Structures

TECHNOLOGICAL BASIS OF WASTEWATER SEDIMENT TREATMENT

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Annotation

The textbook outlines the technological foundations of the treatment, utilization and elimination of wastewater sediment. Much attention is paid to the choice of the best technologies for wastewater sediment dewatering, including excess activated sludge, as well as their possible disposal. Foreign experience, including scandinavian countries, treatment and utilization of wastewater sediment as an organic-mineral fertilizer, as well as domestic experience in sludge combustion are considered.

Meets the requirements of the Federal State General Education Standard of Higher Education of the latest generation.

The book is intended for master's students, graduate students, teachers and specialists interested in ways of treating natural and wastewater sediments, and is recommended for an enlarged group of specialties and directions 20.00.00 "Technospheric safety and environmental engineering".

Contents

Introduction

Dewatering and disposal of wastewater sediment, including excess sludge, is quite a challenge. It can be stated that this task is an urgent problem for most countries of the world.

Special attention should be paidto the dewatering and utilization of excess activated sludge. According to various sources, about 3.5 million tons of excess activated sludge biomass are formed annually in our country. The utilization of such a large amount of biomass of sludge microorganisms requires research and development of various areas of use of microbial biomass of activated sludge. The problem of disposal of wastewater sediment and activated sludge is to some extent constrained by the presence of toxic sludge in them. impurities, including heavy metals, as well as the still weak development of methods for processing these hard-to-dehydrate systems.

The process of compaction and subsequent thickening of activated sludge and its utilization is greatly influenced by the mode of growing microbial biomass, as well as its preliminary preparation through the use of physical and chemical methods.

Compaction of wastewater sediment is the primary stage of its treatment and is designed to reduce its volumes. The most common method -gravitation sealing is carried out in settling tanks-seals.

Sediment stabilization is used to destroy the biodegradable part of the organic matter, which prevents sediment from rotting during long-term storage in the open air (drying on sludge sites, use as agricultural fertilizers, etc.).

Conditioning of sediments is carried out to destroy the colloidal structure of the sediment of organic origin and increasetheir water output. Mainly the reactive method of conditioning is used in practice.

Dewatering of wastewater sediment is designed to receive sediment with a humidity of about 60 - 80%. Dewatering is carried out both mechanicallyand thermally, as well as by drying sediments at sludge sites. Mechanical dehydration as the cheapest method is carried out using screw thickeners (dehydrators), vacuum filters, centrifuges, filter presses. Thermal dewatering with the use of dryers of various types.

Disposal or elimination of wastewater sediment is largely determined by its composition and, first of all, the content of toxic impurities, including heavy metals.

Thesetasks are the subject of the presentation of the material of this manual and in some cases are supported by practical calculations. It should be emphasized that according to SP 32.13330.2012 (Code of Rules. Sewerage. External Networks and Structures), the calculation of facilities for the treatment of industrial wastewater and the treatment of their sediments should be carried out on the basis of data from research and engineering organizations, the experience of operating existing similar facilities with taking into account this set of rules and regulations for the design of enterprises of the relevant industries.

Consideration of the solutions to the above tasks in this manual is carried out with a focus on the use of the best available technologies (BAT), taking into account their gradual development in the Russian Federation.

It should be noted that while BAT is being discussed and clarified the possible procedure for their use. In all cases, the listener must understand in what cases to use a particular technology.

When mastering the discipline according to this manual, it is planned to form competencies provided for by the main professional educational program on the basis of the Federal State Educational Standards or the LMS in the direction of training 20.04.01 Technosphere safety (Profile 20.04.01_01 "Integrated anduse of water resources", the level of the magistracy). As a result of mastering the discipline, students must:

KNOW: - normative documents, including reference books on BAT of the environmental direction, indicating the ways of treatment and disposal of wastewater sediment;

- composition and properties of wastewater sediment;
- methods of compaction of wastewater sediment, including activated sludge;
- basics of aerobic and anaerobic treatment of wastewater sediment;
- methods of mechanical dewatering and thermal drying;
- the main directions of utilization of wastewater sediment inod;

BE ABLE TO: - find solutions to improve the environmental situation in the places of formation of wastewater sediment;

- Calculate equipment for the compaction and dewatering of wastewater sediment;
- develop regulations on the technology of dewateringand utilization of wastewater sediment;

OWN: - findingsolutions for the treatment and disposal of wastewater sediment;

- development of technological schemes for compaction, mechanical dewatering and thermal drying of wastewater sediment with their subsequent utilization;
- technology of storage of wastewater sediment.

Consideration of the above problems, assimilation of educational material in the most complete scope and is devoted to this textbook.

1. Approximate composition, properties and control of water extraction properties of wastewater sediment

Sediment is a suspension released from wastewater in the process of their mechanical, chemical, physico-chemical and biological treatment. When treating wastewater sediment, it is planned to minimize their humidity and volume, stabilize and disinfect to prepare for disposal or disposal.

Depending on the method of wastewater treatment and the type of structures, the resulting sediments are in the form of coarse waste, heavy suspensions that settle in sand traps; pop-up and sedimentation of both organic and mineralimpurities. A special type of sediment is active sludge that separates in secondary sedimentation tanks during biological wastewater treatment. On the other hand, depending on the type of treatment, sediments are divided into:

1. anaerobically fermented in clarifiers-rots, two-tier settling tanks or methanenuts;
2. aerobic-stabilized - activated sludge or its mixture with a precipitate lump of primary settling tanks or special stabilizers;
3. compacted activated sludge, sedimentor mixture of sealants;
4. washed from the dense fermented sediment;
5. condensed active sludge from separators or centrifuges;
6. the active sludge or precipitate is fleeted;
7. dehydrated sedimen+t after mechanical dehydration devices;
8. driedsediment from sludge sites; thermally dried sediment, etc.

The composition and properties of sediments from primary and secondary sedimentation tanks depend on the nature of the wastewater being treated and, first of all, on the type and quantity of industrial wastewater treated jointly with domestic wastewater. The average moisture content of the sludge discharged from the primary sedimentation tanks is approximately 94-97% during gravity removal and 93-95% during removal by plunger pumps. The humidity of the activated sludge discharged from the secondary sedimentation tanks after the aeration tanks is approximately 99, 1-99, 4%, after the biofilters - 95-96%. Active sludge compacted in the sludge compactors of the vertical type has an average humidity of 97-98%, in the sludge compactors of the radial type about 95-97%.

For indicative calculations, the amount of a mixture of sediment of primary sedimentation tanks and compacted excess activated sludge at an average humidity of 96.5% can be taken to be equal to 0.7-0.9% of the volume of wastewater treated.

The amount of sludge formed during the physicochemical treatment of wastewater depends on the type and dose of reagents taken, while the moisture content of the sludge is approximately 95-96%..

When fermenting a mixture of sediment from primary sedimentation tanks and compacted excess activated sludge, the average humidity of the discharged sludge can be: from methane tanks - 97%, from two-stage methane tanks and clarifiers-rotors - 93%, from aerobic stabilizers after 1.5-5-hour compaction - 95-97%.

Most of the dry matter of the sediment from the primary settling tanks and activated sludge is organic matter. In the raw sediment from the primary settling tanks, proteins are about 2 times less, and carbohydrates are 2.5-3 times more than in active sludge. The dry matter of the sediment from the primary settling tanks has the following approximate composition, % by weight: carbon - 35-85%; hydrogen - 4 -8%; sulfur - 0.3-0.8%; nitrogen - 1.6-7.5%; oxygen - 6.5-30.5%, 5%. Dry matter of activated sludge contains 45-65% carbon; 5.5-7.1% hydrogen; 0.7-2.5% sulfur; 3.0-8.5% nitrogen; 15.5-44.0% oxygen.

Wastewater sediment may also contain lead, cobalt, cadmium, mercury and other elements. The chemical composition of sediments has a significant impact on their processing. Compounds of iron, aluminum, chromium, copper, as well as acids, alkalis help to improve the process of sediment, compaction and dehydration of sediments, reduce the consumption of chemical reagents for their coagulation before dehydration. Oils, fats, nitrogenous compounds increase gas release during sediment fermentation, which leads to a violation of the processes of compaction and thickening. When containing heavy metal ions, chromium compounds, arsenic, etc., as well as dyes and synthetic detergents gas emission decreases, the processes of anaerobic and aerobic fermentation of sediments deteriorate, the quality of the sediment decreases when it is disposed of as a fertilizer.

The water output of sediment largely depends on the size of the particles of their solid phase. The smaller the particles, the worse the water output of sediment. The organic part of the sediment quickly rots, releasing an unpleasant odor, and at the same time the number of colloidal and finely dispersed particles increases, as a result of which the water output of sediment decreases.

According to the Moscow treatment plants, in the sediment of primary sedimentation tanks, the content of particles larger than 7-10 mm is 5-20%, 9-33% in size 1-7 mm and 50-88% of the total dry matter mass is less than 1 mm in size. The precipitate fermented in the methane tanks has a finer and more uniform structure than the fresh one and contains particles smaller than 1 mm in size, with an average of 85%. In active sludge, the number of particles smaller than 1 mm reaches 98%; size 1-3 mm - 1.6%, more than 3 mm - 0.4% of the dry matter weight. The resistivity of filtration precipitates is the resistance of a unit mass of solid phase deposited per unit of filter area when filtered under constant pressure of a suspension whose viscosity of the liquid phase is one. The resistivity that characterizes the water output of sediment determines the need and degree of treatment of sediments before mechanical dewatering, the choice of the method of sediment treatment and the calculation of the corresponding structures. Fresh crude sludge from primary sedimentation tanks and uncompacted active sludge have significantly lower resistivity than fermented sludge and compacted activated sludge. The fermentation of sediment, despite the mineralization, worsens their water return.

The forms of connection of water with particles of the solid phase are different. Moisture in sediment can be in chemical, physico-chemical, physico-mechanical connection with solid particles, as well as in the form of free moisture. The more bound moisture in the sediment, the more energy needs to be expended to remove it. An increase in the water output of sediment is achieved by redistributing the forms of connection of moisture with solid particles in the direction of increasing free and decreasing bound moisture by coagulation of sediment with chemical reagents, introduction of filler materials, freezing with subsequent thawing, heat treatment and other methods.

The thermophysical characteristics of sediment are necessary for the proper organization and calculation of sediment heat treatment processes. The heat of combustion of the dry matter of sediment on average is 16.7-18.4 MJ / kg. With an increase in humidity and ash content of sediment, their specific heat capacity increases and the heat of combustion and the output of volatile ones decrease.

Wastewater sludges are suspensions in which the dispersed phase is particulate matter of organic and mineral origin, and the dispersion medium is water with substances dissolved in it. The control of the water recovery properties of wastewater sediment is of paramount importance in sludge treatment processes. Let's consider these properties of sediment in more detail.

Humidity is the mass content of water in 100 kg of sediment, expressed as a percentage:

$$P = 100 \cdot (m_{ос} - m_{сух}) / m_{ос}$$

or

$$P = 100\left(1 - \frac{m_{cyx}}{W_{oc}\rho_{oc}}\right)$$

where moc, m_{cyx} is the mass and dry residue of the sediment, kg; Woc – draught volume, m3; ρoc – sediment density, kg/m3.

The moisture content does not sufficiently assess the feasibility, conditions and degree of moisture removal from the sediment. This is due to the complexity of its structure and the peculiarities of the distribution of water in it. However, only a directed effect on the structure of the sediment can ensure the effectiveness of the processes of its dehydration.

The specific resistance of sediment filtration as noted above is defined as the resistance exerted by the movement of the filtrate through theloy of the cake depositedby 1 m2 alongthe top of the filtrate and containing 1 kg of dry matter. The specific resistance of filtration is determined by the formula:

$$r = \frac{2pF}{\mu C'} \cdot \frac{\tau}{w^2}$$

where τ is the filtration period, c; w – filter volume obtained for the period τ, m3; μ – dynamic viscosity, Pa×s; C' is the mass of the solid phase of the cake deposited on the filter when obtaining a unit volume of leachate, kg/m3; F – filter area, m2; p is the pressure difference, Pa; r – specific filtration resistance, m/kg.

The filtering rate will increase, remain constant, or decrease as p increases, according to whether the value of S is less than, equal to, or greater than one.

$$S = \frac{\lg(r_1 / r)}{\lg(p_1 / p)} \quad (1.5)$$

where r1 and r are the values of the resistivity of filtration at the difference in filtration pressures p1 and p, respectively.

As a criterion characterizing the water return of sediment in a centrifugal field, a centrifugation index Jc m3 / kg is proposed, determined by the formula:

$$J_c = 1000 \cdot W_k / (CW_o)$$

where Wk is the volume of the cake equal to (Wo-Vf), m3; Vf – fugate volume, m3; C is the concentration of the solid phase of the sludge, kg/m3; Wo – draught volume, m3.

An increase in the efficiency of sludge dewatering by centrifugation is achieved with an index value of at least 6-8.

The ability of the sludge to dehydrate can also be established by measuring the time of capillary absorption. The simplest method for assessing water-dissipation properties is to measure the distance (or time) of capillary absorption of water with filter paper.

The disadvantage of this method is the poorperformance of the results of the experiments. Obtaining comparable results requires certain varieties of scarce paper used as a substrate.

The improvement of the method of express control consists, among other things, in the selection of the filter substrate material, which would not be expensive, scarce and satisfy the main requirement of the experiment - good reproducibility of the results in determining the water-dissipation capacity of the sludge.

As you know, express control is based on capillary absorption of moisture, separated from the solid phase of the sediment, by a porous substrate in the form of filter paper. With the absorption of moisture, an increase in the moistened surface occurs and after a certain time (15 minutes), the diameter D of the moistened surface is measured (see Figure 1.1a). For the convenience of carrying out such measurements, we have improved this method of measurement by using a special indicator in the form of a plastic cylinder with "blue tape" filter paper wound on its surface (Fig. 1.1b). In this case, the effect of water output is measured by the height H of the column of the liquid rise or by the time when a certain value of the height of the column is reached.

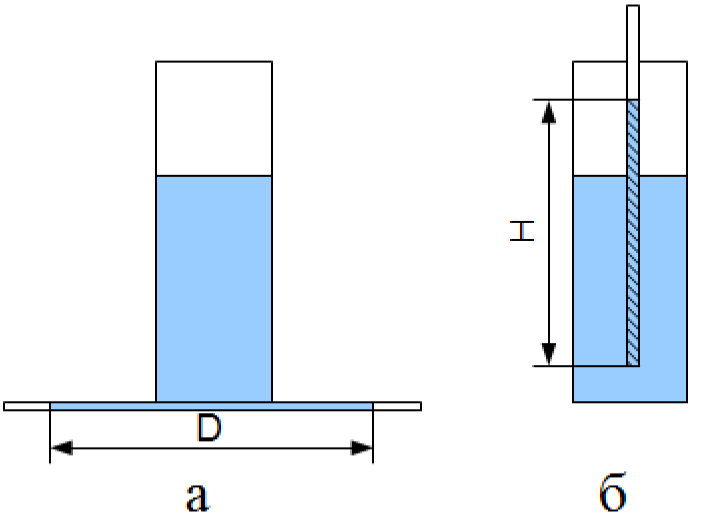


Fig. 1.1. Schemes for measuring water-dissipation properties according to known (a) and proposed (b) methods

Test tests according to the proposed method were carried out at the following facilities: tap water, a suspension of activated sludge without adding reagents and a suspension of activated sludge with the addition of flocculant A130 (Fig. 1.2).

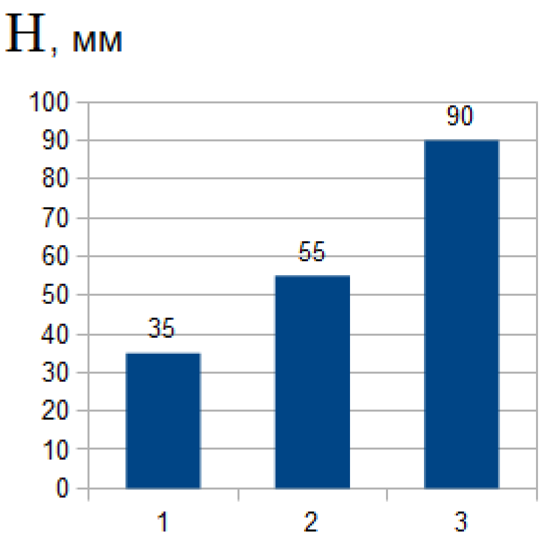


Fig. 1.2. Determination of the efficiency of water recovery according to the proposed method:1

1 - suspension of activated sludge with the addition of flocculant A130;

2 - suspension of activated sludge without the addition of reagents;

3 - tap water.

Presented in Fig. 1.2 The data show that unbound water (tap water) is most easily absorbed by filter paper and gives the highest column height, and bound moisture (sludge samples 1 and 2) is much more difficult to separate from the solid phase of activated sludge and the fluid lift columns are much smaller than in the case of tap water. At the same time, the flocculant of the brand (A130) binds water more strongly than active sludge without the addition of reagents, and in this case the height of the liquid column is minimal.

It should be noted that flocculants added to active sludge can both contribute to moisture binding and vice versa - improve water yield. This last case is of interest for the practice of thickening activated sludge.

The addition of chemical reagents helps to neutralize or reduce the value of negative charges on the surface of solid phase particles and combine them into aggregates. Given that active sludge contains a large amount of organic substances, mineral coagulants with a large number of cationic groups and a high charge were used to improve its water-giving properties: $Fe_2(SO_4)_3$, $Al_2(SO_4)_3$. In addition, the correct selection of the ratio, duration and intensity of mixing with the sediment of the above coagulants is essential. In our case, mixing of the sludge with the coagulant was carried out for 10 seconds at a stirrer speed of 3 $^{s-1}$. The initial concentration of activated sludge was 1%.

The test procedure included treating a suspension of excess activated sludge with a coagulant of a certain concentration. The water-yielding capacity of activated sludge was estimated by the rate of moisture distribution according to the proposed method.

Ceramics, acetate films, filter paper with different porosity, and a de-ashed filter were tested as a porous substrate.

The results of experiments measuring the time to achieve a constant height of the column of liquid are presented in Table. 1.1.

