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Recycling of municipal waste in crop production as condition for reducing the toxicological load on ecosystems

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Abstract. In the period from 2013 to 2020, in all regions of Russia, there was an increase in household waste by 4.5-6.9 times an average. The study has identified that the properties of some wastes allow using them in economic sphere; it predetermines the interest in wastes as a secondary material resource. Some waste can be used as a fertilizer material and a substance for soil formation. It has to be considered that waste use can cause a number of serious negative processes, affecting all components of the ecosystem. Moreover, the polluting strength depends on the chemical composition of waste and the regulations for waste use. The purpose of the study is a geoecologic assessment of the resource potential of household waste in Orel in order to determine the possibility of their subsequent use in the region's agriculture. The authors have presented the results of a ten-year monitoring of the resource potential of sewage sludge. According to chemical and biological components determined by the analyses, the examined waste belongs to IV, V classes of danger to the environment. It proves that they can serve as an organomineral fertilizer for the biological reclamation of disturbed lands.

1 Introduction

The integral part of human activity is the generation of various kinds of waste of municipal and industrial services. The resulting waste is a major problem that needs to be addressed urgently. At the same time, the properties of some wastes allow using them in economic sphere, it predetermines the interest in wastes as a secondary material resource, and their return to the material cycle acquires important environmental, economic and energy-saving significance. This kind of waste is in great demand in crop farming sector.

At the same time, some wastes cannot be directly used as a fertilizer material; they can be used as a substance for soil and filling layer formation during the reclamation of mined-out quarries only after certain technological transformations.

It has to be considered that waste use can cause a number of serious negative processes, affecting all components of the ecosystem – soil, atmosphere, groundwater and surface water,

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etc. For example, soil, plant products and natural waters get polluted with heavy metals. Moreover, the polluting strength depends on the chemical composition of waste and the regulations for waste use (doses, methods, frequency of application, etc.), but in some cases the adjustment of these characteristics can reduce the level of potential negative impact on the environment to an acceptable one.

Sewage sludge (SS) is a group of wastes generated at facilities for mechanical, biological, and physicochemical treatment of surface and ground waters, sewage from settlements and industrial wastewater similar to domestic sewage in composition [1, 2, 3]. One of the main mechanisms for environmentally safe waste management is waste recycling, i.e. the use of agricultural and ornamental crops in agricultural technologies as an organomineral fertilizer, but only after a detailed agrochemical analysis. It should be noted that the resource potential of household waste is high, but waste composition varies in each region [4]. The purpose of the study is a geoecologic assessment of the resource potential of household waste in Orel in order to determine the possibility of their subsequent use in the region's agriculture.

2 Materials and methods

Sampling of sewage sludge was carried out in accordance with GOST 17.4.4.02-84 'Nature Protection. Soils. Methods for taking and preparing samples for chemical, bacteriological, helminthological analysis' and GOST 17.4.3.01-83 'Nature Protection. Soils. General requirements for sampling'. The analysis of the physicochemical properties of the substrates was made in accordance with the following government standards (GOSTs): GOST 27753.3-88 'Greenhouse soils. Method of test for determining the pH value of an aqueous suspension', GOST 26213-91 'Soils.Methods of test for determining organic matter', GOST 27753.5-88 'Greenhouse soils. Method of test for determination of water-soluble phosphorus', GOST 27753.6-88 'Greenhouse soils.Method of test for determination of water-soluble potassium', GOST 26715-85 'Greenhouse soils.Method of test for determination of total nitrogen', GOST R 53380-2009 'Soils and ground.Greenhouse soils.Specifications'. The analysis of the sanitary condition (a set of physical and chemical properties) of urban soils was performed in accordance with MU 2.1.7.730-99 'Hygienic assessment of soil quality in populated areas' and GOST R 54535-2011 'Resource saving. Sewage sludge. Requirements for placement and use at landfills.

Geohelminthes were detected by the method of Romanenko, MUK 4.2.796-99. Coliform bacteria and pathogenic microorganisms, including Salmonella according were tested according to MU 2.1.7.730-99, GOST R 53218-2008 'Organic fertilizers. Atomic absorption method for determining the content of heavy metals', MUK 4.2.2661-10 'Methods of sanitary and parasitological research'. The heavy metal testing was carried out in the Federal State Budgetary Institution 'Center for Chemicalization and Agricultural Radiology 'Orlovsky'.

