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Resource-saving technology for dewatering and decontamination of activated sludge

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Abstract. The authors of the article consider the problem of the formation of huge volumes of liquid toxic activated sludge in the biochemical method of the residential area wastewater decontamination. At present, there are no effective technical solutions and technologies in terms of eliminating the negative impact of activated sludge on environmental components. The article examines the technologies that allow to involve activated sludges in reuse and use them as fertilizers in agriculture. A resource-saving biotechnology for activated sludge dewatering and decontamination from ecotoxicants has been developed. The results of the study confirm the effectiveness of the process of heavy metal extraction from activated sludge.

1 Introduction

Currently, urban sewage treatment plants mainly use biological wastewater decontamination, which leads to the formation of significant volumes of excess activated sludge.

During biological wastewater decontamination, all the high-flow activated sludge is placed in sludge storage tanks, landfills, or accumulate in bottom sediments in biological ponds, which in turn does not protect the environmental components from contamination and further translocation [1].

It should be noted that in residential areas and major territorial complexes, on the one hand, the amount of sewage can reach several thousand m^3/day, on the other, these drains have a multicomponent composition comprising an organic part of the activated sludge (the content of substances of protein origin not more than 50%, the fat content is not more than 20%, carbohydrate content does not exceed 8% and other components) [2]. The positive feature of the sediment is the complex content of nutrients in it in ratios favorable for many agricultural crops. The most promising and relevant direction is the increase of fertility efficiency by introducing active sludges in various aggregate states into the soils of agricultural land.

Thus, the possibility of excess activated sludge practical application is not limited only by using it as fertilizer on agricultural land, its introduction as protein-vitamin feeding to animals and birds is highly perspective [3], as well as extraction of valuable components for

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further inclusion in compound feed (proteins and amino acids, technical vitamin B_{12}). In particular there is the possibility of its use in other fields of national economy (construction materials, asphalt manufacturing, chemical production, etc.). Nevertheless, the limiting factor for the use of excess activated sludge is the content of heavy metal ions and other dangerous pollutants in it, which makes it almost impossible to use it directly in urban aeration stations due to the joint entry of household and industrial wastewater into the water utility networks due to the peculiarities of wastewater collection in urban conditions.

The variety of sources that pollute the activated sludge makes the existing decontamination methods ineffective, the key pollutants are the wastewater that is not decontaminated from heavy metal ions (Table 1).

Table 1. Total heavy metals in the mechanical dewatering section of the Northern Aeration Station of the city of Yekaterinburg [4].

Pollutants	***Al***	***Fe***	***Cu***	***Zn***	***Pb***	***Ni***	***Cr***
Content, mg/kg	˜12000	˜19000	˜1200	˜1978	˜630	˜590	˜1700

Table 1 shows that the total metals are in concentrations that do not allow the use of excess activated sludge without additional decontamination and processing of sediments.

Solution of the problem of wastewater decontamination, sediment processing, and search for methods for heavy metal extraction remains relevant to this day and for all countries [5], but existing approaches are limited only to traditional generally accepted methods, which are mostly flawed [2].

For the use of excess activated sludge in agriculture, its compliance with the norms of SanPiN 2.1.7.753-96 is required. Table 2 shows the values of the indicators of the most harmful substances in the active sludge in comparison with the norms allowed for soils intended for growing of agricultural products.

Table 2. Average values of heavy metal ions in activated sludge.

Substance	Concentration, mg/kg	LOC for soils, mg/kg	Exceedance of the norms, number of times
Boron	1133.3	38	29.8
Cobalt	36.6	18	2
Manganese	6066.6	1000	6
Copper	900	33-132	27-6.8
Nickel	416	20-80	20.8-5.2
Lead	316.6	32-130	9.9-2.44
Chrome	1200	83	14.5
Zinc	1492.3	55-220	27.1-6.8

Table 2 shows that the complex multicomponent composition and significant concentrations of pollutants in the activated sludge do not allow using only traditional technologies for decontamination and extraction of heavy metal ions, where the key indicator is not only efficiency, but also material costs.

The most effective and economical technology is biological decontamination, namely, the method of activated sludge conditioning, can be the use of water-air vegetation (WAV), which contributes to the acceleration of the drying process sediment on sludge beds, as well as the disposal of heavy metals from it [3, 4, 6].