Table 1.1. Results of the study of water-giving properties of excess activated sludge

No p/n	Porous substrate under study	Time to reach a constant value of the column of liquid, c*						
		No Flocculant	Flocculant treatment					
			Iron sulfate, % of the solid phase of activated sludge			Aluminum-potassium alum, % of the solid phase of activated sludge		
			2,5	5	7,5	2,5	5,0	7,5
1	Acetate film	468	343	300	330	405	345	450
2	Cardboard	197	185	182	178	168	175	164
3	Insulated filter	85	68	64	67	53	45	55
4	Coarse porous filter (quick-filtering)	43	40	34	32	23	36	36
5	Fine-porous filter (slow-filtering)	90	78	65	74	68	56	74
6	filter paper ("blue tape")	37	30	20	28	36	28	24
* each of the studied modes was repeated 3 times								

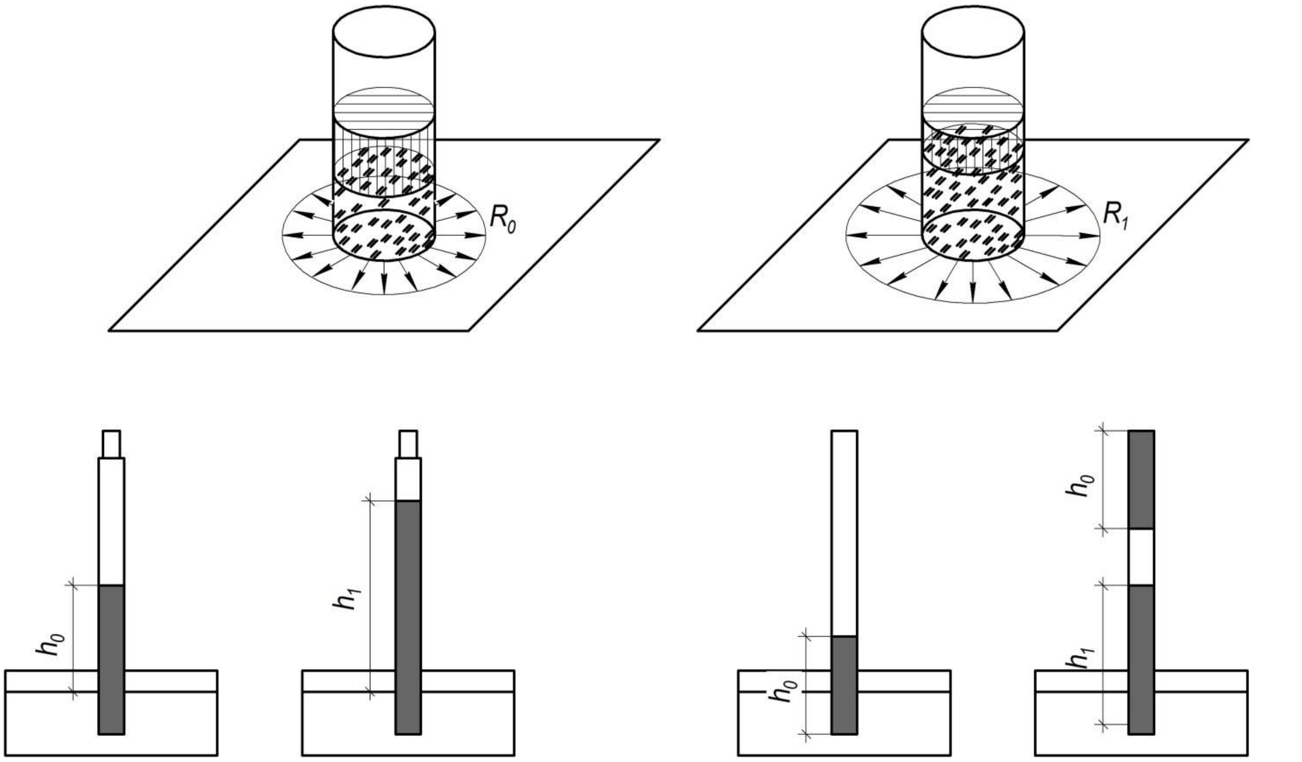
The most reproducible results presented in Table 1.1 were obtained when working on a waterproof filter, which is inexpensive and non-scarce (the "blue tape" filter).

The method offered by us is convenient when working in laboratories with minimal equipment. We believe that the proposed method can be used in the practice of testing the water-giving properties of sediment. This is necessary, for example, at the stage of implementation of the feasibility study on the choice of a method for condensing wastewater sediment.

In the future, the possibilities of using the method described above were expanded, as well as its improvement. Various options for using such an express analysis were considered (Fig. 1.3).

In the method described above, the effect of water transfer, as already noted, is measured by the distance of the spread of the liquid on the filter paper (the standard version is Fig. 1.3, A and B) or by the height H of the column of liquid rise or by the time of reaching a certain value of the height of the column of liquid (proposed by us - Fig. 1. 3, C). In both cases, 2 sheets of paper are used, which in one way or another differ in quality from each other, which generally increases the error of the experiment. In this regard, we propose a more accurate embodiment of this method (Figure 1.3, D). The effect of water output in this case is compared by the height h of the column of liquid rise on one sheet of paper (Fig. 1. 3, D). In this case, a sheet of filter paper was used in the form of tubesand tightening a round rod, and at the same time one end of this tube was in contact first with the standard sample (sediment without the addition of reactants) and the height of the liquid rise h 0 was measured, and then the second end of the tube was lowered into the test sample (sediment with the addition of reagents) and the height of the rise of the liquid h 1 was also determined. $_0$ can be judged on the effectiveness of the use of reagents added to the precipitate. At the same time, the greater the difference between thevalues of h_1 and h_0, the more significant the difference in the properties of water return in the samples under study.

A B



C D

Fig.1.3. Various variants of the express method for determining water dispensers properties of wastewater sludge (standard sample - precipitate without reagents and the tested sample - precipitate with reagents):

A and B – determination of the water-giving properties of sediments by comparing the spread of liquid on filter paper from a standard sample of sediment (R0) and a test subject (R1) using different sheets of paper;

C - determination of the water-emitting properties of sediments by comparing the lifting of the liquid on the filter paper from the standard sample of sediment (h0) and the subject (h1) using different sheets of paper;

D - determination of the water-giving properties of sediments by comparing the lifting of the liquid on the filter paper from the standard sample of the sediment (h0) and the subject (h1) using a single sheet of paper.

As samples for determining the effect of water recovery, sediments of primary sedimentation tanks, excess activated sludge, a mixture of excess activated sludge and sediment of primary sedimentation tanks without and with heating up to 800 C^{o} were used. The efficiency of water recovery of these types of sediments was studied using iron sulfate and various flocculants, in particular Praestol 2540, Praestol 650, Praestol 2530, Praestol 853.

The data obtained during the tests are presented in Table 1.2.

Table 1.2. Water recovery of wastewater sediment depending on the reagents used

Reagent and concentration (% wt.)	Difference in the height of the liquid lift (h1-h0), mm			
Iron sulfate (1.5%) and flocculant (0.2%)	Sediment of primary sedimentation tanks	Excess active sludge	Mixture of sediment of primary sedimentation tanks and excess activated sludge	Heated to 800C mixture of sediment of primary sedimentation tanks and excess activated sludge
Praestol 2540	12	4	11	14

Praestol 650 TR	10	3	12	16
Praestol 2530	14	9	15	19
Praestol 853 BC	11	7	10	15

The data presented in Table 1.2 show that the best effect of water recovery is observed when using iron sulfate and Praestol 2530 as reagents in the case of treatment of a mixture of excess activated sludge with a sediment of primary sedimentation tanks heated to 800 C^{o}.

At the same time, it should be noted that the data obtained are well reproduced, which makes it possible to recommend the use of the express method of water withdrawal with the determination of the effect on one sheet of paper according to the version shown in Fig. 1.3, D. Taking into account the experience we have accumulated and the availability of the measurements described above, it can be assumed that the proposed express method will be in demand in the practice of condensation of wastewater sediment.

2. Compaction of wastewater sediment and excess activated sludge

At the initial stage of the development of sewerage and wastewater treatment, the task of sludge treatment was solved with the help of sludge sites, and only then there was a need for a more significant and rapid reduction in the volume of sludge. This led to the creation of sludge treatment technology, the first stage of which is the compaction of the sludge. At the same time, the role of sludge sites has become in most cases a reserve (see Appendix 1).

Compaction of wastewater sediment is the most economical stage of sludge treatment, which can significantly reduce the volume of structures and energy costs in subsequent stages of sludge treatment. In Fig. 2.1. all the main stages of wastewater sludge treatment are shown. It should be emphasized that all subsequent ones depend on the effectiveness of the sealing stage. This stage of processing is associated with the removal of free moisture and is a necessary stage of all technological schemes for the treatment of sediments.

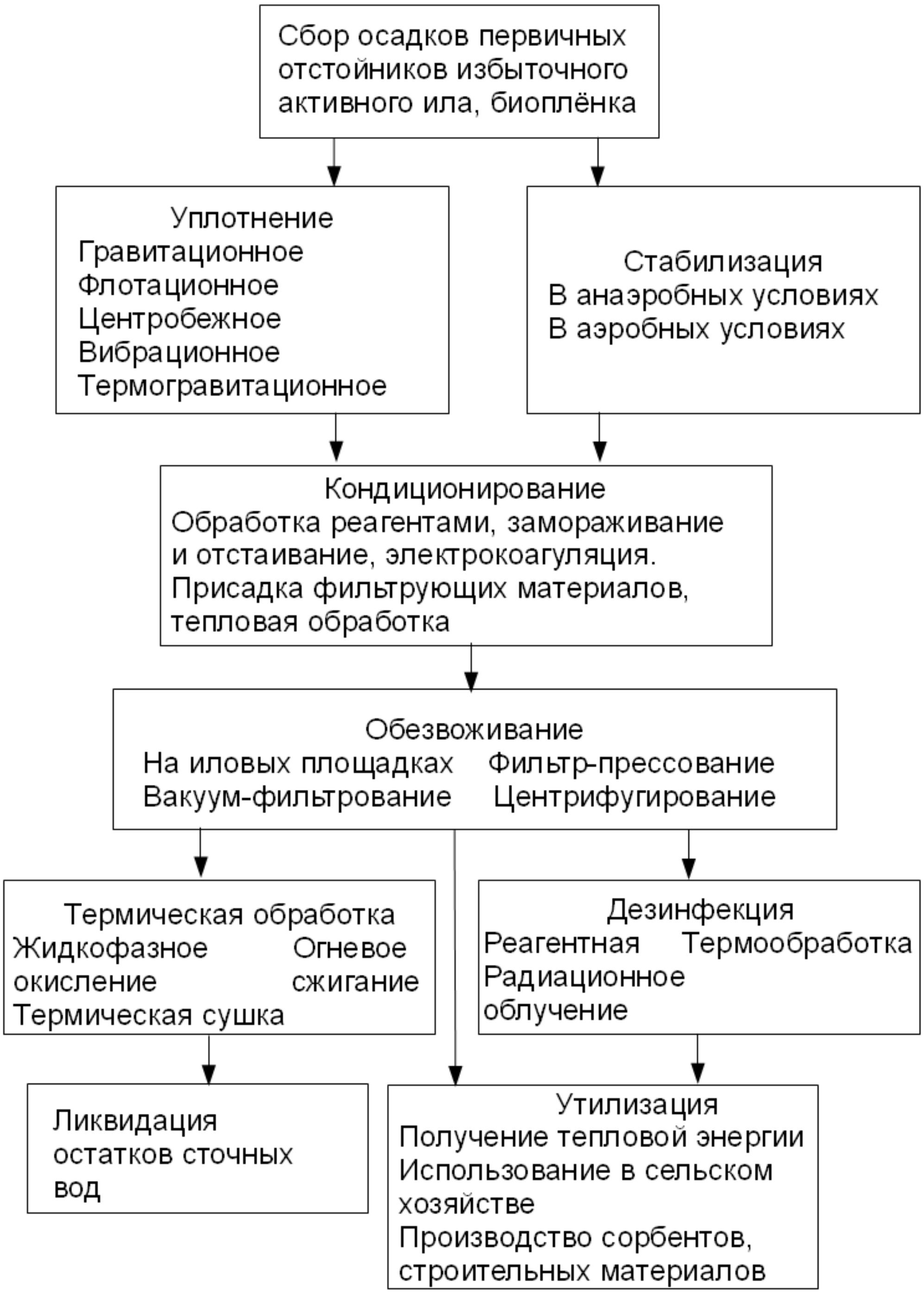


Fig.2.1. Methods used in the treatment, utilization and disposal of wastewater sediment

The most common are gravity and flotation methods of compaction. Gravity sealing is carried out in settling tanks-seals; flotation – in pressure flotation units. Centrifugal compaction of sediment in cyclones is also used. Prospective vibrational compaction by filtering wastewater sludge through filter partitions or by means of precipitated vibrating devices.

The gravity sealing method is the most widespread and is used to compact excess activated sludge and fermented sediments. It is based on the sedimentation of particles of the dispersed phase. Vertical or radial sumps are used as sludge compactors.

The choice of sediment compactor is complicated by the inconstancy of its composition and the relatively low concentration of dry matter. For example, the concentration of the solid phase in the sediments of primary sedimentation tanks varies from about 2 to 5% for absolutely dry matter (ADM), and in the active sludge after secondary sedimentation tanks about 1 - 2.5% of the ADM. These variations, for example, can be due to changes in the composition of wastewater both for a short time (during the day) and seasonal fluctuations. In this regard, it is necessary to take into account possible fluctuations in the composition when choosing a sludge compactor, as well as various other factors affecting the operation of sediment compactors.

2.1. Gravity sludge compactors

It is well known from practice that gravity compaction is the easiest way to reduce the moisture content of wastewater sediment at low energy costs. These undoubted advantages made it possible to widely use this method in the practice of compacting wastewater sediment. Reduction of the volume and humidity of sediment by the gravitational method is achieved by their prolonged settling. In the process of compacting the activated sludge, only free water is removed, and the so-called bound water remains and its removal can be carried out using other methods.

At biological wastewater treatment plants, gravity compaction is used for excess activated sludge, biofilm, biofilter and sediment fermented in methane tanks after washing, as well as for joint compaction of sludge and sediments of primary sedimentation tanks. The duration of compaction depends on the type of sludge and the design of the seal.

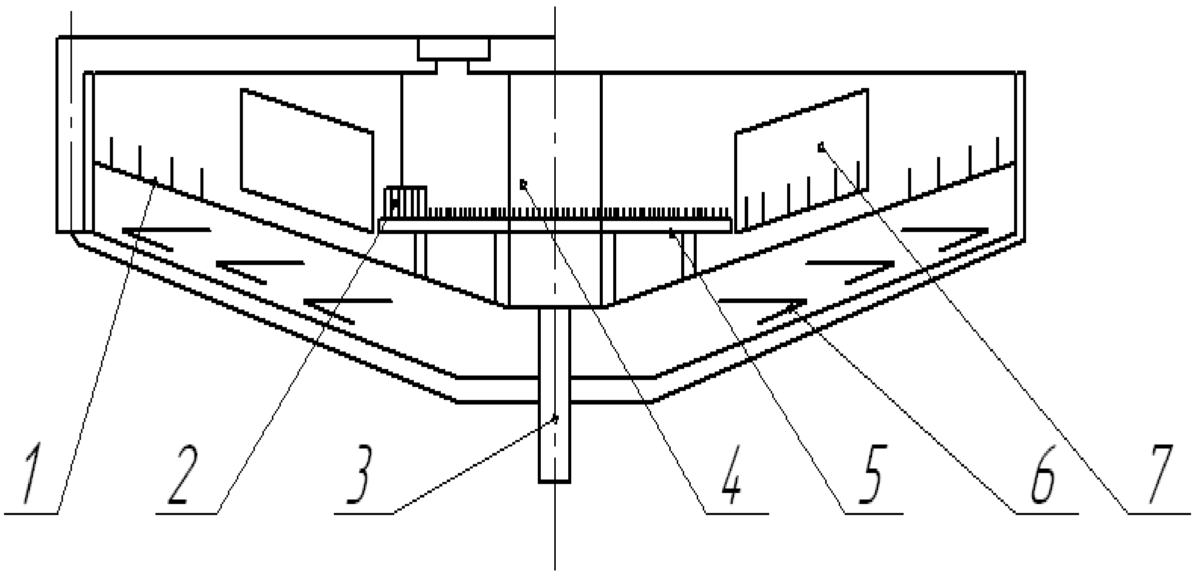
It should be noted that the compaction of activated sludge leads to a marked increase in its specific resistance to filtration and to an increase in the amount of bound water, which does not allow even with an increase in the duration of settling to achieve a further decrease in its humidity.

According to the joint venture "Sewerage. External networks and structures (paragraph 9.2.9.1)

to separate purified water from activated sludge (biofilm), sludge separation facilities should be used: secondary settling tanks, clarifiers with a suspended layer of sediment, flotation plants, membrane modules, etc. To intensify the work of gravity sludge separation structures, the use of thin-layer modules is allowed.The type of secondary sedimentation tank (vertical, radial, horizontal) must be selected taking into account the performance of the station, the layout of structures, the number of operated units, configuration and relief of the site, geological conditions, groundwater level, etc. Structures for compacting sludge in the form of gravity-type sedimentation tanks have not undergone significant changes in recent years.

Typically, the sludge is fed directly into a tank, usually round in shape, equipped with a slowly rotating scraper that breaks the bond between the sediment particles, increasing sedimentation and sludge compaction (Figure 2.2). Design improvements are limited to a variety of attempts to increase the deposition surface while reducing the total area of the settling tank. In such sedimentation plants, closely planted inclinedpipes or parallel disc elements are sometimes used to intensify the process, providing a large deposition surface while reducing the area for particle deposition. Slowly upward flow of wastewater passageit through pipes or between disc elements particles are deposited on the surface and slowly enter the sludge collection bin, while the clarified liquid flows up and is discharged through the drain device.

However, the biomass concentration achieved in such cases in the compacted activated sludge is still insufficient to ensure good dehydration. In subsequent stages, it is necessary to increase the biomass concentration of compacted sludge up to 20% of absolutely dry matter (ADM) or more.



1 - pin agitator; 2 - side drive; 3 - sludge supply pipeline; 4 - intake device: 5 - chain transmission; 6 - scraper mechanism; 7 - shelf blocks.

