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Analysis of the Process of Aerobic Stabilization of Sediment on the Example of Purification Facilities of the Republic of Uzbekistan

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Annotation

This article discusses aerobic stabilization of sludge in sewage treatment plants. Particular attention is paid to the sedimentation rate and the quality of sludge dewatering of primary and secondary sedimentation tanks. Tables and graphs of the results of experimental work on the change in the ability of sediment to rot, change in the rate of oxygen consumption by activated sludge in the process of aerobic stabilization of the mixture of sediments, the dependence of the specific resistance of filtration on the duration of aerobic stabilization for sediments of various aeration stations in the region are presented. Mathematical analysis and calculations of the duration of aerobic stabilization are carried out according to the method developed by the Bukhara Engineering and Technological Institute. At the end of the work, conclusions and recommendations for the application of this method are given.

Keywords: Aerobic stabilization, fermentation, activated sludge, biological oxidation, aeration tank, sludge, dehydration, aeration, sedimentation tanks, oxytank, filtration resistivity.

Introduction

Currently, more than twenty large wastewater treatment plants operate in the Republic with a treatment capacity of 1000 thousand m3 / day. Effective cleaning of these stations is on average 75-80% despite the modernization and re-equipment of technological components. One of the reasons is that until now the dependence of the effectiveness of control and management of treatment facilities on the structure of subsystems and methods of material flow control has not been studied, as a result of which there are no scientifically based methods for the synthesis of these subsystems. The Action Strategy for five priority areas of development of the Republic of Uzbekistan for 2017-2021 sets the following tasks: "... reduction of energy intensity and resource intensity of the economy, widespread introduction of energy-saving technologies in production, ... construction and modernization of household waste processing complexes, strengthening their material and technical base" ... The implementation of these tasks, including the improvement of effective systems for automatic control and measurement of the parameters of technological media in the practice of automating the processes of treatment facilities will provide optimal operating modes of the main equipment in conditions of drift of their characteristics and fluctuations of

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technological parameters are the most important tasks.

Accordingly, the government adopts a number of laws and regulations aimed at stabilizing the country's economic and social status. Based on the above tasks and in order to improve the living conditions of the population, in the Bukhara region, much attention is paid to the treatment and use of wastewater. For example, the team of the Bukhara Institute of Engineering and Technology (BITI) is working on the creation of devices for monitoring the level and concentration of activated sludge during biological treatment of wastewater, energy saving in pumping equipment of treatment facilities, taking into account the resource potential of renewable energy sources to improve the economic performance of the enterprise in the region [24] [20].

In the processes of biological wastewater treatment, an important role is played by aerobic stabilization of sediments from primary and secondary sedimentation tanks. The method consists in the treatment of sediments, in which the organic part is mineralized by aerobic microorganisms. Unlike aeration tanks, in aerobic stabilizers the vital activity of microorganisms occurs with a lack of nutrient medium, as a result of which microorganisms consume the accumulated cellular material and self-oxidize (the process of endogenous respiration).

Methane fermentation of sediments, along with undoubted advantages (low energy consumption, sanitary reliability), has a number of disadvantages, which include the need to seal digester tanks and build boilers for heating them, explosiveness, and a relatively low intensity of the process. In addition, a number of organic sludge and active sludge of industrial wastewater containing salts of heavy metals cannot be processed in digesters at all, since the toxic components of these waters can completely inhibit the anaerobic microflora.

Aerobic stabilization of precipitation has recently become an alternative to methane digestion. The essence of aerobic stabilization is the biological oxidation of nutrient reserves of microorganisms in the presence of dissolved oxygen. Under these conditions, the development of the most viable bacterial species occurs due to the death of others [4].

Compacted and unconsolidated activated sludge, as well as its mixture with the wet sludge of primary clarifiers, can be aerobically stabilized. When only one sludge is stabilized, the process can be considered as the final stage of wastewater treatment, when, with a minimum of nutrient medium, self-oxidation of the cellular substance of microorganisms occurs.

The volume of excess activated sludge generated at the stations, as a rule, is 1.5 - 2.5 times the volume of the wet sludge. High humidity and high protein content in the sludge result in low gas yield during its anaerobic digestion. From an economic point of view, it is much more profitable to ferment one raw sludge in digesters, therefore, recently, more and more often resort to aerobic stabilization of activated sludge.