Purpose and objectives. The purpose of the research is to develop a resource-saving technology for dewatering and decontamination of activated sludge from ecopolutants. To achieve this goal, it was necessary to solve a number of tasks:

- assessment of the negative environmental impact of activated sludge.
- to establish the qualitative composition of activated sludge
- to conduct research on activated sludge dewatering using water-air vegetation.

- to conduct research on the desorption of heavy metals from sediment using calcium materials.

2 Methods and materials

When solving the tasks set, the paper uses a literature review, a theoretical generalization of modern knowledge and ideas about the problem of conditioning and utilization of activated sludge; laboratory studies of the qualitative composition of activated sludge. The complex of laboratory and theoretical research methods is applied in the work. In laboratory conditions, the concentration of heavy metals in the activated sludge after regeneration by the reed and in the reed was determined using a chemical laboratory with the appropriate license. The generalization of knowledge in the field of this problem, a comparison with existing technologies for dewatering and decontamination of activated sludge from heavy metal ions were carried out, and conclusions were made on improvement of activated sludge decontamination technology.

3 Research results

The essence of the activated sludge conditioning method is the dehydration of activated sludge to 65-70% humidity on sludge detention ponds planted with reeds and cattails, and the absorption of heavy metals desorbed from the activated sludge into the soil solution by the latter in the process of vital activity.

The dewatered and neutralized sediment is disposed of on farmland as an organic fertilizer after being released from WAV.

This scheme allows to fully use the high fertilizing properties of excess sludge, while solving the problem of urban wastewater sludge recycling without harming the environment. The proposed method of sediment disposal combines the optimal level of economic costs and technical complexity with minimal environmental damage.

Below are the results of our studies on the migration of copper, iron, zinc and nickel ions into plants from the excess activated sludge taken from the Northern Aeration Station in the city of Yekaterinburg. Phragmites australis (Common Reed) was used as a test object. Large water-air macrophytes (reed), in contrast to dry plants, are able to successfully grow and develop with a lack or even complete absence of oxygen in the soil-water environment due to the aero-chemical structure of root tissues and other organs. Coastal aquatic plants can extract from water and soil not only the nutrients they need, but also other mineral, as well as ballast and toxic substances, including heavy metal salts.

We have carried out research on the possibility of using reed for desorption of heavy metals from excess sludge. For this purpose, three wooden containers with an area of 1m^2 each were filled with excess activated sludge. The content of heavy metals in the sludge is shown in Table 3. In the prepared containers, ordinary reed was planted, the growth and development of which was observed throughout the growing season. At the end of the experiment, the reed was dug up, the roots were cleaned of sludge, washed with distilled water and dried for a week to an air-dry state. The ground part was divided into stems and leaves. After preliminary grinding, the air-dry mass was subjected to "wet" ozonation, and the concentrations of Cu, Fe, Zn, and Ni were determined in the resulting solution by photometric method. At the same time, the content of heavy metal ions in the activated sludge from the experimental tanks was determined.

Table 3. Efficiency of activated sludge regeneration using common reed.

Metals	Heavy metal concentration, mg/kg			
	sludge before the	sludge at the end	regeneration	Norm for soils

	experiment	of the experiment	efficiency, %	
Cu	576	204	64.6	33-132
Fe	54400	31300	42.4	51000
Ni	546	138.25	74.7	20 - 80
Zn	370	198	46.4	55 - 220

Observations (Table 4) showed that the amount of heavy metal ions (Cu and Fe) accumulated in the root parts of the plant is 60-70% more than in the aboveground parts.

Table 4. The content of metal ions in plants (common reed).

Metals	Heavy metal concentration, (mg/kg) / %				
	leaves	stems	green mass	roots	total amount
Cu	19.38/27.0	12.41/17.3	31.79/44.3	39.90/55.7	71.69/100
Fe	619.00/22.0	527.00/18.6	1146.00/40.6	1680.00/59.4	2826.00/100
Ni	33.00/29.7	28.50/25.7	61.50/55.4	49.50/44.6	11.00/100
Zn	:3.65/41.1	48.60/31.3	112.35/72.4	42.80/27.6	155.15/100

Nickel in the root part is retained by 30% less, while the concentration of zinc in the aboveground part was greater than in the underground part. High activity of plants in relation to zinc should also be noted. The results of the experiment show that the migration of zinc from sludge to plants reaches 72%. The use of WAV for neutralization of excess activated sludge by extracting metal ions from it, allows to achieve the remaining concentrations of the latter in the sludge of standard values and will allow to use the sludge as a fertilizer.