Fig. 2.2. Rotating shelf sludge compactor of radial type

The radial-type rotary suspension compactorshown in Figure 2.2 is a design in which the shelf blocks 7 and the pin agitator 1 are connected to a single unit with the scraper mechanism 6 and the intake device 4. The rotation of the entire system is carried out by a fixed drive 8 installed on the service platform. In this case, the rotation frequencyis only 0.08 $^{min-1}$. The shelves are located radially at an angle of 60° to the vertical axis of the sludge compactor and are made of sheets of various plastics or laminated plastic, aluminum, steel and other materials. The intake device connected to the sludge supply pipeline 3 is a pipe with cross-sections varying in the depth of the sludge compactor and holes that ensure uniform distribution of the liquid between the thin-layer elements. The chain transmission 5 is at the same time an intermediate mechanism with a large gear ratio to provide a lower rotational speed of the side drive 2 and to obtain the required rotational speed of the ring. The output of the clarified liquid and the compacted activated sludge is carried out as is customary in such cases, respectivelyfrom above and below (not shown in Figure 2.2).

Gravity sludge compactors are used in two designs: vertical and radial.

From vertical sludge compactors, the sediment is removed under a hydrostatic pressure of at least 1.5 m of water column, from radial ones - by sludge pumps operating under the same hydrostatic pressure.

The diameters of vertical seals are recommended to be taken from 4 to 9 m, and radial - 18, 24 and 30 m.

The number of vertical seals is recommended to take up to 4-6. For larger quantities, radial sludge compactors are recommended.

It is established that the degree of sludge compaction depends on the duration of its stay in the compaction zone and the amount of pressure in it. The duration of the sludge stay in the compaction zone is determined by the dry matter load per unit surface of the sludge compactor - the specific surface load measured in kg of dry matter per 1 m2 of the surface of the water mirror per day. The specific surface load for gravity sludge compactors is taken to be in the range of 20-30 kg / m2.day.

At low-capacity stations, vertical sludge compactors are used, which are arranged on the basis of conventional primary vertical settling tanks with a central pipe.

Data for the calculation of sludge compactors should be taken according to Table. 3 SP 32.13330.2012 Sewerage. Outdoor networks and structures. Updated version of SNiP 2.04.03-85 (with Amendment No. 1), according to which the moisture content of the sludge of urban domestic wastewater should be taken equal to 95-96% for all types of primary sedimentation tanks during gravity removal (under hydrostatic pressure) and 94-95% when removed by pumps, and the time interval for periodic removal should be established based on the volume of the sludge formed and the capacity of the zone of its accumulation, but not more than two days. With mechanized sediment removal, the capacity of the zone of its accumulation in the primary sedimentation tanks should be taken according to the amount of sediment for a period of not more than 8 hours.

From the sludge compactors of the vertical type, the sludge is removed by gravity under hydrostatic pressure.

When designing sludge compactors, it is necessary to take:

release of compacted sludge under a hydrostatic head of at least 1 m; sludge pumps or sludge scrapers for sediment removal;

supply of sludge water from seals to aeration tanks;

the number of sludge compactors is at least two, both working.

An example of the calculation of a gravity sludge compactor is presented in Annex 1.

2.2. Intensification of gravitational seal of activated sludge

In some cases, gravity compaction is of little use, and sometimes even unacceptable. The disadvantages of the gravitational seal have led to the search for ways to increase efficiency. In most cases, the following tasks are set:

reduction of the duration of compaction;

obtaining a sediment with lower humidity;

reduction of the amount of suspended solids in the discharged water.

There are three main ways to intensify sediment compaction:

-biological;

-physical;

-chemical.

If the normal mode of cultivation during biological purification is observed, it is possible to ensure that the sludge will have well-defined sedimentation properties. The sedimentation properties of activated sludge are characterized by parameters such as the sludge index and the deposition rate of activated sludge. It is known that the sludge index is equal to the volume in milliliters (or cm3) occupied by 1 g of dry matter of activated sludge after 30 minutes of settling in the cylinder. The sludge index gives information about the flocculation and sedimentation of sludge. The higher the sludge index, the worse the active sludge is deposited and the turnover. At sludge index values of more than 100 cm3 / g, poor sedimentation is observed, and at even higher values, the so-called "swelling" is observed, i.e. practically no sediment of sludge into the precipitate and its presence in a floating state.

Certain conditions of the biological wastewater treatment regime form active sludge and its ability to flocculate, which is one of the most important characteristics of the state of the biocenosis. The structure and biological properties of sludge flakes determine the efficiency and quality of biological treatment, as well as the sedimentation properties of sludge. In normal purification processes, the mass of activated sludge is represented by flakes with an average density of 1.05–1.4 g/cm3 and a size of 50 to 200 µm. Bacterial cells are present not only in the form of flakes, but also in the form of single bactherianot associated with flakes. Bacteria can be represented by rods, cocci, spirochetes and microcolonies from sticks. Active slud bacteria synthesize and secrete an extracellular biopolymer – a polysaccharide gel – into the medium. It is the presence of a gel that causes the aggregation of microorganisms and the formation of flaky clusters - flocules. Active sludge only in a flocculated state can be well separated from purified water.

Under conditions of stable loads on active sludge and in the absence of toxic impurities in wastewater entering for purification, a significant part of the microbial population is in the form of flakes. At the same time, sludge flakes are large, compact, well flocculated. However, in adverse conditions of overloads, including when wastewater containing toxicants is supplied for treatment, and various violations of the technological regime of treatment, the flakes of activated sludge are dispersed up tothe delible cells. This leads to a sharp deterioration in the sedimentation properties of activated sludge and the emergence of problems in separating the activated sludge from the purified water. In this regard, the restoration and maintenance of the normal regime of biological treatment wastewater is a prerequisite for successfully solving the problems of separating activated sludge from purified water.

Increasing the dose of sludge against optimal values can lead to an increased removal of suspended substances from secondary sedimentation tanks. To prevent this from happening, only the amount of sludge that maintains its calculated working dose in the sludge mixture is returned to the aeration tank (Fig. 2.3).

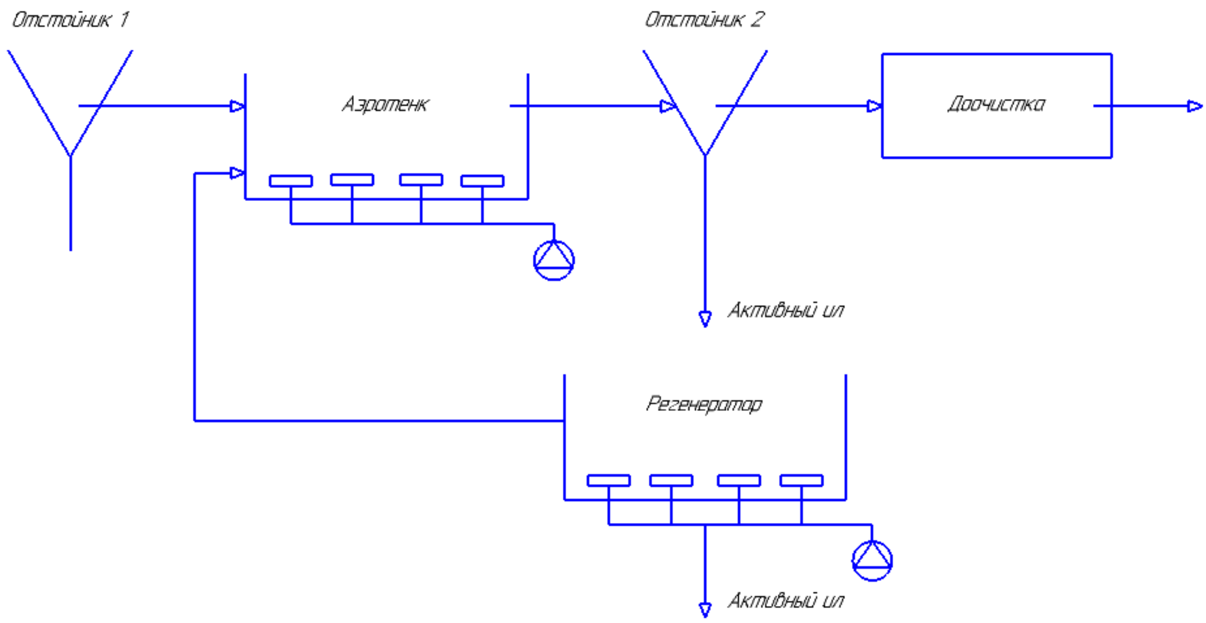


Fig. 2.3. Schematic diagram of biological wastewater treatment

The rest of the sludge in the form of excess, i.e. not required for biological treatment purposes, is removed from the aeration tank -sludge separator system for treatment and elimination. With a balanced mode of biological treatment, problems with the separation of activated sludge from the purified water, as a rule, are not observed.

Among the known physical methods of intensification of the gravitational compaction of activated sludge, it should be noted heating, mixing and degassing of sludge, etc.

Known heating aids are based on the fact that under the influence of temperature, the hydrate shell around the solid particles of sludge is destroyed, and part of the bound water passes into free water and the sludge is rapidly compacted. The optimal heating temperature is $80-90^{0}C$. Thus, the intensification of the gravitational seal of the sludge and in combination with reagents can significantly increase the rate of compaction. This makes it possible to reduce the time of compaction of activated sludge to about 2 - 3 hours.

It should be noted that this method is quite energy-consuming, and in practice is practically not used.

Another method of intensification is to stir the sludge during compaction using various devices, for example, rod agitators. In the process of mixing, gases in the form of bubbles are removed with a certain intensity, with the help of which the flakes of activated sludge are maintained in a suspended state. Removal of gas bubbles from activated sludge flakes contributes to the intensification of the gravitational seal of the activated sludge.

Deeper degassing than with mixing provides a significant intensification of the gravitational seal of the activated sludge. Vacuuming of the sludge suspension for 10-20 seconds allows you to separate the gases accumulated during the aeration process from the cottons of the activated sludge, not only in the form of bubbles, but also partially dissolved gases. Due to this, the cotton acquires a denser structure, the process of sedimentation of suspended substances in the secondary sedimentation tank improves, and the sludge index is reduced by 20-25%.

Such a technological method of biological wastewater treatment consists in degassation of sludge suspension by creating negative pressure.

Before degassing, the aerated mixture is brought into a turbulent state by introducing an additional amount of air into it.

The method of degassing is still at the initial stage of practical development.

To intensify the gravitational seal, reagents can also be used in some cases. During reagent treatment, the process of aggregation of finely dispersed and colloidal particles takes place, which leads to the formation of large flakes with the rupture of solvate shellsand a change in the forms of moisture binding. This leads to an improvement in water-dissipation properties due to a change in the structure of the sediment. However, this method has not yet been widelyused, including for economic reasons.

2.3. Flotation sealing of activated sludge

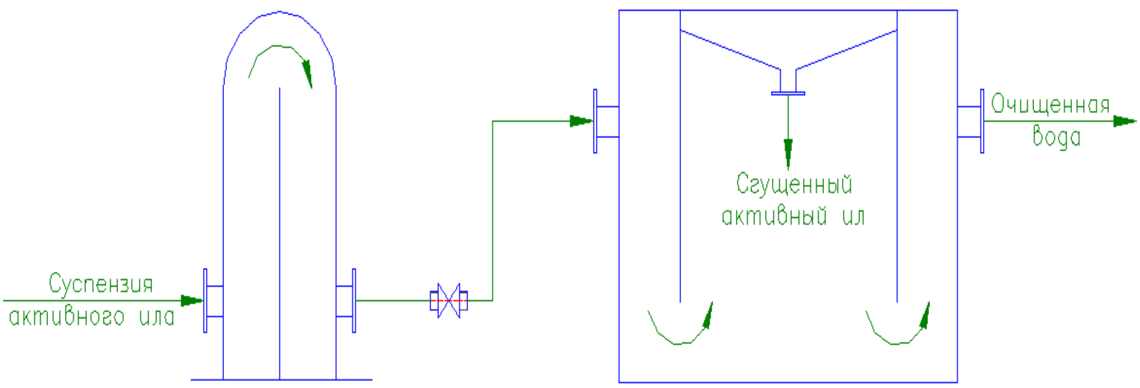
For preliminary thickening of activated sludge, it is advisable to use pressure flotation units or flotation apparatus with a pneumohydraulic aeration system. In some cases, it is possible, for example, to convert a pneumatic flotator into a pressure-type apparatus or to replace a pneumatic aeration system with a pneumohydraulic one. To do this, first of all, it is necessary to equip it with an air saturation system, for example, a saturator, or to supply air at a pressure of 0.5 - 1.0 MPa to the pipeline to supply the initial suspension of activated sludge.

Technological schemes of saturation of the suspension of activated sludge with a saturator and without a saturator (in the pipeline) have their own certain advantages and disadvantages. The advantage of the scheme with a saturator is that excess air is released in the saturator, and not in the flotator, as in the case of a scheme without a saturator. In addition, in the saturator, air dissolves more in the liquid, since the excess pressure and the residence time of the sludge in the saturator allow, as a rule, to carry out this process in an optimal mode. The disadvantages of the scheme with a saturator include a certain severity of the requirements for its manufacture, as well as control over the acceptance and further operation of the saturator in the scheme of flotation thickening of activated sludge. All this to a certain extent complicates both the manufacture of the flotation plant as a whole and its operation.

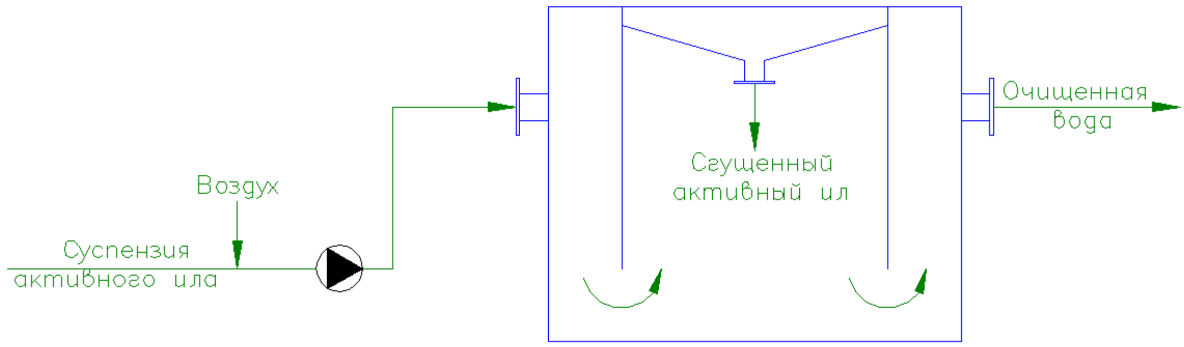
The scheme of operation of the flotator without a saturator includes the supply of air under pressure to the pipeline in front of the pump (Fig. 3, option b). In this case, there is no need to manufacture a saturator, which is the undoubted advantage of this scheme. However, excess air that has not dissolved in the liquid phase, sucked in by an ejector or directly supplied from the compressor, is removed from the suspension in the flotator itself, usually in the form of large bubbles, which worsens the flotation process of active sludge flakes. In this case, it is advisable to use special pumps to supply the sludge sludge or to create conditions under which the dissolution of air in the sludge will occur at a high rate. This will increase the specific amount of air dissolved in the liquid phase and avoid the negative impact of the release of excess air in the form of large bubbles.

Analysis of the above methods of saturation of the suspension of activated sludge with air and the results of experimental studies indicate that none of the described schemes gives a significant advantage (Fig. 1). However, in the case of a complete set of flotation equipment, preference should be given to a scheme with a saturator. In this case, the issue of removing undissolved air is solved. When air is supplied to the saturator, the operation of the pumps occurs without disruption. In the case of ejection of air into the sludge of activated sludge in front of the pump, the efficiency of the latter is reduced.

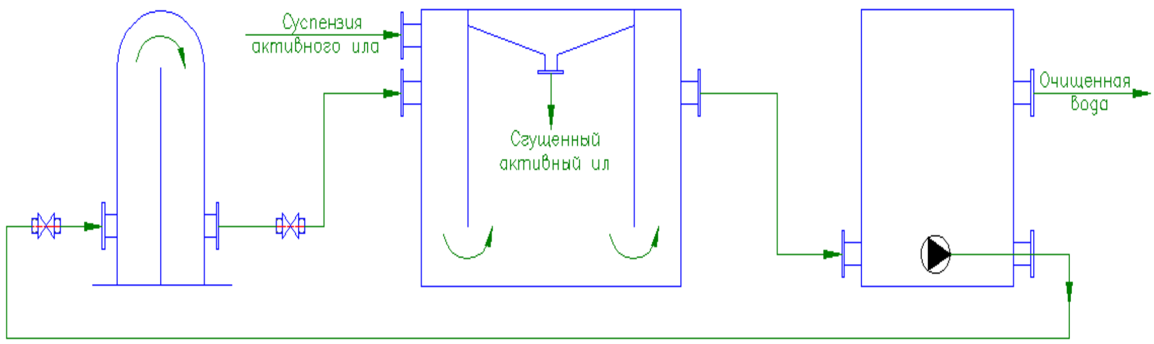
All shown in Fig. 7 variants of flotation thickening of the sludge sludge are carried out in practice, and the choice of one or another method depends on the specific conditions and tasks to be solved. In the case when, after flotation thickening, the sludge of activated sludge is fed to the filter press for dehydration to a residual humidity of about 60-70%, option "b", Fig. 2.4.



a)



b)



c)

Fig. 2.4. Technological schemes of flotation thickening of activated sludge suspension:

a) – pressure version (with a saturator) without working fluid,

b) – without a saturator using a pneumohydraulic aeration system;

(c) - pressure version (with a saturator) with a working fluid.

When sludge is applied to the filter press, the change in the concentration of activated sludge in the foam product in the range of about 3-5% is not of great importance, although the flow rate of sludge supplied to the filter press will change. However, with sufficient filter press performance, this will not lead to additional problems.

In the case of large costs of sludge suspension, this can lead to additional material costs that need to be taken into account.

The effect of the method of air saturation of the suspension of activated sludge on its concentration in the foam product after flotation is presented in Fig. 2.5 These average data indicate some advantage of the method of saturation of the suspension of activated sludge with a saturator.

The intensification of the flotation thickening process of the suspension depends on the pre-treatment of the activated sludge with chemical reagents, as well as on various physical effects, in particular, heating.

