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Sewage sludge fertilizers in urban and forest park economy

V. A. Katsadze[1*], *F. V.* Svoikin[1], *S. N.* Bubnov[1], *D. E.* Prokopyeva[1], *M. V.* Taraban[2], *P. E.* Studnikov[3], and *E. I.* Kudryashov[3]

[1]Saint Petersburg State Forestry University, 5, Institutskiy Pereulok, Saint Petersburg, 194021, Russia
[2]Saint Petersburg State University of Architecture and Civil Engineering, 4, 2nd Krasnoarmeyskaya Street, Saint Petersburg, 190005, Russia
[3]Moscow Aviation Institute, 4, Volokolamskoe Highway, Moscow, 125993, Russia

Abstract. This paper examines the use of fertilizers based on the sewage sludge in urban and forest park economy. The mentioned technologies allow achieving high agrochemical indicators and eliminating pathogenic microorganisms, which makes sewage sludge a valuable resource for increasing agricultural productivity and improving the condition of urban vegetation. The work is interesting for specialists in the field of agronomy, ecology and urban management.

1 Introduction

Wastewater is water discharged by a system of pipes or canals, as well as water formed as a result of precipitation and runoff of irrigation water in populated areas and industrial enterprises after use in the process of human domestic or industrial activities. Depending on the origin, type and quality characteristics of impurities, wastewater is divided into domestic (domestic-fecal), industrial and rain (atmospheric). A new type of wastewater has appeared in modern cities: municipal wastewater, which is a mixed mass of domestic and industrial wastewater [1]. The sewerage system of the Unitary Enterprise "Vodokanal of Saint Petersburg" includes 18 treatment facilities, which treat 2,200,000 m^3 of wastewater daily. As a result of purification, about 15,000 m^3 of sewage sludge is formed, which is a waste of the 4 fourth hazard class, which is removed to the Volkhonka-2 and Severny landfills, where about 4,700,000 m^3 of sludge has accumulated (94% of the maximum capacity). Aquatic ecosystems, unlike terrestrial ones, are adapted to a low content of biogenic elements. Phosphorus contained in wastewater is the main biogenic element causing anthropogenic eutrophication of natural aquatic ecosystems. In particular, an increase in the phosphorus content in aquatic ecosystems causes the rapid development (blooming) of blue-green algae, many species of which are nitrogen-fixing organisms and therefore their development is limited by the phosphorus content in the solution. In turn, the “blooming” of blue-green algae due to the release of toxins and the creation of anoxic zones leads to the degradation and death of aquatic ecosystems. Ultimately, when phosphorus enters to aquatic ecosystems, it can be removed from the cycle for a long time in the form

* Corresponding author: anatol-06@bk.ru

of phosphate sediment. Therefore, it is the removal of phosphorus that is one of the main tasks in the treatment of wastewater discharged into aquatic ecosystems [1, 2]. The main attention is currently paid to processes that can simultaneously remove phosphorus and nitrogen from wastewater. It is known that metal compounds contained in excess in industrial wastewater, F, Cr, Ni, Zn, Cu, Mg and Ca, are toxic and cause various disorders in the human body. Purification of wastewater from these heavy metals is difficult due to the lack of an economically sound and cost-effective productive method for separating them from wastewater. The development of solutions that allow processing wastewater sludge is an urgent task.

2 Materials and methods

Domestic wastewater contains human physiological excreta, as well as household, kitchen waste and household garbage. The nature of their origin determines a high degree of contamination with various types of microorganisms, including bacteria, viruses (including pathogenic ones), yeast, mold fungi, helminth eggs, protozoan cysts, etc. A significant amount of heavy metal ions enters to water bodies with wastewater from many industries, especially with effluents from galvanic shops. Metal compounds carried out by wastewater from galvanic production negatively affect the ecosystem ¨reservoir - soil - plants - wildlife – humans¨. At present, chemical, physicochemical and physical methods are used to purify galvanic wastewater, including such effective but expensive methods as reverse osmosis, ultrafiltration, etc. However, most of the existing technologies are based on reagent methods. Lime is most often used as a reagent, which allows to sharply increase the pH value and precipitate heavy metals in the form of their hydroxides.