Materials and methods

The duration of aerobic stabilization of activated sludge is related to the time of its aeration in aeration tanks, i.e., the age of the sludge. The larger the latter, the shorter the stabilization period and the lower the rate of oxygen consumption, and vice versa. The duration of the stabilization of the mixture of sludge with sediment from the primary settling tanks largely depends on the amount of substrate introduced with the sediment, as well as the intracellular nutrient substrate and the degree of their decay. The process continues as long as

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there is a nutrient substrate.
The process of biochemical oxidation of the intracellular substrate under aerobic conditions occurs in one stage:

$$C_5H_7NO_2 + 7O_2 \rightarrow 5CO_2 + 3H_2O + H + NO_3$$

It can be implemented in open structures, similar to conventional aeration tanks, which is a great advantage of the method, since it significantly simplifies the operation of structures and avoids the complications inherent in digester tanks.

With aerobic stabilization, the organic part of sediments decomposes up to 50%, of which about 70% fats and about 30% proteins. The degree of decomposition depends on the composition of the initial sediment and the period of stabilization. At the same time, the carbohydrate content does not decrease. It is believed that this is due to the formation of polysaccharides in the cells of microorganisms in parallel with the breakdown of extracellular carbohydrates. The mode of aerobic stabilization in mesophilic conditions at a temperature of 10-42 ° C has been studied to the greatest extent.

Thermophilic aerobic stabilization is possible at a temperature of 42-70 ° C. It is noteworthy that this regime can be carried out due to the heat released as a result of biological processes. It provides a significant acceleration of the process, in which the aeration period is reduced to 2 days, the sterility of the stabilized sludge, an improvement in its sedimentation properties and a decrease in specific oxygen consumption. However, for the implementation of thermophilic stabilization at a temperature of 50-60 ° C, it is necessary to provide measures to prevent heat loss during aeration with the outside air. The advantages of thermophilic stabilization are realized in the best way when using technical oxygen in the process. In sealed oxytanks, an autothermal regime is reliably ensured, in which there is no need for additional heating of the sediments.

In accordance with the current KMK standards 2.04.03-85 (Sewerage. External networks and structures), the duration of aerobic stabilization for unconsolidated activated sludge is taken 7-10 days in order to ensure the decomposition of the ashless substance by 20-30%. For a mixture of raw sludge and excess sludge, the stabilization period should be 10-12 days with a decay depth of 30-40%. With such parameters, aerobic stabilization is cost-effective for stations with a capacity of up to 50 thousand m^3/day.

Comparison of the calculation data according to the methods accepted in the world, performed by TA Karyukhina, shows that the volumes of aerobic stabilizers, calculated according to the parameters of the United States, are more than 2 times higher than the volumes of these structures determined according to the current norms and rules [26]. This fact clearly illustrates the inconsistency of the known methods for calculating aerobic stabilization, which is primarily due to the insufficient validity of the criterion (for example, the degree of decomposition of organic matter) by which the moment of the end of the process should be determined. When choosing a criterion for stabilization of sediments, as studies have shown, one should proceed from the conditions of its subsequent processing or storage.

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Table 1. Tentative parameters of aerobic stabilization for some industrial wastewater sludge.

Sediment	Humidity %	Ratio PS /AS[1]	Stabilization period, days	SFR, 10^{10} sm/g
Silk-winding industry	99	0/1	1	25
Plants for primary processing of bast crops	96,5-97	1/1	7	30-35
Hydrolysis plants	96-97	1/1	5-7	25-30
Canning factories	96,5	1/1	6-8	30-40

In accordance with the kinetic laws of biochemical oxidation during aeration of sediments, a decrease in the rate of oxygen consumption is observed, associated with the decomposition of its decaying components, which determine the colloidal structure and high specific filtration resistance (SFR), which determines the parameters of the subsequent dehydration of sediments. Oxidation of these components leads to the destruction of the colloidal structure of the sediments and to a significant decrease in the specific filtration resistance.