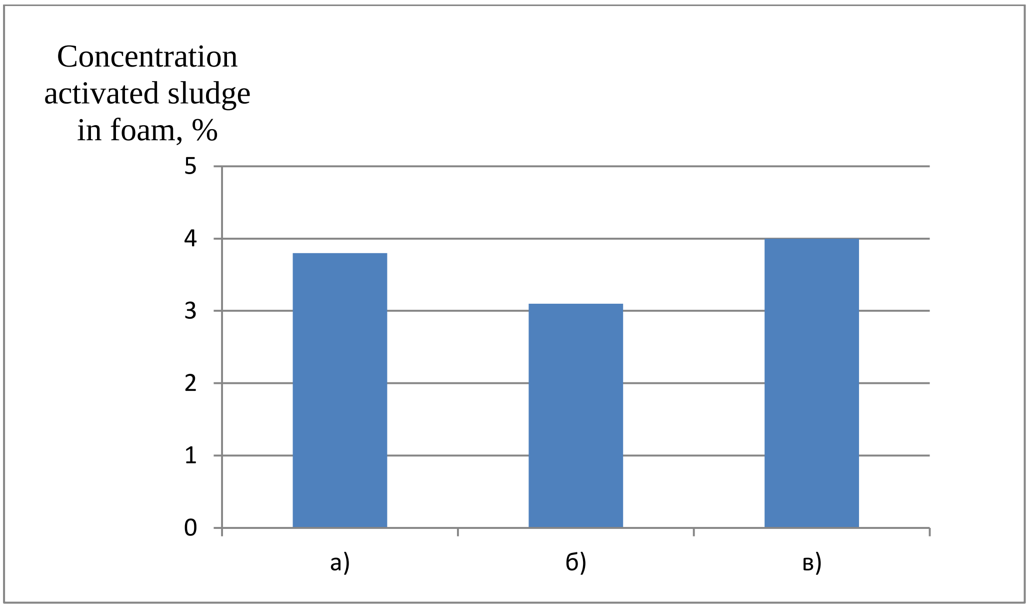


Fig. 2.5. Average values of the concentration of activated sludge in the foam product after flotation thickening depending on the method of air saturation of the initial suspension of activated sludge (variants: a, b, c – see Fig. 2.4)

During the physicochemical treatment of a suspension of activated sludge, for example, during heating or alkalization, the processes of aggregation of microorganisms occur, in particular, under the action of polysaccharides released during such treatment. With an increase in pH to 8.5, the concentration of polysaccharides increases by about 3-5 times and at the same time the effect of aggregation is visually observed. The data obtained indicate the feasibility of such treatment as one of the methods of intensification of flotation thickening of activated sludge.

Another, quite effective, method of intensification is the pre-treatment of the suspension of activated sludge with reagents, in particular industrial cationic flocculants of the Praestol brand.

In the practice of flotation thickening of activated sludge, flotation apparatus with a pneumohydraulic aeration system can also be used and cationic flocculants, for example, Praestol 852, can be added to intensify this process.

In recent years, complex reagents consisting of polymeric flocculants and inorganic electrolytes have been increasingly used for wastewater treatment of various compositions. The results of experimental studies have shown that in all cases of the use of complex flocculation additives, both synergistic and antagonistic effects are observed. The selection of the most effective reagent is carried out using a well-known method of trial coagulation.

The efficiency of flotation compaction of activated sludge is also increased by the use of combined flotation tanks.

As an example of sedimentation tanks of the combined type, we present the schemes of flotation settling tanks developed by us and used in the practice of water purification (Fig. 2.6 - 2.8).

The flotation settling tank with sequentially installed settling and flotation chambers consists of a body 1, on the outside of which there are dirty water supply pipes 3, a reagent solution 4, a flotation sludge branch pipe 8, purified water 9, wastewater sediment 12, 16 installed on conical sludge collection bins and a tubular aerator 14 with a branch pipe 15 for supplying the working fluid in the form of a mixture of water and air.

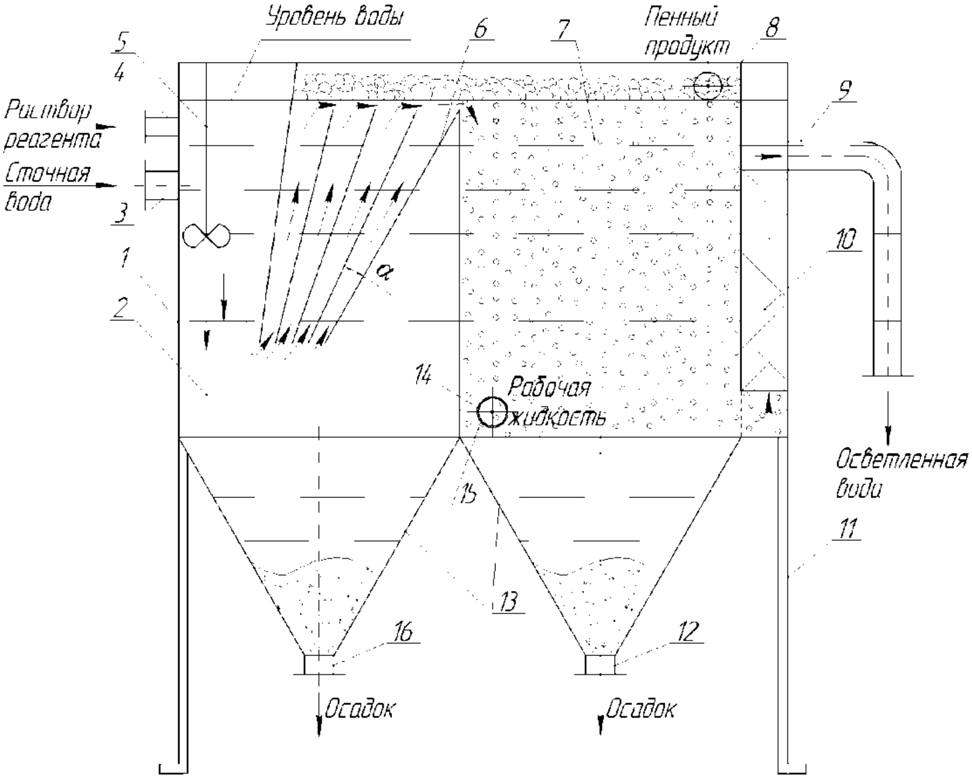


Fig. 2.6. Flotation settling tank with sequentially arranged settling and flotation chambers

Inside the housing 1, in particular in the settling chamber 2, a stirrer in the form of a stirrer 5 and a thin-layer clarification unit 6 consisting of a package of plates inclined to each other at an angle of α of from 3 to 300 are arranged in series, depending on the quality of the clarified water. In this case, the plates can be made of a wavy material with a wavelength and height, respectively, of 10 ... 30 cm and 1 - 5 cm Inside the flotation chamber, in its lower part, there is a tubular aerator 14, and in the middle part - filter 10, made of porous fibrous material with pore sizes of 1 ... 100 µm.

At the bottom, the hull 1 of the flotation sump rests on support struts 11.

As a result of wastewater treatment in the proposed sedimentation tank, the degree of pollution recovery reaches 90 – 99% and the specific hydraulic load is 9... 11 m3/m2·h.

It is possible to perform a flotation settling tank, in which water enters first the flotation chamber, and then into the settling chamber (Fig. 2.7).

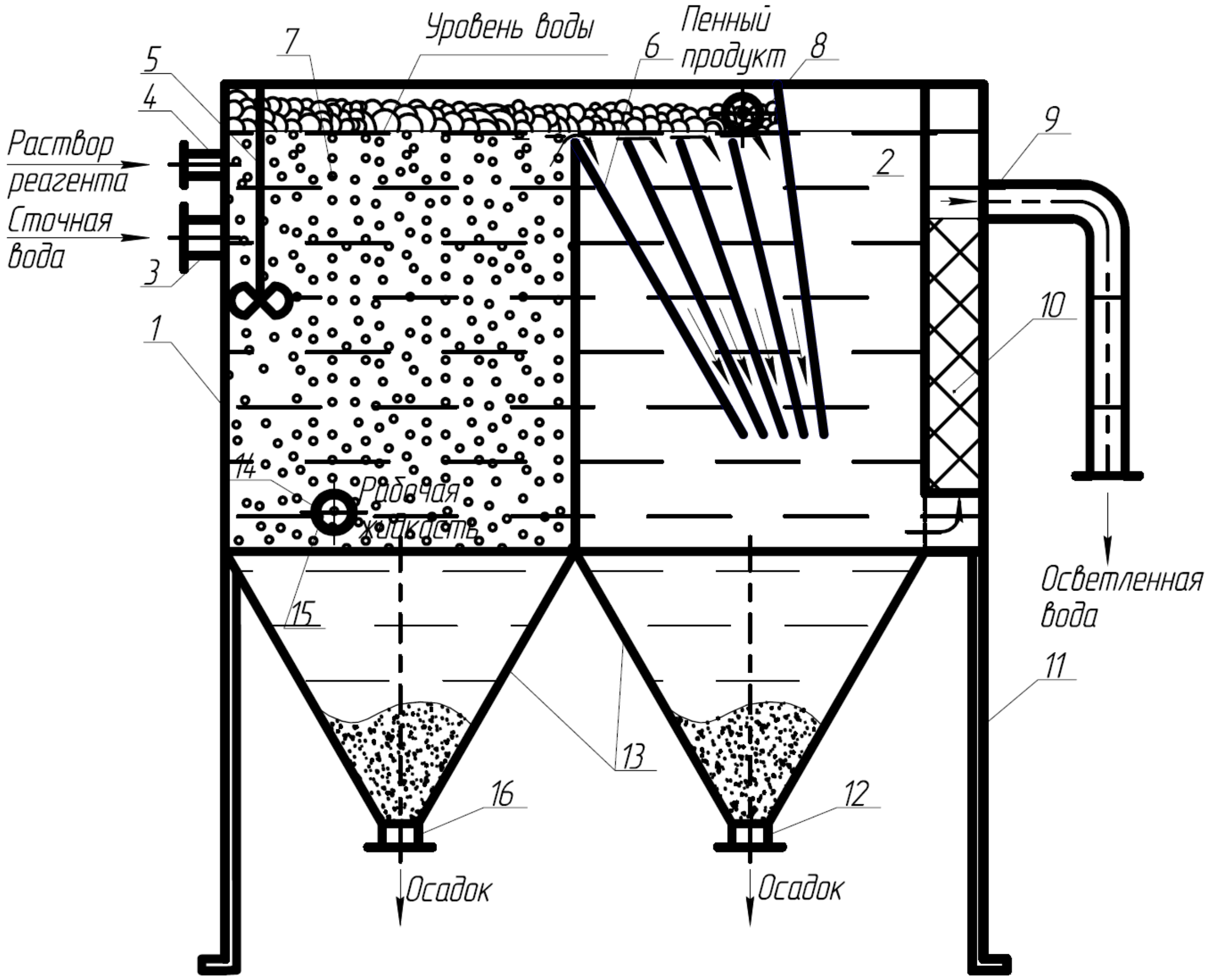


Fig. 2.7. Flotation settling tank with successive flotation and settling chambers

A feature of the flotation settling tank of the column type (Fig. 1.20) is the simultaneous implementation of the processes of settling in chamber 2 and flotation in chamber 7. In this case, the duration of the resulting process is controlled by the limiting stage of cleaning, which is determined as a result of preliminary tests.

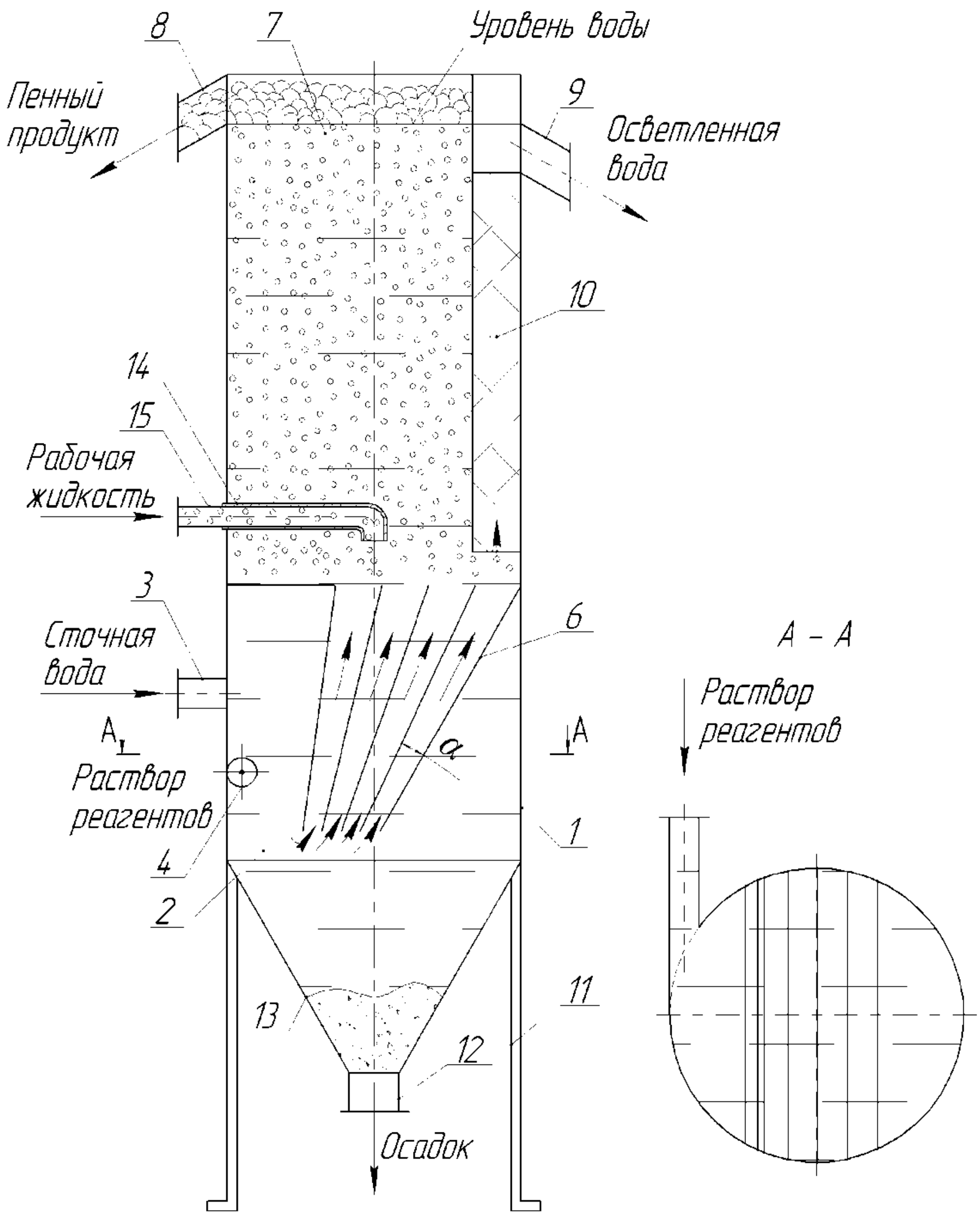


Fig. 2.8. Column-type flotation settling tank

In general, it should be noted that, flotation settling tanks allow for deeper wastewater treatment, in particular, to increase the degree of pollution recovery by about 10 - 15% and to increase the specific hydraulic load by 20... 25% compared to the corresponding analogues.

To determine the basic dimensions of a flotation sludge compactor, an example of its calculation is given in Annex 1. For the flow rate of sludge of 100 cubic meters. m

/ h, the main parameters will be: L = 12600 mm - the length of the flotation part, L1 = 15600 mm - overall size in length, H = 2500 mm - the height of the device, B = 4200 mm - the width of the device. Taking into account the features of a particular placement site, it is possible to make a flotation sludge compactor two- or three-section.

2.4. Intensification of flotation sealing of activated sludge

It is possible to intensify the process with pressure flotation using various methods. For example, by using reagent treatment. Using coagulants and flocculants, as well as various surfactants, it is possible to increase the size of the units, increase their hydrophobicity. The disadvantages of reagent treatment include an additional consumption of reagents, an increase in the amount of foam, which entails difficulties in dehydration and disposal of sediments.

An important issue in the process of pressure flotation is the coalescence of the bubbles. Since a small radius bubble is formed first, flotation is very slow. This entails, in some cases, the carry-away of flotation complexes of bubbles - flakes of activated sludge with purified water and, accordingly, a decrease in the efficiency of the flotation process.

This problem can be partially solved by structural methods, for example, by installing a thin-layer sedimentation unit or filter at the stage of post-cleaning, which was first proposed by the author at the end of the twentieth century. It is also possible to aerate the separated medium with gas bubbles of a larger size (Deryagin B.V., Dukhin S.S., Rulev N.N. Microflotation. Microflotation: Water Purification, Enrichment.

M.: Chemistry, 1986. – P. 56). But with this method, the destruction of fleet complexes occurs due to the creation of a high-speed gradient by a large bubble.

The greatest efficiency in coalescence during pressure flotation was achieved under conditions when small and large bubbles are formed directly in the liquid phase. These conditions are possible, for example, when using two working fluids with gases of different solubility.

This idea was first expressed and experimentally confirmed by B.S. Ksenofontov (Ksenofontov B.S. Wastewater Treatment: Flotation and Condensation of Sediments. M.: Chemistry, 1992. – 144 p.; patent of the Russian Federation 2108974, 1996 Author Ksenofontov B.S.), and later studied by A.S. Kozodaev in a dissertation (2009), carried out under the guidance of the author.

With the introduction of one working fluid saturated with air, a bubble with an average size of about 0.01-0.05 mm is formed. The lifting rate of such flotation units is 0.13-0.26 mm / s. When adding a second working fluid saturated with carbon dioxide, an aggregate complex is formed - an air bubble (insoluble gas) - a vial of carbon dioxide (easily soluble gas). And at the same time, a bubble of carbon dioxide coalesces with an air bubble.

With this method of flotation, the transition of fleetable particles of contaminants into foam occurs 2-2.5 times faster. Thus, the dimensions of flotation apparatus are reduced by about 1.5 -2.0 times. In practice, this process can be carried out by introducing a second working fluid in the form of a saturated solution of carbon dioxide.

The mechanism of release of the gas phase in this case is as follows. Since a hard-to-dissolve gas – air – is first released from the liquid medium, its bubbles are the centers of the origin of a new gaseous phase – an easily soluble gas. The release of an easily soluble gas from a solution is slower than air, and therefore takes longer, but the increase in gas bubbles occurs smoothly, and their strength is not disturbed. As a result, a flotation complex is formed, which is a particle of pollution, in the volume and on the surface of which there are gas bubbles with dimensions of about 1 -2 mm. This leads to an accelerated rise of the resulting fleet complexes and, in general, the intensification of the flotation process using two working fluids.

