Engineering problems of dehydration and disposal of sewage sludge

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Abstract. The engineering problems of processing of sewage sludge in devices of a new type of flotation combine machine are considered. Experimental research of thickening process of activated sludge suspension after secondary tank in the flotation combine machine are conducted. Further dehydration with using of the proposed scheme of drying with the closed circuit heat carrier system is possible. A unit of preparation of the heat carrier, a drying chamber, a device for unloading the finished product, a waste drying agent cleaning system, a waste heat carrier post-treatment unit, and a two-circuit system of pneumatic conveying in the scheme are included. An entry of toxic sludge substances into the environment in the offered scheme is excluded.

1. Introduction
The problem of processing of settled sludge, particularly, the excess activated sludge, and its utilization for the last decades has been very relevant, and so far no universal ways of problem solution in this direction have been noticed [1-8]. Heavy tonnage waste products are still disposed marginally, and most of them are stored at landfills. In this regard, new technical solutions are extremely relevant for practical technologies of processing and utilization of various wastes [9-13]. In the current situation, the development of engineering problems concerning to deliquefaction of sewage sludge, including an excess activated sludge has been of a special interest [14-17]. We have developed a multifunctional flotation combine machine [18] both for sewage cleaning and for deliquefaction of sewage sludge, including an excess activated sludge.

2. Methods
The principle of operation is as follows (Fig. 1). The original feed sewage water supply through the nozzle 2 enters housing 1 of the flotation combine machine, where it mixes with a working fluid, which enters the nozzle 21. Microflotation complexes (with bubble diameter less than 1 mm) coalesce passing through perforated baffle plate during the water filtration process and surface up to the bubble column gathering in a froth-overflow through launder 4, from where they are discharged through the nozzle 5. Purified in the flotation combine machine fluid is discharged through the nozzle 3 of level control device 18. The flotation sludge from the nozzle 5 enters the ejector 6 (where pressure drop should be within 0,05-0,5 m), where under the action of forced air supplied through the nozzle 19, it is destroyed and passed into a suspension. The suspension heads to the hydrocyclone 8, where it is divided into a thickened concentrate water (nozzle 10) and purified liquid (nozzle 7). At the same time, the thickened concentrate water is passed through a pipe-line 11 and then through a pipe-line 12 to the internal space of the dehydration...
unit 13, containing a bag 14 made of synthetic material with cells ranging in size from 0.001 to 0.1 mm. Then under the action of external control devices 15 the filled bag is pressed, that leads to the following deliquefaction of the sludge. Then under the action of external control devices 15 the filled bag is pressed and the sludge is dehydrated. Holding the bag 14 in an unchanged position, it is carried out by a hose clamp 16. The squeezed from the sludge liquid is collected in the tray 17. After squeezing the liquid out of the sludge, the bag 14 is removed and sent for disposal.

As a result of using new additional units in the flotation combine, the fast bleed-off of screenings from the inner space and their subsequent thickening, which ultimately leads to an increase in efficiency of cleaning due to a rapid decline in the rate of particles falling out of the bubble column and to the achievement of the thickened sludge in a single device, are improved.

The determination of the optimal operating mode for activated sludge was carried out at various ratios of the initial suspension of activated sludge and power fluid, and also by varying the processing time of the separated mixture. It should be noted also that the sludge index of the initial activated sludge suspension was 120 ml/g, the temperature of the suspension was 200ºC, and the dynamic viscosity was 0.0011 Pa · s. The tests were carried out on a flotation combine machine with a working volume 0.9 m³. The experimental results are presented in Table 1.

*Figure 1.* Scheme of the flotation combine machine. 1 – housing; 2 – nozzle for waste water supply; 3 – nozzle for diversion of purified water from flotation combine machine; 4 – forth-overflow launder; 5 – flotation sludge discharge nozzle; 6 – ejector; 7 – clarified wastewater nozzle; 8 – hydrocyclone; 9 – outlet nozzle; 10 – nozzle for concentrated flotation sludge discharge; 11 – clarified wastewater nozzle with discharge piping; 12 – sludge discharge nozzle; 13 – sludge deliquefaction unit; 14 – bag; 15 – external control devices; 16 – a hose clamp; 17 – a tray for collecting purified liquid; 18 – level control device; 19 – nozzle for compressed air supply; 20 – perforated baffle plates; 21 – power fluid supply nozzle.
Table 1. Separation efficiency of activated sludge suspension dependence on operation mode in flotation combine machine.

| The ratio between initial suspension and working fluid | Period of separation, min | Concentration of biomass, % ADS (absolutely dry substance) in the initial suspension | Concentration of biomass, % ADS in the sludge | Concentration of biomass, % ADS in the purified water |
|--------------------------------------------------------|---------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------|-----------------------------------------------------|
| 5.0:1.0                                                | 5                         | 0.81                                                                                 | 3.50                                          | 0.24                                                |
| 4.5:1.0                                                | 7.5                       | 0.81                                                                                 | 3.76                                          | 0.18                                                |
| 4.0:1.0                                                | 10                        | 0.81                                                                                 | 3.98                                          | 0.17                                                |
| 3.5:1.0                                                | 12.5                      | 0.81                                                                                 | 4.47                                          | 0.15                                                |
| 3.0:1.0                                                | 15                        | 0.81                                                                                 | 5.66                                          | 0.14                                                |
| 2.5:1.0                                                | 17.5                      | 0.81                                                                                 | 6.14                                          | 0.13                                                |
| 2.0:1.0                                                | 20                        | 0.81                                                                                 | 6.30                                          | 0.11                                                |
| 1.5:1.0                                                | 22.5                      | 0.81                                                                                 | 5.97                                          | 0.17                                                |
| 1.0:1.0                                                | 25                        | 0.81                                                                                 | 3.86                                          | 0.25                                                |
| 0.5:1.0                                                | 27.5                      | 0.81                                                                                 | 1.90                                          | 0.36                                                |