The method of aerobic stabilization, based on the OCR (oxygen consumption rate) criterion, can be used to treat domestic wastewater sludge and a number of industrial wastewater sludge (Table 1.) that do not contain toxic components. The parameters of this method are given in table. 1. For other waters, the possibility of using aerobic stabilization and its parameters should be determined experimentally.

The calculation of the duration of aerobic stabilization can be carried out according to the method developed by the BITI. Stabilization period in the displacement reactor (at a design temperature of 20 ° C):

for activated sludge

$$T_{sx} = T_{s1} / K_s \qquad (1)$$

Here: T_{s1} and T_{sx} - stabilization period of activated sludge, days, at a concentration of 1 g/l and X g/l;

$$K_s = K_x / (K_x + X) \qquad (2)$$

Here: K_x - constant of inhibition of activated sludge biomass by metabenism products;

X - average concentration of activated sludge in the stabilizer;

for a mixture of activated sludge with primary sludge

$$T = T_{ix} + T_{p.s.} \; (3)$$

Here: $T_{p.s}$ - duration of oxidation of the primary sludge, days, determined by the formula

$$T_{ps} = K_1 \ln\left(\frac{V^0 + K_2 X K_s}{V + K_2 X K_s}\right) + \frac{\Delta S}{V_c X K_s}$$

Here:

$$K_1 = V_{max} K_{sat} / V_c^2; \qquad K_2 = V_e K_{sat} / V_c \qquad V_c = V_{max} + V_e;$$

$$\Delta S = S_s + S; \qquad S_s = g_{p.s.} * X_{p.s.};$$

[1]PS- sediment from primary sedimentation tanks; AS - excess activated sludge.

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$X_{p.s.} = C_{p.s.} Q_{p.s.} / Q_{mix}$; $X = X_0 + y\Delta S/2$

Where V_{max}- maximum specific oxidation rate of sediment components, mg (g□h); V_e - oxidation rate of endogenous components of the substrate, mg/(g□h); K_{sat} - saturation constant, mg/g; S_s - concentration (initial) of the substrate in the sediment, expressed in oxygen units, mg/l; X_0 - concentration of activated sludge in a mixture with primary sludge fed to the stabilizer, g/l; y - coefficient of growth of activated sludge biomass, g/g; $g_{p.s.}$ - the amount of oxygen required to stabilize a unit of the ash less part of the primary sludge g/g; $Q_{p.s.}$ и Q_{mix} - amount of primary sludge and a mixture of primary sludge and excess activated sludge, m^3/day.

The parameters included in the calculation equations are determined experimentally for each type of precipitation. The averaged values of these parameters for the sludge of domestic and similar industrial wastewater in composition are given in Table. 2.

Table 2. Values of the parameters of the design equations for the domestic wastewater sludge

Parameter	Numerical value	Unit of magnitude
T_{s1}	1	days
K_x	12	-
K_1	24	h
K_2	210	mg/g
S	10	mg/l
y	0,2	g/g
$g_{p.s.}$	1,1	gO_2/g
V_c	40	m/(g□h)

The duration, in days, of the aerobic stabilization process at a temperature other than 20 ° C should be calculated using the formula

$$T_t = T_{20} \cdot 1{,}05^{(20-t)} \qquad (4)$$

Where : T_t и T_{20} - duration of the process at temperature t and 20 ° C.

Specific air consumption, 1 m^3/kg of ash-free part of the sediment, for aerobic stabilization is determined by the formula

$$D = \frac{q \cdot S_0 \cdot 1000}{K_a K_b K_T K_3 (C_a - C)}$$

Where:

q- specific amount of oxygen required for biochemical oxidation of 1 g of mixture;

S_0- concentration of ash-free matter in the sludge supplied for stabilization, kg/m^3;

$K_a,\ K_{b,},\ K_T,\ K_3, C_a$ – determined according to the data given in KMK 2.04.03-97;

By design, the aerobic stabilizer is similar to an aeration tank - a displacer, consisting of cells separated by partitions. The distribution of air between cells depends on the properties of the original sludge. The ratio between the volumes of the cells and the air

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consumption for domestic and close to them in the composition of industrial wastewater can be taken from table. 3.

To ensure the necessary mixing of the sediment, the intensity of aeration in the stabilizer should be at least 6 m^3/ (m^2□h).

