Use of silt sludge after biological wastewater treatment for crop yields increasing

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Abstract. Researching the possible use of the silt sludge after biological wastewater treatment from the industrial enterprises for increasing the agricultural crops’ yield was spent. Silt sludge is obtained as a result of biological wastewater treatment in column-type aeration tanks. Founded the concentration’s increase of macro- and microelements in the silt sludge, improvement of the sanitary status and decrease of the heavy metals content after its treatment by the enzyme-cavitation method. Low-intensity cavitation with a cavitation number (0.01-0.05) with air oxygen saturation of the sediment (at least 10 mg/m³) allows for deep organic matter mineralization, dehydration pathogenic microflora’s destruction and dehlmintization. Shown the obtained complex fertilization into soil gives it nitrogen, humus and sulfur and increases the winter wheat’s yield.

Among the various wastewater treatment methods the most popular is the biological method based on the disposal of pollutants by microbial communities. Biological wastewater treatment is the largest-capacity technology in terms of recyclable volume flows. However, the use of biological treatment facilities with traditional (corridor) type often leads to the problem of a high residual contaminants’ concentration in the treated water, so there is a need for post-treatment. The water purified by the biological method needs to be decontaminated with various reagent or non-reagent methods, for example, chlorination, sodium hypochlorite treatment, ultraviolet irradiation or ozonation. Despite the high bactericidal infectability (99.8%), these methods have serious drawbacks – danger to service personnel, the expensive equipment use, utilization needs of used consumables (mercury lamps, electrolysis waste, etc.).

The column-type aeration tanks (tower bioreactors) have been used to improve the wastewater treatment effects recently. These constructions are characterized by the large depth with small cross-section, economy and small building area. The main advantage of the column-type aeration tank is the high air oxygen using degree, and, as a result, the higher cleaning process efficiency.

A huge amount of sludge (excess activates sludge) accumulates at the biological industrial wastewater treatment plants, it contains more than 60% of organic substances. The main problem of further activated sludge using is the pathogenic microflora’s and contaminants presence, for example, heavy metals [1]. Most often, the anaerobic methane tanks fermentation is used for the sludge processing. This technology cannot respond to today realities, is characterized by high specific energy
consumption, the sludge treatment’s length, the methane’s, carbon dioxide’s and other gases’ relasing. After anaerobic fermentation, sediments contain excessive heavy metals’ amount, pathogenic microflora, so they can’t be used as fertilizers in agriculture [2].

In recent years, enzymatic cavitation method for processing activated sludge is proposed, it leads to the disinfection and improving the sludge quality through the using of low intensity cavitation and substrate’s deep oxygen saturation [3, 4, 5]. Activated sludge (biofilm or raw settling tanks sediment) is saturated with air oxyjets using oxygen. The generation of low-intensity cavitation with a cavitation number of 0.01-0.05 is carried out using turbujets. At the same time, deep mineralization of the sediment, disinfection and deworming are carried out.

Enzymatic cavitation method with a significant energy saving, allows stabilize sludge and obtain a product with the structure is similar to peat without unpleasant odor. Various forms of humic substances are formed in the sludge. These forms promote the heavy metal ions’ binding. The resulting sediment is biologically stable, harmless in sanitary because of the pathogenic microflora absence and complete deworming. The sediment contains organic substances in a deeply mineralized form, which are available to plants and soil microflora, so this sludge is promising for use in agricultural production as an organic fertilizer.

The purpose of this work was to study the possibility of using silt sludge obtained in column-type aeration tanks after its processing by the enzyme-cavitation method to increase the agricultural crops yield.

The research was conducted in arid conditions of the Saratov region (Engels) and the Lower Volga region (Volzhsky). The water sludge after aerobic biological treatment of industrial and domestic wastewater in tower bioreactors was treated by the enzyme-cavitation method, including homogenization of the processed sludge mixture and low-intensity cavitation treatment with dissolved oxygen concentration in the mixture of at least 10 mg/m³ [6, 7]. Technologically, the achievement of low-intensity cavitation with the number G=0.01-0.05, to the necessary for suppressing pathogenic microflora level, preventing stratification of the water-sludge mixture flow and disrupting the pump operation, is achieved by installing eccentrically narrowed section on the pipeline, where profiled resistance elements-Archiemdes’ spirals-are placed with a clockwise inclination to the flow [7]. Thanks to this, the movement speed of the cleaned liquid reaches the rotation with pump impeller speed, ensuring the continuity of the flow. Thus, the incoming liquid flow for cleaning "swirls", remaining so after the pump, which contributes to the generation of microcaverns.

The resulting sediment was analyzed for its basic physical and chemical properties. The obtained indicators were compared with the regulatory and technical documentation [8, 9, 10] for determining the possibility of sludge’s using as an organic fertilizer. The results of the sediment analysis are in table 1.