Flotation extraction of activated sludge flakes can be described using Ksenofontov's multi-stage model of the flotation process. According to this model, the flotation extraction process includes three states: A, B, C (see Figure 9).

State A - the flakes of activated sludge and bubbles in the volume of the liquid are not connected and do not contact (initial state). In the first stage, cotton contacts the gas bubble. In the process of adhesion, a flotological complex of cotton of activated sludge is formed - a gas bubble (state B), which floats due to Archimedean forces. Flotocomplexes that have floated into the upper part of the liquid form a foam layer (state C). At the same time, transitions are possible not only from state A to state B and further to state C, but also reverse transitions, respectively, from state C to state B and further to state A. Possible transitions from one state to another are presented in Figure 2.9.

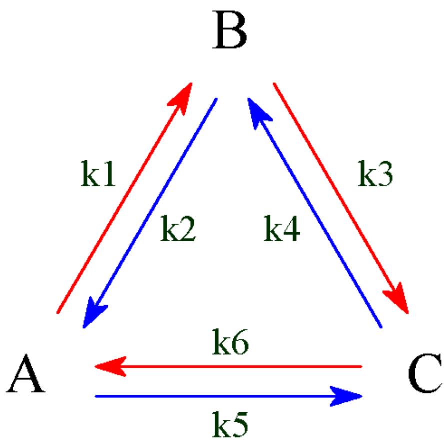


Fig. 2.9. Multi-stage model of Ksenofontov's flotation process

Such a process can be described by the following system of equations:

$$\begin{cases} \frac{dC_A}{dt} = -k_1 C_A + k_2 C_B - k_5 C_C + k_6 C_A \\ \frac{dC_B}{dt} = k_1 C_A - k_2 C_B - k_3 C_B + k_4 C_C \\ \frac{dC_C}{dt} = k_3 C_B - k_4 C_C + k_5 C_A - k_6 C_C \end{cases}$$

where CA, SV, SS are the concentrations of activated sludge, respectively, in states A, B, C;

k1, k2 are the constants of the rate of transition from state A to state B and vice versa;

k3, k4 are the constants of the rate of transition from state B to state C and vice versa;

k5, k6 are the constants of the rate of transition from state C to state A and vice versa.

The solution of the above system of equations leads to a fairly satisfactory consistency with the experimental data when using two working fluids.

Flotation technology used to thicken activated sludge is constantly being improved both in the combination of functions and in the way of increasing the degree of thickening of activated sludge and water purification. In this regard, the flotation combine for wastewater treatment developed by us corresponds to both directions of improving flotation technology and at the same time is a high-level development, which confirmed the great interest shown in this device at various exhibition events, as well as in its practical use.

Usually, the flotation combine includes a hull (Fig. 2.1 (0), on the outside of which there are nozzles for the supply of dirty water, reagents, working fluid (water with air bubbles) and branch pipes for the removal of sediment, flotation sludge and purified water. The working space inside the building is divided into zones of air conditioning (1), settling (11), coalescence of microflot complexes (111), direct flotation (1Y).

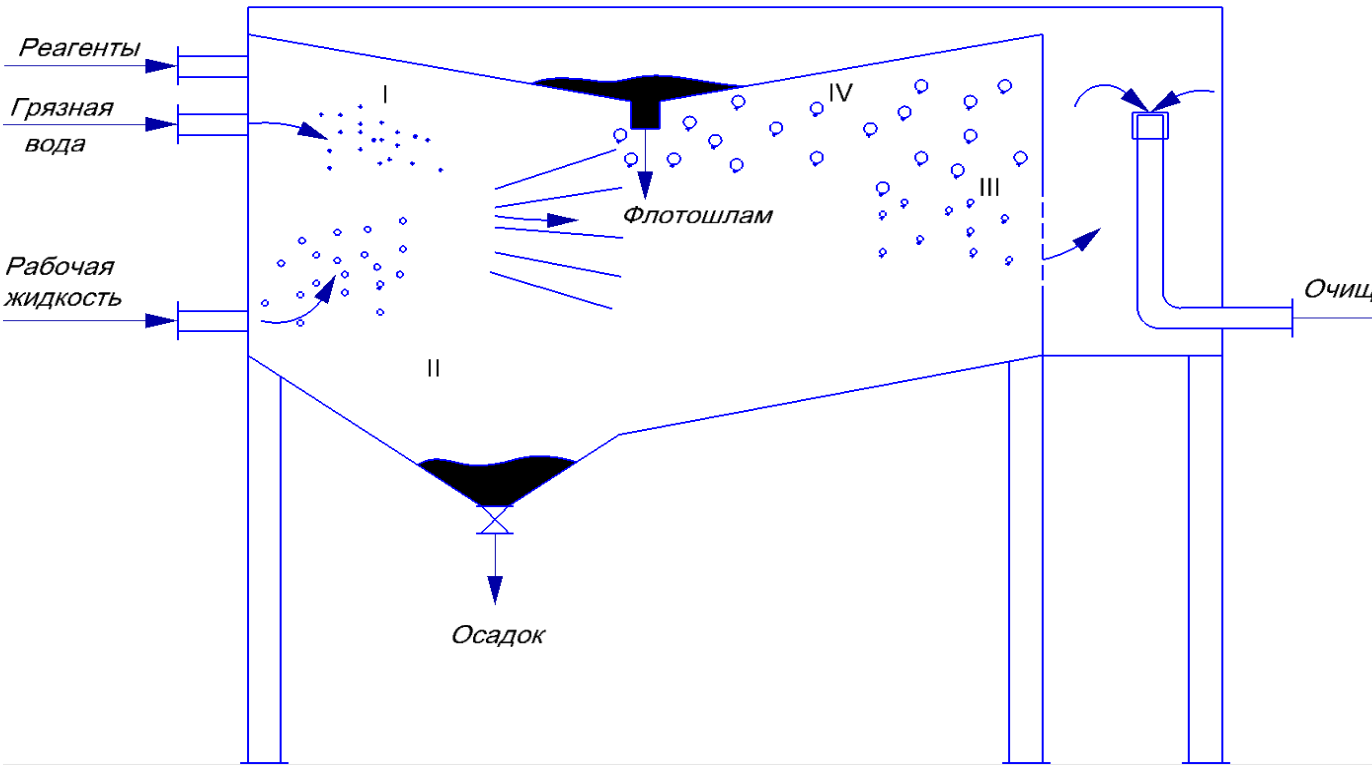


Fig. 2.1 0. Schematic diagram of the flotation combine

The principle of operation of the flotation combine is as follows. At the stage of conditioning, the formation of particle-bubble flotation complexes (zone 1) occurs. At the same time, as a rule, not all pollution particles stick together with air bubbles and remain in a single state or in the form of aggregates precipitate (zone 11).

Particles stuck together with small bubbles form microflotocomplexes (zone 1), which slowly float and, in this connection, they are carried away by a stream of purified liquid moving in a horizontal direction. Such microflotocomplexes, reaching the mesh partition, contact each other with the formation, as a rule, of larger bubbles (zone 111), which quickly surface, forming a flotation slate (flotation zone 1Y). Purified water passing through the mesh partition is removed using a special device and then removed from the flotation combine through the outlet pipe.

The effect of water purification in this case significantly exceeds the results achieved on analog installations.

Schematically, the processes occurring in the flotation combine can be considered using the functional scheme presented in Fig. 2.

Additionally, a mixing device can be installed in the settling chamber to contact dirty water with a solution of the reagent and then flotation, settling, filtration and other related operations can occur that contribute to improving the efficiency of cleaning and thickening the resulting sludge (Fig. 2.11).

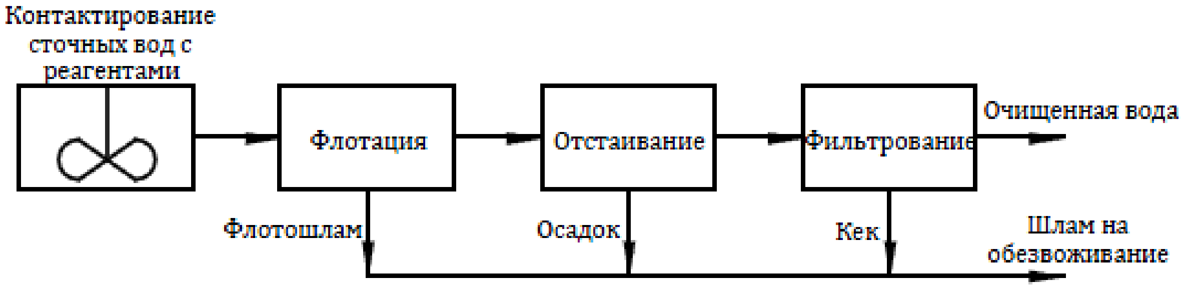


Fig. 2. 11. Functional scheme of water purification in the flotation combine

If necessary, the intensification of the process can be achieved by using additional units, for example, by installing special blocks, etc. In some cases, the cleaning efficiency from the use of these additional units can be increased to about 40 - 50%.

Further development of flotation technology has led to the expediency of using flotation combines, in which, along with wastewater treatment, the processes of condensation of the foam product and the resulting sediments are simultaneously carried out. Consider the main stages of the processes occurring in the workspace of the flotation combine. The scheme of the flotation combine developed byus is presented in Fig. 2.12.

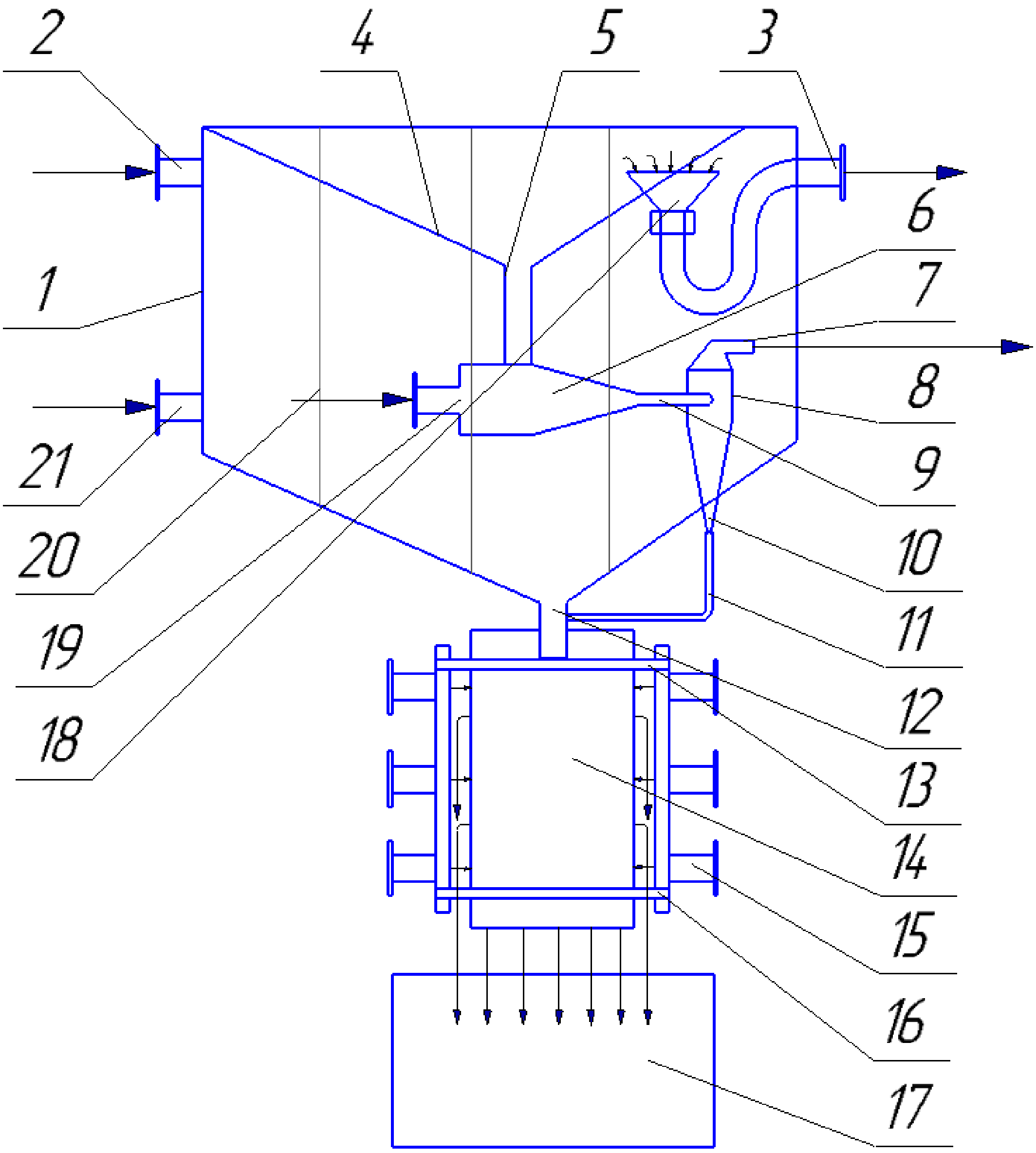


Fig. 2.12. Flotation combain scheme

(author's development, RF patent for utility model No. 172180)

The flotation combine includes a housing 1, on the outside of which there are branch pipes for supplying wastewater 2, draining wastewater 3, removing the foam product 5, ejector 19 with the outlet pipe of the flotation sludge 9, hydrocyclone 8 with the outlet pipe of the condensed product 10 and the outlet pipe of the liquid phase 7, the outlet of the condensed flotation sludge 11, the clarified liquid 6, the output of the sediment 12, the supply of the working fluid 21, with an additionally mounted on the outside sediment dewatering unit 13 consisting of an internal chamber 14 and external control devices 15, a crimping clamp 16 and a leachate collection tray 17. In this case, inside the flotation combine there are perforated partitions 20 and a device for regulating purified water 18.

The principle of operation of the flotation combine is as follows. The original wastewater enters the housing 1 of the flotation combine through the nozzle 2, where it is mixed with the working fluid entering through the branch pipe 21. As a result of mixing these flows, the formation of flotation complexes of pollution particles occurs - gas bubbles contained in the working fluid. The resulting flotation complexes with large bubbles of the order of 1 mm or more quickly float into the foam layer, and flotation complexes with a smaller size of gas bubbles, called microflotocomplexes, are carried away by the flow of the purified liquid, which is further filtered through the perforated partitions 20. When passing through perforations, microflotocomplexes coalesce, combining into larger flotation complexes, and then float into a foam layer, which is collected in the foam trough 4 and then discharged through the branch pipe 5. After that, the flotation sludge is absorbed into the ejector 19, where, under the action of compressed air, the foam product is destroyed and converted into a liquid containing the initial contaminants. After the ejector, the liquid is sent to the hydrocyclone 8, where it is separated into a condensed concentrate and a purified liquid. Further, the condensed concentrate enters the inner space 14 of block 13, in which a bag of synthetic fabric is placed. Under the influence of external forces from the control devices 15, dewatering of the sludge in the bag occurs. In this case, the leachate is squeezed from the sediment, which is collected in the pallet 17, and the dehydrated sediment is removed along with the bag.

Pure water is discharged from the working space of the housing 1 by means of the device 18 and the branch pipe 6.

It should be noted that with the use of a flocombine, it is possible to obtain a sufficiently high degree of clarification of the purified water, which in some cases exceeds in some cases by 20-25% the same indicator using known analogue devices. In addition, in this case, a precipitate is obtained, dehydrated to a residual moisture content of 85-90%.

The assessment of the processes taking place in the flotation combine will be carried out in stages.

After the flow of wastewater and working fluid into the working space of the flotation combine, the formation of particle-bubble flotation complexes occurs. At the same time, as a rule, not all particles of pollutants stick together with air bubbles and remaining in a single state or in the form of aggregates precipitate.

Particles stuck together with small bubbles form microflotocomplexes that slowly float and in this connection they are carried away by the flow of the purified liquid moving in a horizontal direction. Such microflotocomplexes, reaching the reticulate septum, come into contact with each other with the formation, as a rule, of larger vesicles, which quickly surface, forming a flotilla. The purified water, passing through the mesh partition, is withdrawn using a special device and then removed from the flotation combine through the outlet pipe. The effect of water purification in this case significantly exceeds the results achieved on analog installations. Consider the process diagrams in the flotation combine of the above type.

Let's denote the concentration of contaminants in water in the form of C, where part of the contaminants that have hydrophobic properties is C1, and the other part in the form of C2 is hydrophilic pollution.

Herewith

C = C1 + C2

Let the flotation extraction process proceed according to the following scheme:

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C \xrightarrow{k_3} X$$

For the initial conditions: t = 0, C1A = a0, C1B = C1C = C1X = 0.

Kinetic equations are:

$$\frac{dC_{\mathrm{A}}^{1}}{dt} = -k_1 C_A^1$$

$$\frac{dC_B^1}{dt} = k_1 C_A^1 - k_2 C_B^1$$

$$\frac{dC_C^1}{dt} = k_2 C_B^1 - k_3 C_C^1$$

$$\frac{dC_X^1}{dt} = -k_3 C_C^1$$

Constants k1... k3 is characterized by the rates of transition of extracted hydrophobic particles from state A to B, C and X to obtain condensed flotation sludge.

Decision:

$$C_A^1 = a_0 e^{(-k_1 t)}$$

$$C_B = \frac{a_0 k_1}{k_2 - k_1}\left[e^{(-k_1 t)} - e^{(-k_2 t)}\right]$$

$$C_C^1 = k_1 k_2 a_0 \left(\frac{e^{(-k_1 t)}}{k_3 - k_1} + \frac{e^{(-k_2 t)}}{(k_2 - k_1)(k_2 - k_3)} + \frac{e^{(-k_3 t)}}{(k_3 - k_1)(k_3 - k_2)}\right)$$

$$C_X^1 = a_0 \left(1 - \frac{k_2 k_3 e^{(-k_1 t)}}{(k_2 - k_1)(k_3 - k_1)} - \frac{k_1 k_3 e^{(-k_2 t)}}{(k_2 - k_1)(k_2 - k_3)} - \frac{k_1 k_2 e^{(-k_3 t)}}{(k_3 - k_1)(k_3 - k_2)}\right)$$

For the accompanying settling process we have:

$$A \xrightarrow{k_4} D \xrightarrow{k_5} Y$$

with initial conditions: $t = 0$, $C^2_A = b_0$, $C^2_D = C^2_Y = 0$.

the following kinetic equations can be written:

$$\frac{dC_A^2}{dt} = -k_4 C_A^2$$

$$\frac{dC_D^2}{dt} = k_4 C_A^2 - k_5 C_D^2$$

Here the constants $k_4 ... k_5$ characterize the rates of transition of extracted hydrophilic particles from state A to D and Y to obtain condensed precipitate.