The analysis of the data presented in Table 1 shows that the best results were achieved when processing activated sludge in a flotation combine machine with a ratio of the initial suspension of activated sludge and power fluid of 2:1 and a treatment time during 20 minutes. Using this operating mode, a concentration of activated sludge biomass of more than 6% ADS is achieved, which makes such a sludge transportable and, if necessary, suitable for composting [19, 20].

3. Results

Conducted research of possible ways to utilize wet microbial biomass led to the development of a method for producing organic fertilizers based on thickened activated sludge (microbial biomass) and peat.

The main idea of the proposed method is that a thickened suspension of activated sludge is mixed with peat. Mixing of activated sludge with peat leads to an effective adsorption interaction of active substances microorganisms and mineral elements on the particles of peat. This reduces the energy consumption for dehydration the peat-activated sludge mixture and improves the quality of the fertilizer obtained on its basis.

The use of activated sludge biomass, grown for 5-15 hours, can significantly reduce the content of heavy metals in the activated sludge and more effectively use the adsorption properties of activated sludge during its thickening. In addition, activated sludge obtained from wastewater treatment of any kinds of production containing heavy metals at low concentrations can be used.

Thickening process of activated sludge-peat resulting mixture is carried out by settling. The interaction of peat particles with activated sludge microorganisms leads to the formation of large enough aggregates that have a positive effect on the process of thickening of the mixture of peat and activated sludge. At the same time, the use of this mixture in a ratio of high-moor and low-profile peat in the corresponding range from 1:1 to 1:5 is the most preferable. With such chosen ratio of high-moor and low-moor peat the best aggregation of peat particles with activated sludge microorganisms is observed.
Table 2. Yield and starch content in potato tubers in the control experiment and with the addition of various fertilizers.

| No. | Experience variant                      | Average yield, cwt/ha | Increment cwt/ha | Starch content, % |
|-----|-----------------------------------------|-----------------------|------------------|------------------|
| 1   | Control                                 | 62.3                  | -                | 17.09            |
| 2   | N_{146} P_{140} K_{277}                 | 103.6                 | 40.4             | 63.9             | 17.90            |
| 3   | MB ** 300 kg/ha                         | 87.9                  | 24.7             | 39.1             | 16.42            |
| 4   | MB 600 kg/ha                            | 96.2                  | 33.0             | 52.2             | 18.05            |
| 5   | MB 300 kg + P_{33} K_{228}              | 109.9                 | 46.7             | 73.9             | 18.70            |
| 6   | Straw 5 ton/ha                          | 79.6                  | 16.4             | 25.9             | 19.51            |
| 7   | Straw 5 ton/ha + N_{146} P_{140} K_{277} | 115.5               | 52.5             | 83.1             | 14.00            |
| 8   | Straw 5 ton/ha + MB 300 kg/ha           | 89.2                  | 26.0             | 41.1             | 12.31            |
| 9   | Straw 5 ton/ha + MB 600 kg              | 98.7                  | 35.5             | 56.2             | 17.09            |
| 10  | Straw 5 ton/ha + MB 300 kg + P_{22} K_{226} | 80.3                 | 17.1             | 27.1             | 17.76            |
| 11  | Transition-moor peat 58 ton/ha + N_{146} P_{140} K_{277} | 101.9               | 38.9             | 61.2             | 17.76            |
| 12  | Peat-sludge compost 50 ton/ha + K_{223} | 97.2                  | 34.0             | 58.3             | 14.80            |

* the value of the subscript – amount of this element in 1 kg per 1 ha
** MB – microbial biomass

For agrochemical performance evaluation of the use of compost based on wet microbial biomass and peat, experiments with potatoes were laid. The soil before the experiment was homogeneous with low acidity level, with a high degree of saturation with bases and a high phosphorus content. All fertilizers were applied in spring during the main tillage.

Potato yield and starch content in tubers using mixture fertilizers of microbial biomass and peat are given in Table 2.

From given data (Table 2) it is clear, that compost from peat and silt at its lower cost can have a bigger effect on the yield of various crops, for potatoes it is up to 80-85%.

Conducted economic research has shown that 1 ton of wet microbial biomass, which is used as fertilizer, can provide additional income by increasing the yield. It is also important to note that such kind of compost has a good water-retaining property due to the use of peat in the required amount. That compost has become widespread in the regions of the Russian Federation, where there are factories with local biological wastewater treatment.

4. Conclusion
Thus, the design is proposed and the operating mode of the flotation combine machine is determined for the thickening of activated sludge, which is obtained during the wastewater treatment of any kind of production.

The thickening of activated sludge in the proposed flotation combine machine makes it possible to obtain a sludge of such moisture that can be used for its further composting. It should be emphasized that the use of organic fertilizer in the form of peat-silt compost indicates an increase in yield, for example, for potatoes up to 80-85%, and, therefore, a significant economic effect with a low prime cost.

As a result of the tests, the obtained experimental data have shown that microbial biomass is a valuable component of fertilizers for various crops.
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