Table 3. Relationship between the volume of the stabilizer cells and the air flow rate.

№ Cell	Share of cell volume,%	Air consumption share,% of the total stabilization consumption	№ Cell	Share of cell volume,%	Air consumption share, % of the total stabilization consumption
1	25—30	35—40	4	10—12	10—15
2	20—25	25—30	5	8—10	5
3	10—12	6—10	6	8—10	5

At a sediment temperature below 10°C, the processes of aerobic stabilization are significantly slowed down [see. formula (4)]. To reduce heat loss in the stabilizer, an overlap can be arranged or other measures can be taken, the feasibility of which is determined by technical and economic calculations.

Results

It has been shown experimentally that the rate of aerobic oxidation of easily decaying components of the sediment decreases to a certain point, after which it remains practically constant. This indicates the end of the stabilization process, and further aeration does not give qualitative changes in the organic part of the sediment and its ability to decay. Subsequent long-term aeration leads to the lysis of bacterial cells, accompanied by a decrease in biomass, activated sludge and an increase in its ash content, but no longer reduces the amount of easily decaying components that determine its stability.

Studies carried out during long-term storage of the sludge have confirmed the compliance of the quality of the stabilized sludge according to the criterion associated with the rate of oxygen consumption with sanitary requirements (Table 4).

Table 4. Changes in the ability of sediment to decay during aerobic stabilization.

Sediment	Stabilization period, days	SFR 10^{10} sm/g	Multiplicity of dilution to the odor threshold during storage, days				
			1	3	10	20	45
Initial unstabilized	0	350-700	Strong putrid odor				
Partially stabilized	3	60-80	0	4	15	40	100
Stabilized by OCR criterion	5,5	35-60	0	0	0	0	0
Parameter-stabilized KMK 2.04.03-97	13-18	120-152	0	0	0	0	0

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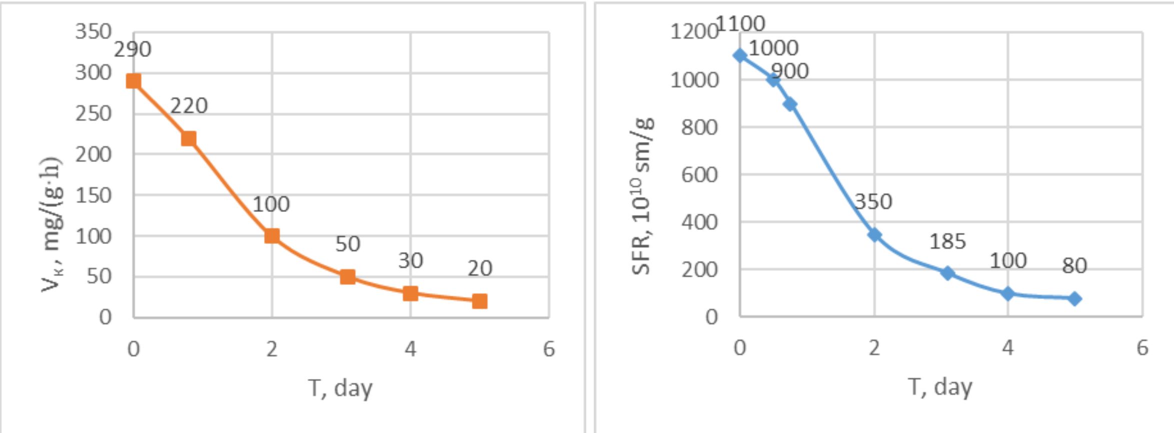
It should be noted that a decrease in the rate of oxygen consumption during aeration of precipitation corresponds to a drop in the specific resistance of filtration (Fig. 1). By the end of the oxidation process of enzymes and endogenous sediment substrates, the resistivity takes on a minimum value. With the subsequent aeration, the water-yielding properties of the sediment are significantly deteriorated and the value of the SFR increases sharply (Fig. 2). Experimental data on the productivity of sludge beds were obtained under the condition of timely removal of sludge water thr ough drainage. The data of testing the process of aerobic stabilization according to the recommended criterion associated with the rate of oxygen consumption are given in Table.5.



a) **b)**

Figure: 1. Change in the rate of oxygen consumption by activated sludge (a) and SFR (b) in the process of aerobic stabilization of the sediment mixture.