**Table 1.** Physical and chemical parameters of water-silt sediment after treatment by the enzyme-cavitation method.

| Monitored indicators | The indicator value in the sludge | Value for regulatory and technical documentation |
|----------------------|----------------------------------|-----------------------------------------------|
| pH                   | 6.7                              | 5.5-8.5                                       |
| Moisture content, %  | 35                               | < 82                                          |
| Organic matter, %    | 15                               | > 20                                         |
| Total nitrogen, %    | 2.54                             | > 1.0                                        |
| Total phosphorus, %  | 4.2                              | > 4.0                                        |
| Total                | 1.25                             | > 0.3                                        |
| potassium, %         |                                  |                                               |
| Mobile sulfur, mg/kg | 1950                             | not normalized                               |
| Mobile copper, mg/kg | 8.2                              | not normalized                               |
| Mobile zinc, mg/kg   | 35.0                             | not normalized                               |
| Mobile cobalt, mg/kg | 0.18                             | not normalized                               |
| Mobile manganese, mg/kg | 56.5                         | not normalized                              |
Lead, mg/kg 68.0 1000
Cadmium, mg/kg 30.0 30
Zinc, mg/kg 684.3 4000
Copper, mg/kg 137.1 1500
Mercury, mg/kg 0.10 15.0
Cobalt, mg/kg 6.10 not normalized
Mercury, mg/kg 2.3 20.0
Manganese, mg/kg 390.0 2000
Nickel, mg/kg 136.9 400
Fluorine, mg/kg 1.20 10.0
Radium-caesium (134+137), Bk/kg 10.8 not normalized
Index of enterococci not detected 1
Pathogenic bacteria, including Salmonella, helmints eggs and intestinal protozoa not detected absense

The data presented in table 1 indicate the sludge after aerobic enzyme-cavitation treatment is characterized by lower amounts of heavy metals: manganese, nickel, copper, zinc, mercury and lead. The amount of organic matter in the sludge (15%) does not formally correspond to the regulatory and technical documentation (RTD) (20%), but in terms of nitrogen, phosphorus and potassium, it significantly exceeds the standards. Sludge treated by the enzyme-cavitation method is actually a complex organo-mineral fertilizer, and RTD is been developed for organic fertilizers with high organic substances and micronutrients deficiency. The complex nature of the fertilizer obtained by authors is confirmed by the presence of the significant amount of microelements. In addition, it should be emphasized that the sludge has the high sanitary and hygienic conditions (the absence of pathogenic microorganisms and helminths). In addition, a feature of the sediment treated by the enzyme-cavitation method is the high content of sulfur (about 2 g/kg). Sulfur is a biogenic element and a part of amino acids, proteins, enzymes and other biologically active substances, sulfate ions are the most important source of mineral nutrition of plants.

In order to test the efficiency of the using silt sludge as a fertilizer, it was applied to light chestnut soil during the cultivation of winter wheat of the Don-93 variety in the Lower Volga Research Institute of Agriculture (Gorodishchenksy district of the Volgograd Region). Silt sediment with a moisture content 35% was introduced into the soil in the proportion of 20 t/ha. Two variants of soil treatment were used in the studies:

- deep loosening with a turnover of the topsoil to the depth of 15 cm. In this case, the sediment is sealed to the depth of 10-15 cm.
- surface (shallow) tillage to the depth of less than 10 cm.

Inoculation of winter wheat made after the autumn introduction of fertilization. In the spring, friendly shoots were observed in the areas with the applied fertilizer, and in the case of the sludge absence in the soil, the shoots appeared only after heavy rains. The highest yield of winter wheat (49.3 kg/ha) were observed after the surface soils’ treatment with sludge. The results of the physical and chemical parameters of the soil determining in the autumn and spring periods were shown in table 2.

| Treatment | Sediment presence | Sampling depth, cm | Phosphorus, mg/kg | Potassium, mg/kg | Nitrogen, mg/kg | Humus, % | Iron, mg/kg | Sulphur, mg/kg |
|-----------|-------------------|--------------------|-------------------|------------------|----------------|---------|-------------|---------------|
| Autumn    |                   |                    |                   |                  |                |         |             |               |
| Small     | +                  | 264.5              | 560               | 414.6            | 6.78           | 23150   | 1860        |               |
| Deep      | +                  | 205.5              | 618               | 461.8            | 6.42           | 22635   | 2070        |               |

Table 2. The results of physical and chemical analysis of the soil
The data given in table 2 allow us to conclude the sediment introduction into the soil after its enzyme-cavitation treatment leads to a significant enrichment of its macro-and microelements, especially nitrogen, phosphorus and sulfur. It should be emphasized after the sediment’s introduction in the soil the humus amount increases.

To determine the aftereffect of the silt sediment in the third year after its introduction, Prairie barley was sown on the same plots. The yield on the experimental plots was 28 c/ha, it was 73% more than in the control (the same loosening, but without the introduction of sediment).

To study the possibility of using silt sediment to increase crop yields on sandy soils, field tests were conducted on fine-grained polymineral, medium humus sand. The rate of sediment application in this substrate was 20 t/ha. As an agricultural crop, long term fodder rye was used. Shown during the introducing the sediment into the sandy substrate, it becomes blackened, and the yield of the green rye mass in the experimental plot increased by 23.3% compared to the control one.

Thus, the studies found that the aerobic enzyme-cavitation method of treating sludge, obtained during biological industrial wastewater purification, contributes increasing the macro - and micronutrients, improving the sanitary condition and reducing the heavy metals’ concentration. Shown the possibility of using the resulting sediment as a fertilizer in the winter wheat cultivation on light chestnut soil. The introduction of sediment enriches the soil with phosphorus, nitrogen, humus and sulfur. The highest yield of winter wheat (49.3 c/ha) was observed after surface tillage with sludge.

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