mg/kg	<20	0,5	0,6
HCH, mg/kg	<0,1	<<0,007	<<0,005
DDT, mg/kg	<0,1	<<0,005	<<0,005

The use of lime-stabilized sediment on agricultural land is constrained by the presence of toxic elements and parasitological indicators in wastewater sediments. However, the carried out experiments and the obtained results of the analysis show that the use of such sediment is safe. As it is shown in Table 3, the mass fraction of heavy metal impurities in the treated sediment is significantly less than the required ones [12].

Accordingly, the resulting sediments can be applied to reclamation fields with a frequency of no more than 2-3 years, in the amount of 5-15 t/ha in terms of dry matter, according to the formula (1).

The concentration of substances necessary to improve soil fertility increases when the sediment is treated with lime [8-10,16]. A decrease in the content of heavy metals in the treated sludge compared to the initial concentration in the sewage sludge was revealed.

One of the main factors of influence of the applied treated sediment on soil fertility is the content of macronutrients of mineral nutrition in the soil and the reaction of the soil environment. During the studies, an increase in the content of exchangeable potassium in the soil by 3.5 mg/100 g of absolutely dry soil (or by 18.6%) was observed. The increase in the content of mobile phosphorus was different: when applying dehydrated sludge, it increased by 4.5 mg/100 g of absolutely dry soil (or by 7.6%), and when applying sludge treated with CaO, it remained almost at the control level. An increase in the content of nitrate nitrogen in the soil with silt sediment was 0.8 mg/kg of absolutely dry soil (or by

11.9%), with CaO it was 1.5 mg/kg of absolutely dry soil (or by 22.4%). The determination was carried out during the growth of five real rapeseed leaves.

Application of sewage sludge treated with CaO changes the reaction of the soil environment to increasing the alkalinity of the soil solution by 0.11 pH units compared to the control version, which is significantly less than accepted in the practice of design and operation [15, 16, 19]. Thus, the use of such wastewater sludge will be more effective on soils with an acidic reaction of the medium.

4 Conclusions

1. Voronezh City wastewater sludge treated with CaO is safe and refers to clean soils in accordance with regulatory requirements by its microbiological parameters,.
2. In accordance with the regulatory requirements, the sewage sludge of the Voronezh silt sites is safe in terms of the content of toxic elements which is significantly less than the regulatory ones and can be used as organic fertilizer in reclamation.
3. As a result of the use of silt sludge treated with CaO and SE-1 decontaminating agent, pathogenic microflora, viable helminth eggs, cysts of pathogenic intestinal protozoa, enterococci and other dangerous biological agents are destroyed.
4. Dewatered sludge treated with CaO and SE-1 decontamination agent can be used in industrial floriculture, forestry and for biological reclamation of disturbed lands and landfills. The application of such sediment increases the fertility of the soil, by increasing the content of nitrogen, phosphorus and potassium in the soil and leads to an increase in the yield of winter rapeseed by 20.1%. As organic fertilizer the silt sludge does not affect the quality of the grown plants. All indicators are within the maximum permissible concentrations (MPC) or significantly lower.

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