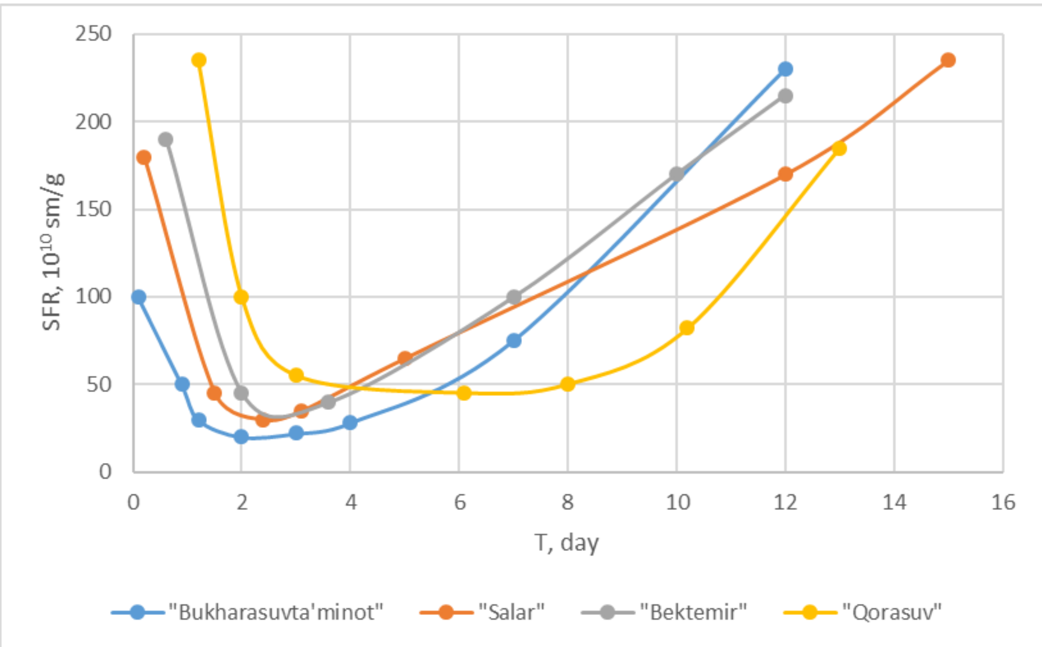


Figure. 2. Dependence of the SFR on the duration of aerobic stabilization for precipitation of various aeration stations.

Aerobic stabilization, improving the water-yielding properties of sediments, does not ensure their complete disinfection, which in some cases can cause difficulties in using them

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for fertilizing agricultural crops. Heat treatment is one of the widespread methods of disinfection of sediments, but it causes destruction of the structure of sediments and this significantly worsens their water-release properties. Such a negative effect can be compensated for by subsequent aeration of the thermally neutralized sludge, as a result of which the damaged structure is able to recover.

Studies on aerobic stabilization of thermally treated sediments have shown a significant effect of the temperature of the aerated mixture on its water-releasing properties. The minimum value of the USF is observed at a temperature of the aerated mixture of 25-27 ° C; a further increase in temperature causes a change in the structure of the mixture, sharply increases the specific resistance of filtration and the sludge index. To cool the thermally treated sludge to optimal temperatures, heat exchangers with circulation of the original sludge can be used.

Aerobic stabilization can be used in combination with anaerobic digestion. Such a scheme was tested at a number of treatment facilities and showed that the productivity of sludge beds can be increased by 3-4 times in comparison with the option of dehydration of only anaerobically fermented sediments. Improving the water-releasing properties of sediments during aerobic stabilization according to the OCR criterion makes it possible to significantly increase the throughput of mechanical dehydration devices (vacuum filters, filter presses and centrifuges), while reducing the consumption of reagents. The quality of the sludge water of stabilized sediments is characterized by relatively low BOD_5 values, which makes it possible to direct the sludge water to secondary sedimentation tanks without increasing the load on biological treatment facilities. This is a significant advantage over anaerobic digestion, in which sludge water significantly contaminates the total wastewater entering biological treatment facilities.

Table 5. Results of industrial tests of the process of aerobic stabilization of precipitation.