3 Results

In Russia, the amount of household waste generated every year is steadily increasing. In 2013-2018, waste volume varied from 20755.1 to 28095.5 thousand cu m. In 2019, the volume increased by 1.8 times, and in 2020 – by 2.9 times compared to 2018 (Figure 1).

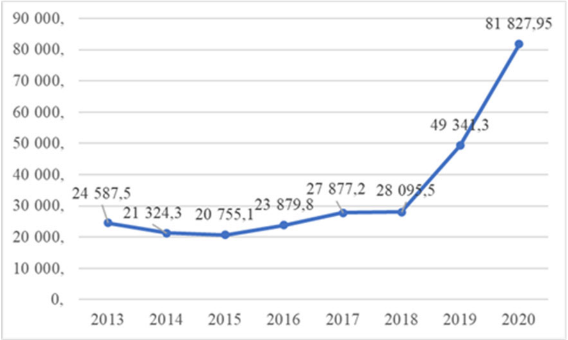

Fig. 1. Volume of household waste moved to storage facilities (thousand, cu m).

The share of used and neutralized waste in the total amount of waste generated has not changed significantly over the past decade (Figure 2).

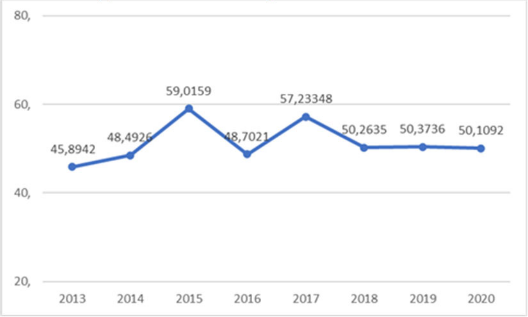

Fig. 2. The share of used and neutralized waste in the total volume of generated waste, %.

Thus, we can conclude that this problem has not been sufficiently studied. The solution of the problem is primarily aimed at stabilizing the environmental situation.

Such factors as presence of toxic chemical elements and biological hazards in the composition of sewage sludge limit their practical use [5]. The authors have monitored the composition of sewage sludge collected from the communal water and sewage management utility 'Orelvodokanal'. The properties of sewage sludge of 'Orelvodokanal' are shown in Figure 3.

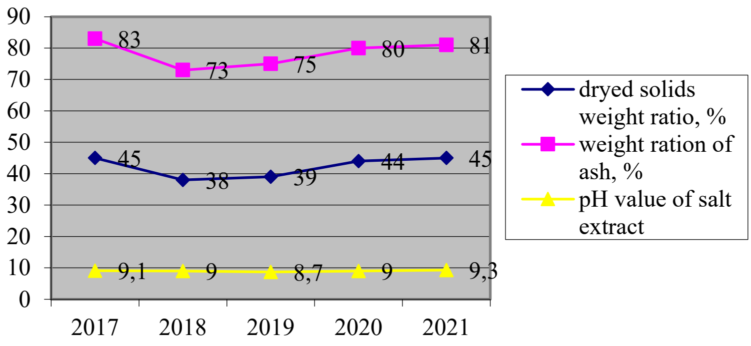

Fig. 3. The indicators of the properties of sewage sludge collected from 'Orelvodokanal'.

The tests have shown that the content of dry solids in sewage sludge did not undergo major changes over the years and ranged from 38% to 45% (permissible concentration: not less than 35%), the weight ration of ash – from 73% to 8% on a dry basis (maximum

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allowable concentration: not less than 65-85% on a dry basis), the pH value of the salt extract varied from 8.7 to 9.3 (maximum allowable concentration: 5.0-8.5%).

Sewage sludge can serve as an organomineral fertilizer in agricultural industry, landscape work and land reclamation. In this case, the content of fertilizer macronutrients in the composition is important.

The content of fertilizer macronutrients in the sewage sludge of 'Orelvodokanal' are shown in Figure 4.

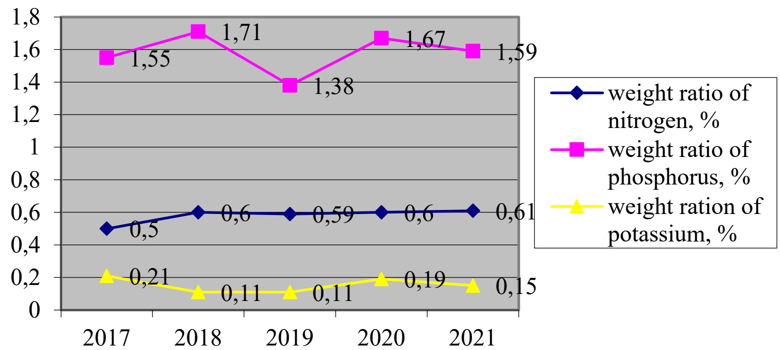

Fig. 4. The indicators of the content of fertilizer macronutrients in the sewage sludge of 'Orelvodokanal'.