Decision:

$$C_A^2 = b_0 e^{(-k_4 t)}$$

$$C_D^2 = \frac{k_4 C_A^2}{k_5 - k_4}\left[e^{(-k_4 t)} - e^{(-k_5 t)}\right]$$

At

$$t = t_m = \frac{1}{k_5 - k_4} ln \frac{k_5}{k_4}$$

the concentration of the intermediate product reaches a maximum:

$$C_{Bmax}^{2} = b_0 \left(\frac{k_5}{k_4}\right)^{\frac{k_5}{k_4-k_5}}$$

Concentration of the final product:

$$C_Y^2 = b_0\left(1 - \frac{k_5}{k_5 - k_4} e^{(-k_4 t)} + \frac{k_4}{k_5 - k_4} e^{(-k_5 t)}\right)$$

Comparison of theoretical and experimental data indicates the possibility of using the proposed mathematical models in practical calculations. It should be noted that the theoretical data exceed the experimental results. This indicates that some assumptions are simplified and do not take into account individual phenomena, although they do not seem to have a significant impact on the efficiency of cleaning, since the discrepancy does not exceed 10%. The order of such a discrepancy does not significantly affect the calculations of the main overall dimensions of the flotation combine.

For more accurate calculations, more complex models can be used.

Consider the so-called competing processes in which one substance interacts in parallel with several reactants (e.g., coagulant and flocculant), which thus compete with each other. For example, coagulant B selectively acts on pollution that is in state A and that can go into state X or Y.

$$A \xrightarrow{k_1} X \quad A + B \xrightarrow{k_2} Y$$

Kinetic equation:

$$\frac{dC_X}{dC_Y} = \frac{k_1}{k_2(b_0 - C_Y)}.$$

For initial conditions: t = 0, concentration of initial contaminants in state A

CA = a0,

and in other states:

CB = b0, CX = CY = 0 decision:

$$C_X = \frac{k_1}{k_2}(\ln b_0 - \ln(b_0 - C_Y));$$

$$C_A = a_0 - C_X;$$

$$C_B = b_0 - C_Y.$$

$A + B \xrightarrow{k_1} X \; A + C \xrightarrow{k_2} Y$ (substance A interacts with coagulant B and flocculant C)

Kinetic equation:

$$\frac{dC_X}{dC_Y} = \frac{k_1(b_0 - C_X)}{k_2(C_0 - C_Y)}.$$

For initial conditions: t = 0, CA = a0, CB = b0, CC = c0 solution:

$$\ln\frac{b_0}{b - C_X} = \frac{k_1}{k_2}\ln\frac{c_0}{c_0 - C_Y}$$

or

$$\frac{k_1}{k_2} = \ln\frac{b_0(c_0 - C_Y)}{c_0(b_0 - C_X)};$$

$$C_A = a_0 - C_X - C_Y; \; C_B = b_0 - C_X; \; C_C = c_0 - C_Y.$$

In successive processes, a product of one stage moves to the next stage.

Sequential processes can contain from two to several thousand stages.

For example, a simple case of a multi-stage flotation model.

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$

For the initial conditions: t = 0, CA = a0, CB = CC = 0.

Kinetic equations:

$$\frac{dC_A}{dt} = -k_1 C_A;$$

$$\frac{dC_B}{dt} = k_1 C_A - k_2 C_B.$$

Solution: CA = a0 exp(–k1 t),

$$C_B = \frac{k_1 C_A}{k_2 - k_1}\left[\exp(-k_1 t) - \exp(-k_2 t)\right].$$

When the concentration of the intermediate product reaches a maximum:

$$t = t_m = \frac{1}{k_2 - k_1}\ln\frac{k_2}{k_1}$$

$$C_{B\max} = a_0\left(\frac{k_2}{k_1}\right)^{\frac{k_2}{k_1 - k_2}}.$$

Concentration of the final product:

$$C_C = a_0\left(1 - \frac{k_2}{k_2 - k_1}\exp(-k_1 t) + \frac{k_1}{k_2 - k_1}\exp(-k_2 t)\right).$$

Consider the case of the model of formation of megaaeroflocules in the process of flotation of activated sludge.

$$A \xrightarrow{k_1} P_1 \xrightarrow{k_2} P_2 \cdots P_n \xrightarrow{k_{n+1}} X$$

For initial conditions t = 0, $C_A = a_0$, the solution for intermediate products:

$$C_{P_1} = C_{P_2} = \cdots = C_{P_n} = 0$$

$$C_{P_i} = a_0 \prod_{j=1}^{i} k_j \sum_{j=1}^{i+1} \frac{\exp(-k_j t)}{\prod_{m=1}^{i+1}(k_m - k_j)},$$

Where is m = j.

Of great interest is the case of conditioning wastewater using a reagent - collector B, interacting with the initial pollution A. At the same time, P is the state of the flotation complex, the particle is a gas bubble, and D is the state in the foam layer.

$$A + B \xrightarrow{k_1} P \xrightarrow{k_2} D$$

For initial conditions: t = 0, $C_A = a_0$, $C_B = b_0$, $C_P = C_D = c_0$.

Kinetic equations:

$$\frac{dC_A}{dt} = \frac{dC_B}{dt} = -k_1 C_A C_B;$$

$$\frac{dC_P}{dt} = k_1 C_A C_B - k C_P.$$

Decision:

$$C_A = a_0 \frac{b_0 - a_0}{b_0 \exp\left[k_1 (b_0 - a_0) t\right] - a_0};$$

$$C_B = b_0 - (a_0 - C_A);$$

$$C_P = -\frac{a_0}{1 + a_0 k_1 t} + b_0 \exp(-k_2 t) + \frac{k_2}{k_1} \exp\left[-\left(k_1^{-1} k_2 a_0^{-1} + k_2 t\right)\right] \times$$
$$\times \left[l_i \exp\left(k_1^{-1} k_2 a_0^{-1} + k_2 t\right) - l_i \exp\left(k_1^{-1} k_2 a_0^{-1}\right)\right],$$

Where is $l_i x = \int_0^x \frac{dz}{\ln z}$ – integral logarithm.

It is interesting to consider the case of the formation of microflotocomplexes and their coalescence according to the following scheme:

$$A \xrightarrow{k_1} P,\ 2P \xrightarrow{k_2} C,$$

where A is the initial pollution, P is the non-flotated microflot complex (Flotocomplex, which does not have time to surface into the foam layer during its stay in the flotation zone due to the low lift of the microbubble), 2P is a flotated microflot complex (Flotocomplex, which can float into the foam layer in the flotation zone with a long stay in it.). For the initial conditions: t = 0, $C_A = a_0$, $C_P = C_C = 0$ solution:

$$C_P = a_0 \left[\frac{\exp(-xt)}{x}\right]^{\frac{1}{2}} \times$$

$$\times \frac{iJ_1\left[2i\left(x\exp(-xt)\right)^{\frac{1}{2}}\right] - \beta H_1^{(1)}\left[2i\left(x\exp(-xt)\right)^{\frac{1}{2}}\right]}{J_0\left[2i\left(x\exp(-xt)\right)^{\frac{1}{2}}\right] + \beta H_0^{(1)}\left[2i\left(x\exp(-xt)\right)^{\frac{1}{2}}\right]},$$

Where is $x = a_0 \frac{k_2}{k_1}$, $\beta = \frac{iJ_1\left(2i\sqrt{x}\right)}{H_1^{(1)}\left(2i\sqrt{x}\right)}$, i – imaginary unit; J0, J1 – Bessel functions; - Gankel functions.$H_0^{(1)} H_1^{(1)}$

Flotation of contaminants in the form of microflot complexes according to the scheme:

$$2A \xrightarrow{k_1} P \xrightarrow{k_2} C,$$

where A is the initial pollution in the form of an unfluated microflotome, P is a flotated microflote complex, C is a state in the foam layer.

For the initial conditions: t = 0, $C_A = a_0$, $C_P = C_C = 0$

decision:

$$C_P = \frac{1}{2} a_0 \left\{ e^{-\eta(\tau-1)} + \eta e^{-\eta\tau} \left[E_i(\eta\tau) - Ei(\eta) \right] \tau^{-1} \right\},$$

Where is $\eta = \frac{k_2 a_0}{k_1}$; $\tau = 1 + a_0 k_1 t$; $C_{P\max} = \frac{1}{2} \eta \tau_{\max}^2 a_0$; Ei – integral exponential function.

Consider the flotation of submicrofloral complexes according to the scheme

$$2A \xrightarrow{k_1} P \; 2P \xrightarrow{k_2} C,$$

where A is the initial contamination in the form of an unflated submicrofloral complex (Flotocomplex, which cannot surface into the foam layer for an arbitrarily long period of stay in the flotation zone due to the very low lift of the microbubble), P is an unflated microflot complex, C is a state in the foam layer.

For initial conditions: t = 0, CA = a0, CP = CC = 0 solution:

$$C_P = \frac{a_0}{2\eta\tau} \left[(\alpha+1) - 2\alpha \left(1 + \frac{\alpha-1}{\alpha+1} \tau\alpha \right)^{-1} \right];$$

$$C_{P\max} = a_0 \tau_{\max} \left(\frac{1}{2\eta} \right)^{1/2};$$

Where is $\eta = \frac{k_1}{k_2}$; $\tau = 1 + a_0 k_1 t$; $\alpha = (1 + 2\eta)^{1/2}$.

It is of great practical interest to consider processes with a limiting stage.

If the process includes a number of successive stages and the velocity constant of one of them is much less than the velocity constant of the remaining stages, then such a stage is limiting, and it is she who determines the speed of the entire process. For example, for cleaning processes using ion flotation occurring according to the scheme

$$A \xrightarrow{k_1} P_1 \xrightarrow{k_2} P_2 \xrightarrow{k_3} B,$$

where A is the initial contamination (metal ion), B is the metal ion complex is the collector, C is the metal ion complex is the metal ion complex is the collector is the gas bubble, X is the state in the foam layer,

if k1 < k2 and k1 < k3, then the first stage is the limiting stage, but if k2 < k1 and k2 < k3, then the second stage limits, etc. When the orders of successive stages are different, it is not the velocity constants that should be compared, but the specific velocities of successive stages. For example, in the case of a process that occurs according to the scheme:

$$A \xrightarrow{k_1} P_1$$

$$P_1 + B \xrightarrow{k_2} P_2$$

$$P_2 + C \xrightarrow{k_3} D$$

the second stage will limit under the condition k_2CB < k1 и $k_2C_B < k_3C_C$.

Series-parallel processes flotation and sedimentation:

$$A \xrightarrow{k_1} P \xrightarrow{k_2} C \quad A \xrightarrow{k_1'} C$$

For initial conditions: t = 0, $C_A = a_0$, $C_P + C_C = 0$.

Kinetic equations:

$$\frac{dC_A}{dt} = -\left(k_1 + k_1'\right)C_A;$$

$$\frac{dC_P}{dt} = k_1 C_A - k_2 C_P;$$

$$\frac{dC_C}{dt} = k_1' C_A + k_2 C_P.$$

Solutions:

$$C_P = \frac{a_0 k_1}{k_2 - k_1 - k_1'}\left[\exp\left(-(k_1 + k_1')t\right) - \exp(-k_2 t)\right];$$

$$C_C = \frac{a_0 k_1'}{k_1 + k_1'}\left[1-\exp\left(-(k_1+k_1')t\right)\right] + \frac{a_0 k_1}{k_2 - k_1 - k_1'}\{1-$$

$$-\exp(-k_2 t) + k_2(k_1+k_1')^{-1}\left[1-\exp\left(-(k_1+k_1')t\right)\right]\};$$

$$\frac{dC_C}{d\Delta C_A} = \frac{k_1'}{k_1+k_1'} + \frac{k_2}{k_1+k_1'}\frac{C_P}{C_A}.$$

Of interest is the process of formation of flocules using coagulants and flocculants:

$$A + B \xrightarrow{k_1} P_1 \; P_1 + B \xrightarrow{k_2} P_2 \; P_2 + B \xrightarrow{k_3} C$$

The initial sections of kinetic curves are described by the equations:

$$\frac{dC_{P_1}}{dt} = k_1 C_A C_B, \; C_{P_1} \cong k_1 a_0 b_0 t;$$

$$\frac{dC_{P_2}}{dt} = k_2 C_B C_{P_1}, \; C_{P_1} \cong \frac{1}{2} k_1 k_2 a_0 b_0^2 t^2;$$

$$\frac{dC_C}{dt} = k_3 C_B C_{P_2}, \; C_{C_1} \cong \frac{1}{6} k_1 k_2 k_3 a_0 b_0^3 t^3,$$

and the ratio between concentrations to equations:

$$-\frac{d\,C_{P_1}}{d\,C_A} = \frac{k_1 C_A C_B - k_2 C_B C_{P_1}}{k_1 C_A C_B} = \frac{\eta_1 C_A - C_{P_1}}{\eta_1 C_A};$$

$$-\frac{d\,C_{P_2}}{d\,C_A} = \frac{k_2 C_B C_{P_1} - k_3 C_B C_{P_2}}{k_1 C_A C_B} = \frac{\eta_2 C_{P_1} - C_{P_2}}{\eta_1 \eta_2 C_A}.$$

Solutions:

$$C_{P_1} = \frac{\eta_1}{1-\eta_1} C_A + \frac{\eta_1}{\eta_1 - 1}\left(\frac{C_A}{a_0}\right)^{\frac{1}{\eta_1}} a_0;$$

$$\frac{C_{P_2}}{a_0} = \frac{\eta_1 \eta_2}{(1-\eta_2)(\eta_1 - 1)}\left(\frac{C_A}{a_0}\right)^{\frac{1}{\eta_1}} + \frac{\eta_1 \eta_2 C_A / a_0^{-1}}{(1-\eta_1)(1-\eta_1 \eta_2)} +$$

$$+\frac{\eta_1 \eta_2^2}{(1-\eta_1)(1-\eta_1 \eta_2)}\left(\frac{C_A}{a_0}\right)^{\frac{1}{\eta_1 \eta_2}},$$

Where is $\eta_1 = \frac{k_1}{k_2}$, $\eta_2 = \frac{k_2}{k_3}$.

In some cases, the flotation of microflot complexes can be described according to the scheme:

$A \xrightarrow{k_1} P \; A + P \xrightarrow{k_2} C$

For initial conditions: $t = 0$, $C_A = a_0$, $C_P = C_C = 0$.

Kinetic equations:

$$\frac{dC_A}{dt} = -(k_1 C_A + k_2 C_A C_P);$$

$$\frac{dC_P}{dt} = k_1 C_A - k_2 C_A C_P.$$

Solutions:

$$C_P + 2\eta \ln \frac{\eta - C_P}{\eta} = C_A - a_0;$$

$$\frac{C_P}{\eta} + 2\ln\left(1 - \frac{C_P}{\eta}\right) = -\frac{a_0}{\eta}\left(1 - \frac{C_A}{a_0}\right).$$

Stationary value of intermediate concentration

$$C_{P\,стац} = \eta = \frac{k_1}{k_2}.$$

In the case of flotation of microflotocomplexes with reagents (coagulants) we have:

$A + B \xrightarrow{k_1} P \; B + P \xrightarrow{k_2} C$

For initial conditions: $t = 0$, $C_A = a_0$, $C_B = b_0$, $C_P + C_C = 0$.

Kinetic equations:

$$\frac{dC_A}{dt} = -k_1 C_A C_B;$$

$$\frac{dC_B}{dt} = -(k_1 C_A C_B + k_2 C_B C_P);$$

$$\frac{dC_P}{dt} = k_1 C_A C_B - k_2 C_B C_P.$$

Decision:

$$\frac{C_P}{C_A} = \frac{1}{\eta - 1}\left[1 - \left(\frac{C_A}{a_0}\right)^{\eta - 1}\right],$$

Where is $\eta = \frac{k_2}{k_1}$.

Maximum concentration of intermediate product

$C_{\mathrm{Pmax}} = a_0 \eta^{\varepsilon}$,

Where is $\varepsilon = \frac{\eta}{1-\eta}$ for h 1;

$C_{\mathrm{Pmax}} = \frac{a_0}{e}$ for h = 1

Consider the process of coalescence and flotation of microflotocomplexes:

$$\mathrm{A} \xrightarrow{k_1} \mathrm{P}, \quad \mathrm{P} + \mathrm{P} \xrightarrow{k_2} \mathrm{C}, \quad \mathrm{P} \xrightarrow{k_3} \mathrm{D}$$

For initial conditions:t = 0, $C_A = a_0$, $C_P = C_C = C_D = 0$.

Kinetic equations:

$$\frac{dC_{\mathrm{A}}}{dt} = -k_1 C_{\mathrm{A}};$$

$$\frac{dC_{\mathrm{P}}}{dt} = k_1 C_{\mathrm{A}} - k_2 C_{\mathrm{P}}^2 - k_2 C_{\mathrm{P}},$$

Solutions:

if $\frac{k_3}{k_1}$ – an integer, then

$$C_{\mathrm{P}} = \frac{k_1\sqrt{\eta_2}}{k_2} \cdot \frac{N_{-\eta_1}(2\sqrt{\eta_2})J_{-\eta_1}(2\sqrt{\eta_2}\sigma) - J_{-\eta_1}(2\sqrt{\eta_2})N_{-\eta_1}(2\sqrt{\eta_2}\sigma)}{N_{-\eta_1}(2\sqrt{\eta_2})J_{1-\eta_1}(2\sqrt{\eta_2}\sigma) - J_{-\eta_1}(2\sqrt{\eta_2})N_{1-\eta_1}(2\sqrt{\eta_2}\sigma)};$$

$$\eta_1 = 1 - \frac{k_3}{k_1}; \quad \eta_2 = a_0 \frac{k_2}{k_1}; \quad \sigma = \exp\left(-\frac{1}{2}k_1 t\right);$$

if $\frac{k_3}{k_1}$ – not an integer, then

$$C_{\mathrm{P}} = -\frac{k_1\sqrt{\eta_2}}{k_2}\sigma \times$$

$$\times \frac{J_{\eta_1}(2\sqrt{\eta_2})J_{-\eta_1}(2\sqrt{\eta_2}\sigma) - J_{-\eta_1}(2\sqrt{\eta_2})J_{\eta_1}(2\sqrt{\eta_2}\sigma)}{J_{\eta_1}(2\sqrt{\eta_2})J_{1-\eta_1}(2\sqrt{\eta_2}\sigma) - J_{-\eta_1}(2\sqrt{\eta_2})J_{1-\eta_1}(2\sqrt{\eta_2}\sigma)},$$

where J is the Bessel function; N – Neumann functions.