Wastewater treatment plants of cities	Ratio PS /AS	SFR, 10^{10} sm/g		Performance of sludge site, $м^3/(м^2$-year) by sediment	
		original	stabilized	original	stabilized
Bukharasuvta'minot	3/1	320	12-18	1-2	5-6
Salar	2,2/1	67	8	1,3	5-6
Qoradaryo	2/1	600	10-20	1.5	8
Bektemir	7/1	2000	50-70	1,8	12
Qorasuv	0/1	30	20	1,4	8

When centrifuging a stabilized sludge, the centrifuge contains a significant amount of suspended solids. This suspension contains activated sludge, which, in terms of its oxidizing capacity, is practically not inferior to sludge from aeration tanks, but has a lower sludge index, not exceeding 50 cm^3/l. In this regard, it is advisable to direct the centrate to the aeration tank, using it as part of the circulating sludge. A low sludge index and good sedimentation properties are also inherent in stabilized sediments, therefore, it is advisable to partially return them to the aeration tank to improve the structure of activated sludge.

The high sorption activity of aerobically stabilized sludge is used in the method

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developed at BITI. A distinctive feature of this method is that excess activated sludge is subjected to aerobic stabilization, and then it is mixed with the fermented sediment of the primary sedimentation tanks and the resulting mixture is blown with air immediately before compaction. With this method of processing, non-decaying activated sludge is formed, which has not lost its biological activity, i.e. the ability to adsorb fine and colloidal particles of the fermented sludge, which, in turn, leads to an increase in the efficiency of compaction. This produces a precipitate with good filtration properties. The technical and economic comparison showed that with a relative equality of capital costs for the implementation of the known and proposed methods, the latter is more economical due to the reduction of operating costs. [28-40]

Dewatering of aerobically stabilized sludge can be carried out naturally (on sludge areas) or in mechanical dewatering devices.

For dehydration in natural conditions, it is most advisable to use sludge pads on an artificial foundation with drainage and surface water drainage. The drainage surface should be 8-10% of the site area. ‘It is rational to take the dimensions of the map on the basis of filling it up to full working height (1-2m) in no more than 3 days

The load on sludge pads with a sediment moisture content of 96-97% for areas with a climatic coefficient equal to 1 can be taken as 2-4 $m^3/(m^2$□year) (with proper operation of the sites). To determine the load on sludge pads located in other climatic zones, use the conversion climatic coefficient specified in KMK 2.04.03-97.

The conditioning of the aerobically stabilized sludge before dehydration on vacuum filters and filter presses is carried out with ferric chloride and lime. At the same time, the doses of reagents are reduced by 1.5-2 times compared to the consumption of reagents during dehydration of sediments anaerobically discharged under the mesophilic regime. The productivity of the apparatus corresponds to the parameters specified in KMK 2.04.03-97. Dehydration of the sludge in centrifuges can be carried out without preliminary conditioning with the return of the centrate to the aeration tank.

Conclusions

The field of application of the method depends on local climatic conditions and the adopted sludge dehydration scheme. According to preliminary data, it is economically feasible for structures of average throughput, located in the south and in the middle zone of the country.

Due to the reduction of the aeration period in comparison with the recommendations of KMK 2.04.03-97 and a decrease in the costs of dehydration of stabilized sediments, the introduction of the aerobic stabilization method based on the SPC criterion can give a significant economic effect. For a station with a throughput capacity of 100,000 m^3/day, it can be 150-200 thousand dollars/year.

Particularly promising is the use of aerobic stabilization at stations with a low wastewater flow rate at a low concentration of suspended solids in the water. In this case, the plant layout is greatly simplified, since primary sedimentation tanks are excluded from it. The only sediment formed at the station is excess activated sludge, which is mineralized under aerobic conditions in mineralizers.

Compaction of activated sludge before aerobic stabilization can be carried out by gravity and flotation methods up to a concentration of 15-25 g/l. Duration of gravity

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compaction should not exceed 6-8 hours. The concentration of compacted active sludge is 15-18 g/l. The sediment after aerobic stabilization should be additionally compacted in gravity or flotation compactors. The concentration of the compacted stabilized sediment can reach 30-45 g/l.

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