It should be noted that the selected method of detoxification of excess activated sludge with the help of WAV and its effectiveness meet the requirements of nature protection legislation. The process laour intensity when collecting plant rhizomes, planting them in regenerated sludge, and the duration of the detoxification process (1-3 growing seasons) should be noted.

At the St. Petersburg State University of Technology and Design, a method for the neutralization of activated sludge and sediments using low-soluble calcium materials was proposed, which is very effective in terms of desorption of heavy metals from activated sludge.

We have performed studies confirming the effectiveness of the process of extracting heavy metals from sludge with poorly soluble calcium materials, for which real samples of specific sewage sludge from the Northern aeration Station of the city of Yekaterinburg were taken. The experiment was carried out by mixing crushed calcium material (6 g) and activated sludge (5 g) with aeration for 15, 30, 60 minutes. The presence of oxygen in the system apparently leads to partial oxidation of organic compounds, including due to the development of aerobic microflora, which decomposes complex compounds.

Aeration maintains the sludge - calcium material system in a suspended state, which increases the available surface of the calcium material for the immobilization of microorganisms, the adsorption of organic substances and enzymes. The process of desorption of heavy metals from the sediment using calcium materials was monitored using iron ions determined by chemical analysis. In parallel, using the same method, studies were conducted on the extraction of iron ions from activated sludge without the addition of chalk (Table 5). From the experimental data obtained, it can be seen that the process of transition of iron ions from activated sludge to an aqueous solution with the addition of calcium materials takes place intensively for 30 minutes. Then there is a rapid coagulation and precipitation of various forms of iron.

Table 5. Changes in the content of iron ions in activated sludge after chalk treatment.

Excess activated sludge under study	Iron content, mg/kg		
	Aeration time, min.		
	15	30	60
Sludge without adding chalk	7200	6960	2820
Sludge with adding chalk	7400	2780	3960

After determining the required aeration time, studies were conducted to determine the optimal dose of the introduced calcium materials. According to the results of these experiments, it was found that at 30 min. mixing of activated sludge with chalk, the best dose for desorption of heavy metal ions from sewage sludge is 50 g/l (Table 6).

Table 6. Changes in the residual concentrations of heavy metal ions in activated sludge when mixed with different doses of calcium material

Component	Concentration mg/kg			
	15 g/l	25 g/l	50 g/l	Source sludge
aluminum	5691.5	4019.9	1379.3	11239.3
cobalt	< 0.1	< 0.1	< 0.1	< 0.1
chrome	44.2	31.7	11.8	96.6
copper	84.9	60.6	18.5	174.1
iron	9787.6	6959.9	2522.8	22007.3
manganese	180.6	126.5	59.3	385.2
nickel	41.7	32.2	11.7	104.0
phosphorus	4295.8	2810.6	864.9	9308.5
zinc	372.9	268.9	68.9	790.5

4 Conclusions

The developed technology of disinfection, conditioning and decontamination of activated sludge to 65-70% humidity on sludge detention ponds planted with reeds and cattails, and the absorption of heavy metals desorbed from the activated sludge into the soil solution by the latter in the process of vital activity. Depending on the requirements for the residual concentrations of heavy metals in the excess sludge, technical capabilities and economic feasibility, a single aeration can be used or the calcium material can be introduced into the system. Aeration with the simultaneous introduction of calcium materials reduces the process duration. The concentration of heavy metal ions in the activated sludge is reduced by 10-50% compared to the use of a single aeration without the addition of calcium material. This method of dewatering and decontamination of activated sludge from heavy metal ions can be adopted at any treatment facilities for the decontamination of household or industrial wastewater, where large volumes of sludge beds are formed. The decontaminated sludge can be used in agriculture as the fertilizer.

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