Consider successive processes with equilibrium stages.

For example, reversible first stage flotation:

$$\mathrm{A} \underset{k_2}{\overset{k_1}{\rightleftarrows}} \mathrm{B} \xrightarrow{k_3} \mathrm{C}$$

For initial conditions: $t = 0$, $C_A = a_0$, $C_B = C_C = 0$.

Kinetic equations:

$$\frac{dC_{\mathrm{A}}}{dt} = -k_1 C_{\mathrm{A}} + k_2 C_{\mathrm{B}};$$

$$\frac{dC_{\mathrm{B}}}{dt} = k_1 C_{\mathrm{A}} - (k_2 + k_3) C_{\mathrm{B}};$$

$$\frac{dC_{\mathrm{C}}}{dt} = k_3 C_{\mathrm{B}}.$$

Solutions:

$$C_{\mathrm{A}} = a_0 \left\{ \frac{\lambda_2 - k_1^{-1} k_3}{\lambda_2(\lambda_2 - \lambda_3)} \exp(-\lambda_2 k_1 t) + \frac{k_1^{-1} k_3 - \lambda_3}{\lambda_3(\lambda_2 - \lambda_3)} \exp(-\lambda_3 k_1 t) \right\};$$

$$C_{\mathrm{B}} = \frac{a_0}{\lambda_2 - \lambda_3} \left[\exp(-k_1 \lambda_3 t) - \exp(k_1 \lambda_2 t) \right],$$

Where is $\lambda_2 = \frac{1}{2}(\alpha + \beta)$; $\alpha = 1 + \frac{k_2}{k_1} + \frac{k_3}{k_1}$; $\lambda_3 = \frac{1}{2}(\alpha - \beta)$; $\beta = \left(\alpha^2 - \frac{4k_3}{k_1} \right)^{1/2}$.

Reversible second stage flotation:

$$\mathrm{A} \xrightarrow{k_1} \mathrm{B} \underset{k_3}{\overset{k_2}{\rightleftarrows}} \mathrm{C}$$

For initial conditions: $t = 0$, $C_A = a_0$, $C_B = C_C = 0$,

$t \rightarrow \infty$, $C_B \rightarrow C_B$, $C_C \rightarrow C_C$.

Kinetic equations:

$$\frac{dC_{\mathrm{A}}}{dt} = -k_1 C_{\mathrm{A}};$$

$$\frac{dC_{\mathrm{B}}}{dt} = k_1 C_{\mathrm{A}} + k_3 C_{\mathrm{C}} - k_2 C_{\mathrm{B}};$$

$$C_{\mathrm{A}} = a_0 \exp(-k_1 t).$$

Solutions:

$$C_B = C_{B\infty}(k_1 + k_2 - k_1)^{-1}\{a_0(k_1 - k_2)\exp(-k_1 t) -$$
$$-\left[k_2 C_{B_\infty} - C_{C_\infty}(k_3 - k_1)\right]\exp\left[-(k_2 + k_3)t\right]\};$$
$$C_C = C_{C_\infty} - (k_2 + k_3 - k_1)^{-1}\{a_0 k_2 \exp(-k_1 t) -$$
$$-\left[C_{B_\infty} k_2 - C_{C_\infty}(k_3 - k_1)\right]\exp\left[-(k_2 + k_3)t\right]\}.$$

Flotation with collector and flocculant:

$$A + B \underset{k_2}{\overset{k_1}{\rightleftarrows}} C, \quad A + C \xrightarrow{k_3} D$$

For initial conditions:t = 0, CA = a0, CB = b0, CC = CD = 0.

Kinetic equations:

$$\frac{dC_A}{dt} = -k_1 C_A C_B + k_2 C_C - k_3 C_A C_C;$$
$$\frac{dC_B}{dt} = -k_1 C_A C_B + k_2 C_C;$$
$$\frac{dC_C}{dt} = k_1 C_A C_B - k_2 C_C - k_3 C_A C_C.$$

If att = 0 $C_C = c_0$, and the concentrations of the remaining products are zero and the equilibrium concentration is quickly established $C_A = \frac{k_2 C_C}{k_1 C_B}$, то

$$\frac{dC_C}{dt} = -\frac{2k_2 k_3 C_C^2}{k_1 C_B} \text{ и } \frac{C_C}{W_C} = \frac{k_1}{2k_2 k_3}\frac{C_B}{C_C}.$$

Flotation using various reagents:

$$A + B \underset{k_2}{\overset{k_1}{\rightleftarrows}} C, \quad A + D \xrightarrow{k_3} F, \quad C + D \xrightarrow{k_4} G.$$

Suppose that a stationary concentration of C is quickly reached in the system:

$$C_C = \frac{k_1 C_A C_B}{k_2 + k_4 C_D};$$

$$W = -\frac{dC_A}{dt} = \frac{k_1 k_4 C_A C_B C_D}{k_2 + k_4 C_D} + k_3 C_A C_D;$$

$$k_{эксп} = \frac{W}{C_A} = \frac{\Delta \ln C_A}{\Delta t} = \left(\frac{k_1 k_4 C_B}{k_2 + k_4 C_D} + k_3\right) C_D = k' C_D;$$

$$\lim_{C_B \to 0} k' = k_3, \ \lim_{C_D \to 0} k' = \frac{k_1 k_4 C_B}{k_2} + k_3, \ \lim_{C_D \to \infty} \overline{k_{эксп}} = k_1 C_B + k_3 C_D.$$

The proposed solutions can be used in the practice of flotation thickening of activated sludge, in particular with a more accurate calculation of flotation machines and devices with different aeration system.

In the simplest version of the flotation combine in the form of a flotation settling tank (Fig. 2.13) it is possible to carry out deeper wastewater treatment compared to conventional technology, in particular to increase the degree of pollution recovery by about 10 - 15% and to increase the specific hydraulic load by 20 ... 25%, and also to obtain a condensed sludge of 15 -20% compared to the corresponding indicators of known flotation sludge compactors.

Fig. 2.13. Photo of an industrial sample of a flotation settling tank

The described examples of the use of certain types of flotation equipment for the compaction of activated sludge do not exhaust all the possibilities of using seals of this type, but indicate quite large prospects for their improvement.

2.5. Sedimen thickeners

The use of sediment compactors of various types should ensure compaction to a given humidity:

(a) Mixtures of wet sludge and uncompacted excess activated sludge prior to their mechanical dewatering or fermentation in methane tanks;

b) wet sludge after its cleaning from sand on hydrocyclones or a mixture of it with excess sludge before dehydration;

c) the sediments fermented in the methane tanks with their preliminary washing with purified wastewater.

When operating sediment compactors, it is necessary:

(a) Distribute sediment or mixtures thereof proportionately among individual installations;

(b) ensure that, as far as possible, the sediment and excess activated sludge or a mixture of fermented sludge with wash water are applied uniformly to the sediment compactors and the compacted sludge is discharged from them;

Consider some types of plastic thickeners. Such thickeners (Fig.2. 14) are used to obtain pure plum and condensed product with an increased concentration of solid.

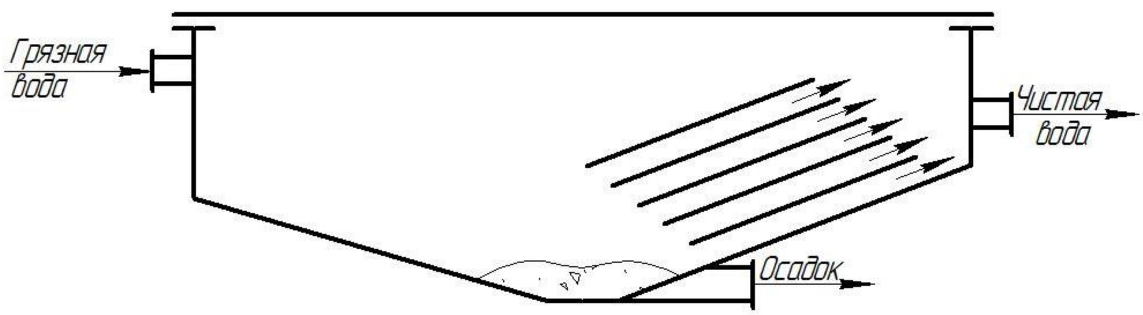


Fig. 2.14. Diagram of a plate thickener

In plate thickeners (Fig.2. 14) The main parts are closely spaced inclined planes, which allow you to divide the flow into jets with laminar motion and reduce the sedimentation path of solid particles.

According to the principle of operation, plate thickeners are divided into direct-flow, countercurrent and transverse flow.

Inclined plates in plate thickeners have a dual purpose: they serve to form thin layers of low height and to divert the deposited particles to the lower part of the tank.

Solid particles during the passage between the plates fall to the inclined planes in the form of a condensed product and move to the lower part of the thickener, and the clarified water is poured into the drain chute.

The time required for the particle to reach the plate shall not be longer than the time of movement of the liquid phase over the distance from the lower to the upper edge of the plates.

Advantages: high performance per unit condensation area, no moving parts and drive, low operating costs.

Disadvantages: uneven supply of power to all channels, it is unacceptable to churn the suspension, consisting in mixing the original product with condensed.

Inclined plates in plate thickeners have a dual purpose: they serve to form thin layers of low height and to divert the deposited particles to the lower part of the tank.

Solid particles during the passage between the plates fall to the inclined planes in the form of a condensed product and move to the lower part of the thickener, and the clarified water is poured into the drain chute.

The time required for the particle to reach the plate shall not be longer than the time of movement of the liquid phase over the distance from the lower to the upper edge of the plates.

Advantages: high performance per unit condensation area, no moving parts and drive, low operating costs.

Disadvantages: uneven supply of power to all channels, it is unacceptable to churn the suspension, consisting in mixing the original product with condensed.

3. Stabilization of wastewater sediment

3.1. Anaerobic digestion

As is known, aerobic digestion is the process of mineralization of the organic matter of sediment under anaerobic conditions, accompanied by increased gas release. It is generally accepted that the process of disintegration of the organic matter of sediment under anaerobic conditions occurs in two stages: - acidic - hydrolysis of complex organic substances, as a result of which fatty acids, alcohols, aldehydes, etc. are formed; - alkaline (methane) - conversion of these intermediate products into methane and carbon dioxide, and carbonate salts. The main technological parameters that determine the effectiveness of the process of anaerobic fermentation of sediment are their chemical composition, temperature and duration of fermentation, the load on organic matter, the concentration of the loaded sludge, as well as the mode of loading and mixing the contents of the fermentation chamber. It has been established that the gas that is released during the fermentation of the sediment, often called biogas, is formed only due to the breakdown of fats, carbohydrates and proteins. At the same time, 60-65% of biogas is formed during the breakdown of fats, and the remaining 35-40% are approximately equally accounted for carbohydrates and proteins. All three components in question are not completely fermented: the degree of their fermentation is approximately 55 - 70% - for fats, 50 - 65% - for carbohydrates, 40 - 50% - for proteins. In turn, the content of fats, carbohydrates and proteins in the organic matter of the sludge, depending on the composition of wastewater , is approximately 60-80%.

The composition of the sediments contains organic and inorganic substances, which under certain conditions can show a toxic effect on the fermentation process. Such substances include heavy metal ions, dissolved oxygen, sulfides, ammonium nitrogen, surfactants, etc. The most sensitive to toxic substances are methane bacteria. The consequence of the toxic effect on them of various chemicals is a decrease in the formation of methane until its complete cessation. One of the most important factors affecting the growth rate of anaerobic microorganisms and the effectiveness of the decay of the precipitate is temperature. There are three main temperature zones of vital activity of anaerobic microorganisms: psychrophilic - up to 20^0 C (optimum 15-17^0C), mesophilic - from 20 to 40^0C (optimum 33 - 35^0C) and thermophilic - from 50 to 70^0C (optimum 53-55^0 C). In each zone, biochemical processes are carried out separate specifically An association of microorganisms for which temperature is essential in the vital processes of microorganisms.

Thermophilic digestion differs from mesophilic fermentation in greater intensity and ends about 2 times faster. Due to this, the required volume of structures is approximately halved and the sanitary and hygienic indicators of sediment are improved, but almost twice as much heat consumption is required.

The temperature at which the sediment is fermented also significantlyaffects the gas emission process. However, with continuousfermentation, the gas yield per unit of dry matter of the loaded or fermented sludge is substantially the same for both the mesophilic and thermophilic digestion regimes, and is determined only by the chemical compositionof the sludge, which depends on the composition of the wastewater.

With thermophilic fermentation, complete deworming of the sediment is achieved, whereas under conditions of mesophilic temperatures, only 50-80% of the total number of helminth eggs dies. And this must be taken into account when treating the sludge.

To maintain the required fermentation regime, it is necessary to load the sludge into the structures evenly throughout the day, and to reduce stagnant zones, equalize the temperature, prevent delamination of the sediment and the formation of a crust, intensive mixing of the sediment in the fermentation chamber should be carried out. The main structures for anaerobic stabilization of sediment are septic tanks, two-tier sedimentation tanks, clarifiers-rotters and methane tanks.Septic tanks are structures in which at the same time clarification of wastewater and anaerobic digestion of the resulting sludge are carried out.The advantages of septic tanks are the high effect of removing suspended substances from wastewater and ease of operation. They are widely used for pre-clarification of wastewater before its subsequent treatment. To reduce the removal of suspended substances from septic tanks, they are arranged with two- or three-chamber ones. The volume of the sedimentation zone of septic tanks is determined

approximately on the basis of a 3-day stay of wastewaterwith a flow rate of up to 5 m3 / day, and with operating modes of 2.5-day stay - with a flow rate of more than 5 m3 / day.

Two-tier settling tanks are used for preliminary clarification of wastewater and simultaneous anaerobic digestion of the resulting sludge, as well as excess (dying) biofilm or activated sludge.Usually these are round structures with a conical bottom. In the upper part of the structure there are settling gutters, and the lower part serves as a fermentation chamber, in which conditions are created for the vital activity of anaerobe microbes.

The duration of wastewater clarification in settling gutters is about 1.5 hours, and the efficiency of their clarification is 40-50%. To increase the efficiency of clarification of wastewater, the gutters of two adjacent two-tier sedimentation tanks are performed in a combined version, making them paired. Biofilm or active sludge is fed for fermentation directly into the sludge chamber. Due to the significant influence of temperature on the course of fermentation processes, it is necessary to ferment Carry out measures to prevent hypothermia of the sludge part of two-tier sedimentation tanks.Mixing of sediment in the sludge chambers of two-tier settling tanks is carried out only due to bubbles of fermentation gases that rise to the surface of the structure. The sediment, which is located in the lower layers of the sludge chamber, is practically not mixed, which slows down the process of its fermentation. The sediment is clenched and compacted under the influence of its own weight to a humidity of 85%. The average humidity of the sediment, which is released from the structure under hydrostatic pressure, is about 90%.

The advantage of two-tier settling tanks is the simplicity of design and operation. But they also have significant drawbacks: the great depth of the structures, which increases the cost of their construction; the need for accommodation in heated rooms in areas with low winter temperatures; the possibility of reducing by up to 30% the effect of wastewater clarification due to the penetration of fermentation gases and particles of fermented sludge into the gutters.

A further development of the design of two-tier settling tanks are clarifiers-rots, which are structures that consist of a clarifier with natural aeration, concentrically placed in the middle of the decay. Clarified wastewater is discharged through a circular peripheral tray, and the retained sediment under hydrostatic pressure flows by gravity into the pumping station and is further fed into the rotter through a pressure pipeline. Compared to two-tier sumps, clarifiers-rots have significant advantages, which are as follows. The clarifier and the decayer are separated from each other, which eliminates the possibility of fermentation sludge entering the clarification zone and reduces the concentration of suspended solids in wastewater by about 70% and the BPCp by 15%.

Mixing of the sediment in the decay contributes to the intensification of its fermentation, makes it impossible to form a crust on the surface and compact the sediment at the bottom of the clarifier.

Excess biofilm and excess activated sludge are fed for fermentation directly into the sludge part of the structure. The duration of the sediment in the decay is determined mainly by the concentration of the solid phase, namely its organic part, as well as the fermentation temperature. It should be noted that when placing the clarifier in the middle of the decay, the temperature of the sludge in the clarifiers-rots almost coincides with the rate of evaporation of wastewater supplied for treatment.Methane tanks are tanks for anaerobic digestion of raw sludge, excess activated sludge or biofilm, as well as their mixtures. Unlike two-tier settling tanks and clarifiers-rotters in methane tanks sediment is heated, their intensive mixing , which creates favorable conditions for the vital activity of microorganisms, allowing to organize an effective process for obtaining biogas.

In methane tanks, a mesophilic (t = 33 ° C) or thermophilic (t = 53 ° C) fermentation mode is created. At most stations, fermentation is carried out under mesophilic conditions, which makes it possible to produce biogas in an amount sufficient both to heat the methane tanks and to obtain additional heat. The thermophilic process makes it possible to accelerate the decay of organic matter by 2 times and improve the sanitary and hygienicsediment indicators. However this requires almost twice as much heat consumption.

During fermentation, the decay of organic matter of sediment is approximately 43-53%, respectively, the amount of dry matter decreases and the humidity of sediment increases. The approximate composition of the generated biogas: methane - 60-70%, carbon dioxide - 16-34%, nitrogen - up to 3%, hydrogen - up to 3%, oxygen - 0.4%, carbon monoxide - 2-4%. Calorific value of methane is 5000-5500 kcal/m3.

According to the recommendations of the JV "Sewerage. External networks and structures" (Appendix 2) The volume of methane tanks should be determined by calculating the organic load on the working volume of the structure. The volumetric dose of sludge loading should not exceed 15% for the thermophilic process and 7% for the mesophilic process.

The degree of decay of the organic matter of the sludge should be determined by calculation taking into account the types of sediment, process temperature, availability and pretreatment methods.