Figure 4 shows that sewage sludge contains a sufficient amount of nitrogen (more than 0.5%) and phosphorus (more than 1.38%) with minimum values. According to GOST R 54534-2011, the permissible values of these indicators are 0.5% for nitrogen and 1, 5% for phosphorus. Thus, sewage sludge can be considered as nitrogen-phosphorus fertilizer.

Heavy metals in sewage sludge limit its use as soil conditioner [6, 7]. The content of arsenic, mercury and cadmium in the sewage sludge of 'Orelvodokanal' is shown in Figure 5.

The analysis of the content of arsenic, mercury and cadmium in the sewage sludge has shown that their amount does not exceed the standard values determined by GOST R 54534-2011. Thus, the content of arsenic varies over the years within the limits of 8.1-10.0 mg/kg of a dry basis (maximum permissible concentration: no more than 20 mg/kg of a dry basis), mercury 2.0-3.3 mg/kg of a dry basis (maximum permissible concentration: not more than 15 mg/kg of a dry basis), cadmium – 8.0-10.0 mg/kg of a dry basis (maximum permissible concentration: not more than 30 mg/kg of a dry basis).

Fig. 5. The indicators of the content of arsenic, mercury and cadmium in the sewage sludge of 'Orelvodokanal', mg/kg of a dry basis.

Nickel, copper and zinc in small concentrations are among essential plant elements. The content of nickel, copper and manganese in the sewage sludge of 'Orelvodokanal' is shown in Figure 6.

Fig. 6. The indicators of the content of nickel, copper and manganese in the sewage sludge of 'Orelvodokanal', mg/kg of a dry basis.

When exceeding the threshold value established empirically and reflected in GOST R 54534-2011, micronutrients can cause a toxic effect on artificial ecosystems (agroecosystem, urban ecosystem). Chemical analysis of the sewage sludge of 'Orelvodokanal' has shown its environmental safety. The content of nickel, copper and manganese did not exceed the maximum allowable concentration.

The chemical oxygen demand (COD) of the water extract (mg/dm^3) and biochemical oxygen demand (BOD) of water extract (mg O_2/dm^3) are used as an integral indicator of waste hazard for the environment, i.e. this indicator regulates the class of danger to the environment [8].

The research has shown that the waste is not dangerous for the environment (Figure 7).

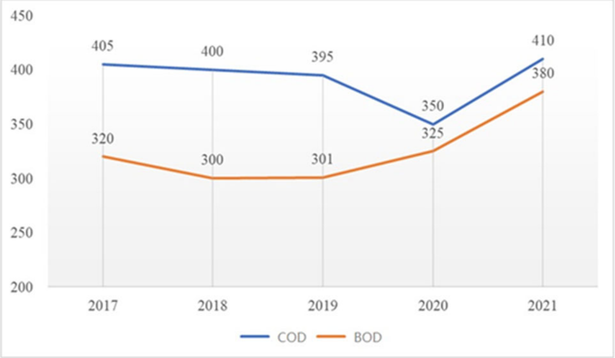

Fig. 7. The indicators COD (mg/dm3) and BOD (mg O_2/ dm^3) in the sewage sludge of 'Orelvodokanal'.

It should be highlighted the fact of absence of pathogenic microorganisms, helminth ova and protozoan cysts, larvae and pupae of synanthropic flies, and that the content of Coliform bacteria did not exceed an index of 100.

Thus, the study has shown that the sewage sludge of 'Orelvodokanal' can be used for reclamation of disturbed lands.

4 Conclusion

The amount of household waste in all regions of the Central Federal District increased on average in 4.5-6.9 times from 2013 to 2020. The resource potential of household waste is large. After chemical and agronomic analysis, it is recommended to use them as an organomineral fertilizer.

The results of the study allow concluding that it is expediently to search for ways of recycling sewage sludge.

Monitoring studies of the dynamics of waste accumulation and the content of elements, substances and compounds in them allow concluding that they belong to IV, V classes of danger to the environment, and they can serve as an organomineral fertilizer for the biological reclamation of disturbed lands.

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