But sewage sludge in solution and in suspended matter also contains significant amounts of nitrogen, phosphorus and potassium substances, which are the basis for fertilizers used in reclamation and landscaping. Dissolved substances are most accessible for absorption by plants.

It should be noted that sewage sludge sent to landfills is toxic to plants due to partial contamination with products of incomplete biochemical processes of decomposition of carbohydrates, fats, proteins, which make up the bulk of organic matter (80%) of the dry matter of the sludge.

There are many systems for wastewater treatment, and the best one must be selected taking into account their toxicity and economic feasibility. There are three main types:

- local treatment facilities, installed directly after the process equipment and are a part of the overall process flow. These facilities extract valuable impurities. For this purpose, settling, extraction, filtration, sorption and coagulation methods are used;
- factory treatment facilities, designed for biological treatment and disinfection of wastewater;
- district or city treatment facilities, they carry out mechanical (filtration, settling) or biological treatment of domestic wastewater.

At present, achievements of modern sciences and technologies are actively used for wastewater treatment. Various methods of treatment are used, among which mechanical, physical-chemical, chemical, biochemical, thermochemical and thermal methods stand out. These methods allow for the effective removal of contaminants and minimization of the harmful impact of wastewater on the environment [2].

3 Results and recommendations

The degree of pollution of the sewage sludge is determined by the biochemical oxygen demand index (mg/L; g/m^3). Lack of oxygen determines the incompleteness of the processes of nitrophication and denitrification of organic substances and purification from pathogenic contaminants. The rate of biochemical processes depends, with a sufficient amount of oxygen, on the particle size of the substances (oxidation area), which are presented in the wastewater treatment plant in the form of: suspension (20%), suspension (20%), emulsion (10%) and colloidal and dissolved foam (50%). Currently, there is a problem of optimizing the time of biochemical reactions in the sewage sludge. A solution to the problem of reducing the time of biochemical reactions is proposed, for example, in patent No. RU 2702164 [3].

This method reduces the period of the sewage sludge treatment by treating the sewage sludge with ozone (saturating the sewage sludge with oxygen (ozone)), at a lower temperature, taking into account that the solubility of oxygen depends on the temperature of the sewage sludge (for water, if t=0^{o}C – 14.6 mg/L; if t=10^{o}C – 11.33 mg/L; if t=20^{o}C – 9.17 mg/L; if t=30^{o}C – 7.63 mg/L).

Also, the period of the sewage sludge treatment is reduced by grinding substances using ultrasonic cavitation action, resulting in particles smaller than a micron.

Guaranteed elimination of the viability of helminth eggs, worms can be achieved by thermal action (t=70-80^{o}C) within a certain time period.

The choice of separation technologies (hardware scheme, modes) should be carried out, guided by the requirements of GOST R 17.4.3-07-2001 "Environmental protection. Soils. Requirements for the properties of the sewage sludge when using them as fertilizer" [4]; SanPiN 2.1.7.573-96 "Hygienic requirements for the use of wastewater and sludge for irrigation and fertilization" [5].

We consider the technology used to obtain the organomineral fertilizer "Iloplant". It includes the following stages of work (Figure 1, Figure 2):

1. Sewage sludge treatment: the first step is to treat the sewage sludge with a nitric acid solution. This procedure allows for disinfection and improved nutrient absorption, which is important for further application of the fertilizer.
2. Acidity neutralization: after acid treatment, the sludge is neutralized with an alkaline agent. This is an important step, as the correct pH level is critical for the effectiveness of the fertilizer and for reducing its aggressiveness when used in agriculture.
3. Grinding and moistening: at this stage, the sludge is ground to achieve a uniform consistency and the desired degree of moisture. Moistening can improve the efficiency of granulation and facilitate better mixing with mineral additives.
4. Magnetic separation: it removes metallic impurities, which improves the purity of the final product.
5. Mixing with mineral additives: the processed sludge is mixed with mineral additives, which are stored in at least two feed silos. These additives may include phosphates, potassium salts and other microelements necessary for plant development.
6. Aeration of additives: each of the additives is aerated, which can be aimed at improving their properties before mixing and homogenization.
7. Granulation and packaging: the resulting mixture undergoes a granulation process, which improves the convenience of its distribution and application.
8. Express quality analysis: after granulation, an express analysis of the quality of the ingredients and the mixture is carried out. This allows us to establish a correspondence between the composition of the fertilizer and its declared properties.
9. Automated monitoring and control: based on the analysis results, the automated process control system determines the volumes of each of the ingredients depending on the

fertilizer formula and opens the valves of the silos with additives. This ensures precise adherence to the recipe and process optimization.

The invention allows to expand the range of organomineral fertilizers. Thus, the described technology allows to use resources effectively and create high-quality organomineral fertilizers [3].

Fig. 1. Liquid organomineral fertilizer.

Fig. 2. Granulated organomineral fertilizer.

The characteristics of the sewage sludge after heat treatment, ultrasonic cavitation and ozonation are:

• agrochemical indicators, permissible gross content of heavy metals and arsenic, sanitary-bacteriological and sanitary-parasitological indicators comply with the requirements of GOST R 17.4.3.07-2001 Environmental protection. Soils. Requirements for the properties of the sewage sludge when using them as fertilizer" [4];

• pathogenic bacteria, salmonella, helminth eggs, intestinal protozoan cysts and other microorganisms are guaranteed to be eliminated (Table 1, Table 2).

Table 1. Characteristics of liquid organomineral fertilizers.

Indicator name	Standard for fertilizer brands		
	Brand A	Brand B	Brand C
Appearance	Liquid of yellow, pink, brown or their shades		
Smell	Odorless or with a weak organic odor		
Content of water-soluble humic acids, g/L	Less than 10.0	From 10.0 to 30.0	More than 30.0
Acidity	From 6.3 to 7.45		
Content of microelements in dry matter:	17%		
- ammonia nitrogen	16.9%		
- mobile forms of phosphorus	6.2%		
- mobile forms of potassium	4.1%		
- ash content	0.11%		

Table 2. Characteristics of granulated organomineral fertilizers.

Indicator name	
Appearance	granules 2-4 mm in size
Color	from light to dark brown
Moisture content, %	1%
organic substances mass fraction (in terms of dry matter), %	10%
humic acid mass fraction (in terms of dry matter), % not less than	10%
total nitrogen mass fraction (in terms of dry matter), % not less than	8%
granules smaller than 2 mm mass fraction, % not more than	7.0
From 2 to 4 mm, %	90.0
5 mm and above, % not more than	3.0
granule density	not less than 3.0 MPa
Friability	100%
ammonia nitrogen mass fraction (in terms of dry matter), % not less than	11%
P205 mass fraction (in terms of dry matter), % not less than	6.15%
K205 mass fraction (in terms of dry matter), % not less than	3.12%
PH	6.0-7.5
pathogenic microflora	absent
helminth eggs	absent

The main criteria in the development of original technologies for selecting technological solutions were:

- economic analysis of the product obtained on the market by the following indicators: long-term demand trends, comparison with analogues by price and quality indicators, cost price per unit of output (т or m^3) and also determination of the impact of production scale;

- compliance of the product with the standards and requirements of GOST R 17.4.3-07-2001 "Environmental protection. Soils. Requirements for the properties of the sewage sludge when using them as fertilizer" [4]; SanPiN 2.1.7.573-96 "Hygienic requirements for the use of wastewater and sludge for irrigation and fertilization" [5-9];

- ensuring instrumental control over the technological process and obtaining a product of a given quality (according to technical specifications and special orders of the buyer) by methods of an automatic analytical control system.

To determine the possible rate of fertilizer application, two potential dosages were used for application to the base substrate. Due to the high hygroscopicity of the peat base substrate, the addition of the organomineral fertilizer "Iloplant" was carried out according to volume indicators of 10% and 2% of the total volume.

4 Conclusion

The proposed technologies allow achieving high agrochemical indicators and eliminating pathogenic microorganisms, which makes sewage sludge a valuable resource for increasing agricultural productivity and improving the condition of urban vegetation.

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