It is believed that of the existing forms of methane tanks (Fig. 3.1-3.2), the best is the cylindrical shape with conical overlaps and the bottom, which has the maximum volume with a minimum surface area, whichreduces the volume and heat loss during operation.

Fig. 3.1. Methane tanks in the form of reinforced concrete tanks buried in the ground.

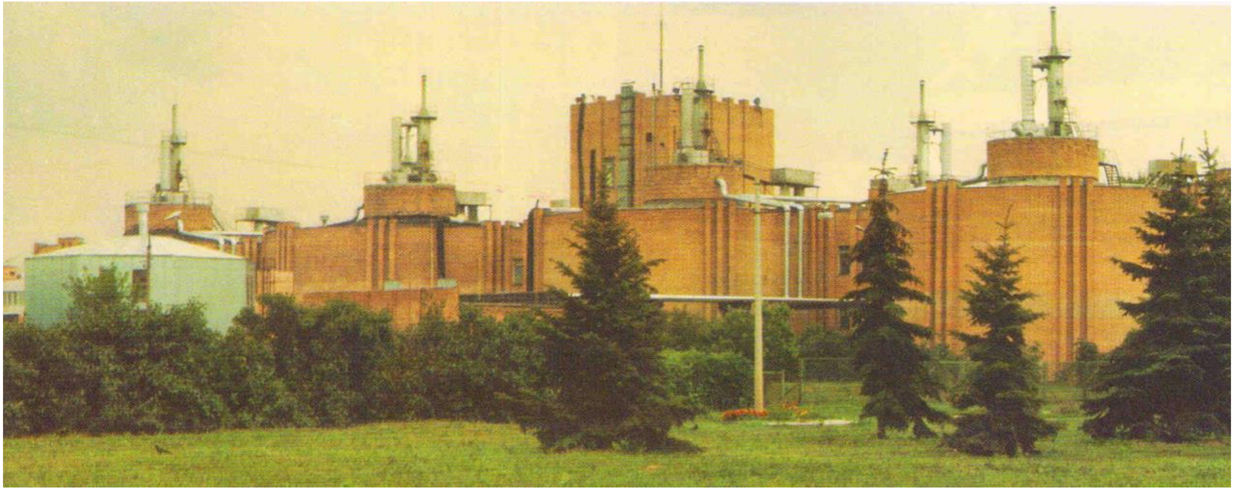


Fig. 3.2. Methane tanks in the form of ground tanks

In the upper part of the hemispherical overlap of the methane tanks is the neck. The surface of the fermenting mass is above the base of the neck, so the area of the free sludge mirror in the methane tanks is very small, which increases the intensity of gas emission per unit area and reduces the risk of crust formation. In the upper part of the ceiling there is a cap for collecting gas.Mixing of sludge in the methane tank can be carried out in several ways:
- hydro elevators using as a working fluid the sediment supplied by the pump from the lower zone of the methane tank;- propeller agitators located in the central pipe in the middle of the methane tank;- pumping using pumps without hydraulic elevators;- recirculation of fermentation gases by means of compressors;- with the helpof mouths for heating the sludge, for example by steam injectors.

Methane tanks are used mainly in large treatment plants and are much less often used in treatment plants of small capacity.

It is interesting to note that historically, practical interest in using methane tanks to treat sediment has varied over time. There were periods when the emphasis in the practice of processing sediments was with the mandatory use of methane tanks, and in other years there was almost their complete ignoring. At the beginning of the twentieth century, in our opinion, a more balanced approach to the use of methane tanks in the practice of sediment treatment became more balanced.

3.2. Aerobic stabilization

The process of aerobic stabilization of hell waspsconsists in prolonged aeration of them with air. At the same time, the main part of organic ashless substances is oxidized by microorganisms in the presence of oxygen. Fig. 3.3. General view of the aeration tank

For aerobic stabilization, any capacitive structures available at aeration stations can be used, in particular aeration tanks of standard designs with a depth of up to 5 - 6 m (Figures 3.3-3.4).

Fig. 3.3. General view of the aeration tank

Fig. 3.4. Aeration tank with pneumatic aeration system

Small treatment plants usually use aerobic stabilizers that work on the principle of complete mixing.

Such a process, however, has a significant drawback. The discharged precipitate has some, albeit insignificant, amount of substances that have been in the stabilizer for a very short time. Therefore, for stabilization, it is recommended to use structures such as aeration tanks-displacers. The effectiveness of the stabilization process depends on the duration and intensity of aeration, temperature, as well as the composition and properties of the sediment.

The selection and use of a suitable aeration system is important.

Of the various methods of saturation of water with oxygen, pneumatic aerators received an overwhelming spread in biological wastewater treatment plants. In Fig. 3.5 – 3.7 presents individual samples of various aerators used in the processes of aerobic stabilization of sediment, including activated sludge.

Consider as an example the FORTEX aeration systems (Fig. 15).

Medium bubble elements AME - P, AME - S are designed for various modes of mixing and aeration, including in tanks of aerobic sludge stabilization, etc.

Fine-bubble aeration elements FORTEX are produced of three main types:

· Disk (AME - 260)

· Lamellar (AME -D)

· Tubular (AME - T 750 and AME - T 370)

Fig. 3.5. Fortex aeration elements

AME – T 750, AME – T 370. The finely bubbled tubular aeration element consists of a rubber perforated membrane attached to a carrier tube with a diameter of 63 mm. At both ends, the membrane is fixed with clamping tapes. The tubular element is equipped with an air supply hole and it has a significantly simplified method of fastening to the aeration line. Tubular aeration elements are used in cases of high and extreme density of aeration elements, with specific forms of settling tanks and on removable aeration grates. For special applications, it is possible to manufacture this type of stainless steel aerators so that the element does not contain plastic parts.

Good dispersion of the bubbles can be obtained using membrane aerators, for example, presented in Figure 3.6.

A. Disc membrane aerators Gummi-Jaeger

B. Tubular membrane aerators Gummi-Jaeger

Fig. 3.6. Memban aeratotors: A. Disc membrane aerators Gummi-Jaeger ; B. Tubular membrane aerators Gummi-Jaeger

Effective saturation of wastewater with air oxygen is an important condition for aerobic biochemical treatment of organic and inorganic contaminants and in this regard, the choice of aerators is essential. Along with the presented samples, there is a wide variety of other types of aerators. In this case, this is for illustrative purposes only.

The duration of aeration, which ensures the complete disintegration of the ash-free substance and the stabilization of the sediment, is taken for uncompacted sludge - 2-5 days, for a mixture of raw sludge and compacted activated sludge -8-12 days approx. Air flow - 1-1.5 m^3 / m^3 * h.

The efficiency of the aerobic stabilization process depends on the duration of the process, temperature, aeration intensity, as well as the properties and chemical composition of the sediments, including excess active sludge.After aerobic stabilization, the sediment should be kept for 1.5-5 hours in separately located seals or in a specially allocated settling zone inside the stabilizer. The humidity of the compacted aerobically stabilized sludge is 96.5-98.5%. Sludge water from seals containing up to 100 mg/dm3 ofweighed substances and having a BPCp of up to 200 mg/dm3 should be sent for purification to aeration tanks.

The process of aerobic stabilization leads to a slight decrease in the content of pathogenic microflora in the sediment. Depending on the duration of aeration and the mode of operation of the stabilizers, the decrease in the content of Escherichia coli reaches 70-99% and inactivation of viruses is observed. However, helminth eggs do not die, so the use of stabilized sediments as a fertilizer is possible only after their deworming.

The advantages of aerobic stabilizers are the simplicity of their design and operation, explosion safety, improvement in some cases of the water-releasing capacity of sediments, a small dependence of the stabilization process on the presence of toxic impurities, heavy metal ions, and surfactants in the sediment compared to anaerobic fermentation.

The disadvantages of aerobic stabilizers include a large consumption of electricity for aeration, the need for mandatory disinfection of stabilized sediment, and a decrease in the effectiveness of aerobic stabilization in winter due to supercooling of the sediment.

The disadvantages of this method are also the long duration of the stabilization process, as well as the insufficient degree of decomposition of the organic matter of the sediment.

4. Conditioning of wastewater sediment

4.1. Heat treatment of wastewater sediment

In a numberof industrialized countries, the heat treatment of sludge before dehydration has become widespread (Fig. 4.1).

The essence of the method is to warm up sediment at a temperatureof 140-200 °C and increase dm pressure.

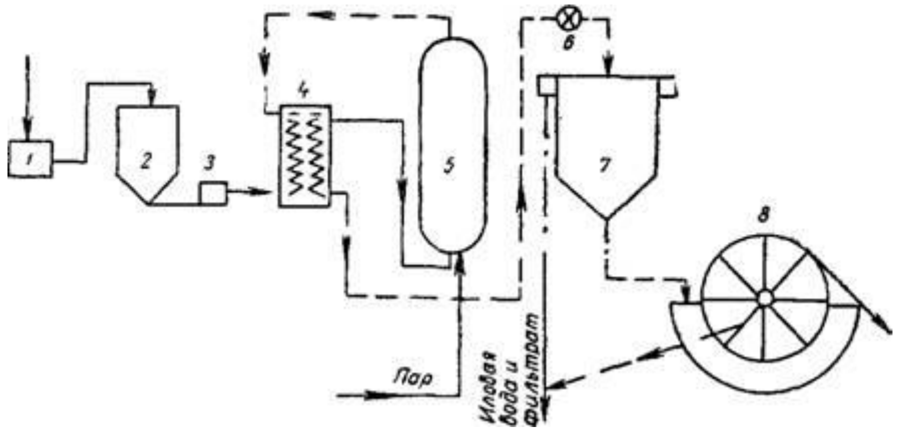


Fig. 4.1. Scheme of heat treatment and mechanical dewatering of municipal wastewater sediment

1 — crusher; 2 — reservoir of crushed sediment; 3 — pump; 4—heat exchanger; 5 — reactor; 6 — throttling device; 7 — iloullotnizer; 8 – vacuum filter

The scheme of heat treatment of the precipitatea is presented in Fig. 4.1. The sediment after heating in the heat exchanger is fed into the reactor, where it is heated at a certain temperature for a given time. The treated precipitate is returned to the heat exchanger, where it gives its heat to the incoming sediment and cools to 30-40 ° C. After settling in the compactor, the sediment without any additional treatment about the heat lives on a vacuum filter. As the latter, other types of devices can also be used.

It is known that the temperature regime and the duration of treatment depend on the nature of the treated sludge. In particular, for compacted activated sludge, it is necessary to warm it up at temperature of 185 - 196 °C for 60 - 75 min. During heat treatment, part of the organic substances are destroyed and thedecay elements pass into sludge water and gas. Only the gravity seal allows you to remove up to 75% of the water originally contained in the sediment. One of the essential advantages of this method is the complete sterility of the treated sediment. In addition, when such sediments are dewatered on vacuum filters, for example, a lower humidity cake (60 -

70%) is formed, which eliminates the thermal drying of the sludge. Sediment after dehydration can be stored in open areas.

Among the disadvantages of the method are the complexity of the design and the high concentration of organic substances in sludge water, which must therefore be directed to biological treatment. However, a significant reduction in the scheme of treatmentof sediment, for example, the possibility of excluding methane tanks, and also the rejection of washing and reagent treatment of the sludge, suggests that this method is promising for individual cases of implementation in practice.

4.2. Reagent treatment of wastewater sediment

One of the most effective methods of conditioning wastewater sediments is their treatment with reagents, in particular iron salts, aluminum, mineral acids, alkalis, lime, synthetic and natural flocculants. Reactive treatment of sediments and excess activated sludge allows to enlarge particles of the solid phase of the condensed suspension due to coagulation and flocculation processes.

Coagulation is a complex of chemical and physical effects between negatively charged colloidal particles and positively charged chemical reagents. It should be noted that the polarity of contaminants and reagents in some cases may be different. At the same time, the action of various forces of repulsion and attraction is manifested, which provide stability or vice versa, instability of the shared system.

Aluminum and iron salts are often used to treat sediments, including the following coagulants: aluminum sulfate $Al_2(SO_4)_3 \cdot 18H_2O$, ferrous sulfate (II) $FeSO_4 \cdot 7H_2O$ (iron sulphate), iron(III) chloride $FeCl_3 \cdot 6H_2O$, aluminium hydroxychloride $Al_2(OH)_5Cl$, lime, sodium metalaluminate $NaAlO_2$, etc., in particular aluminium oxychloride.

The main factor characterizing the rate of coagulation of sediment particles is the stage of flaking formation. The resulting flakes settle under the influence of gravity and at the same time carry the suspended particles with them. It is known that the faster the flakes grow, the greater their mass and size, the more intensive the sedimentation process is.

The minimum concentration of coagulant corresponding to the best thickening of the sediment is called the optimal dose. It is determined empirically and depends on many factors, including the composition of the sediment, the size of the sediment particles, etc. The effectiveness of the coagulants is checked under the same conditions and, based on the data obtained, a conclusion is made about the advisability of further use of the selected coagulant.

To intensify the thickening of sediment by coagulation, reagulations of another type are used - flocculants, which make it possible to accelerate the processes of flaking formation and condensation of sediments.

To intensify the condensation of sediment, both natural flocculants and organic high-molecular compounds obtained by synthesis are used. According to the presence or absence of charged groups in macromolecules, flocculants are divided into cationic (cationic) groups having positively charged groups, anionon-active (anionic) with negatively charged groups and non-ionic without charged groups. In the practice of condensation of sediment, cationic and anion-active flocculants are more often used and much less often non-ionic ones.

Of particular importance is the knowledge of the mechanism of flocculation, since it is from the efficiency of this process in most cases that the achievement of high technological indicators at the stage of subsequent mechanical dehydration depends.

According to one point of view, the most likely cause of instability in dispersed systems is the formation of bridge bonds between particles of the dispersed phase.

Polymer adsorption on solid phase particles does not always lead to flocculation. A necessary condition for the latter is the adsorption of one macromolecule or associate of macromolecules on several particles and the formation of flakes consisting of particles connected by polymeric bridges.
Based on these ideas, the theory of flocculation of neutral particles was developed by La Mer. According to La Mer, during flocculation, primary adsorption first occurs and each macromolecule is attached in several segments to one colloidal particle. Adsorbed molecules occupy part of the θ surface of the particles (more precisely, the active centers on which adsorption is possible), and the rest of the surface (1 - θ) remains free. Then, in the process of secondary adsorption, free segments of the adsorbed molecules are fixed on the surface of other particles, binding them with polymer bridges.
When assessing the possibility of adsorption of already fixed macromolecules on the free surface of other particles, the following factors should be taken into account: 1) the ratio of the areas of the free surface of the particles and the surface occupied by macromolecules; 2) competition of macromolecules in solution and segments of macromolecules already adsorbed on the same particles; 3) steric difficulties that prevent the approach of particles with adsorbed macromolecules tothe free surface of other particles.
The most common theory of flocculation is based on the mechanism of bridge formation. In this case, flocculation occurs due to the sorption of the polymer macromolecule on two or more particles and the formation of "bridges" between them. This leads to the appearance of large floccules. First, primary adsorption is carried out (the flocculant molecule is attached to part of the segment to one particle), then secondary (the remaining free segments of the molecules are fixed on other particles, forming polymer bridges).

The adsorption of macromolecules can be described by the following equation:

$$\frac{\theta}{(1-\theta)\nu} = K_{\alpha}C\nu$$
,

where θ is the proportion of the surface (active centers on this surface), occupied by an adsorbent;

K_{α} – the constant of adsorption-desorption equilibrium;

C – equilibrium concentration;

ν is the number of segments participating in the adsorption of one macromolecules.

Analysis of this equation shows that the function reaches a maximum at θ = 0.5. With smaller values of θ, the flocculation rate decreases, at higher values - flocculation does not occur.

Flocculation is maximum with the same number of particles covered and uncoated with adsorbed flocculant molecules in the system, which is explained on the basis of modern ideas about the structure of the adsorption layer of macromolecules and ideas about "bridge formation". The polymer adsorbed on a solid surface forms, near the phase junction, a dense layer directly adjacent to the surface and a layer of solution-facing tails and loops, the density distribution of which decreases according to an exponential law. When particles containing sufficiently thick polymer shells with long tails and loops, with an equal number of particles free of polymer molecules, come into contact, optimal conditions are created for the formation of a bond through the adsorbed high-molecular substance between the surface of uncovered and coated particles, which leads to flocculation. Therefore, the effectiveness of flocculation depends significantly on the method of mixingthe flocculant with sediment particles. In this respect, it is advisable to use the "double additive" method. The essence of the method is that by adding a starting precipitate with a given volume to a certain volume of the same suspension, but containing an adsorbed polymer, it is possible to adjust the ratio of the number of coated and uncoated particles in the system. The dependence of the particle concentration on the concentration of the polymer additive with the equality of particles coated and not coated with the polymer, in all cases occurs through a minimum, i.e. increasing polymer additives lead first to the localization of the precipitate particles, and then to its stabilization. This is explained by the fact that at low polymer concentrations, the thickness of the adsorption layer of the coated particles is still insufficient for the onset of flocculation, whereas at high concentrations part of the polymer remains unadsorbed and covers the free particles, leading to their stabilization. For the emergence of adsorption bonds between the particles, unimpeded convergence of coated and uncovered particles is necessary, which can be achieved by the disappearance of a potential barrier between particles due to the repulsion of double electric layers, or the displacement of this barrier by a distance known to be less than the thickness of the polymer shell. Thus, the flocculation of the dispersed system by the polymer will be determined by the ratio of the thickness of the shell and the radius of action of the electrical repulsive forces. The compression of the double electric layer with an increase in the concentration of the electrolyte leads to the fact that at some point it will be located inside the polymer layer. At the same time, the loops and tails located on the surface of the protected particles acquire the ability to bind to the uncovered surface of sufficiently suitable particles, which leads to their aggregation. Therefore, for flocculation during the introduction of a polymer, it is not necessary to completely disappear the potential barrier, due tothe repulsion of double layers. Onlyits displacement to a distance less than the thickness of the polymer shell remains.

Other researchers tend to believe that the flocculation of charged particles of the dispersed phase, for example, cationic polyelectrolytes, mainly occurs due to the compensation of their charge by adsorbed macromolecules of the polymer. The possibility of forming bridge bonds is allowed only at significant ionic forces in highly concentrated dispersions or at high pH values of the medium, when the macromolecule of the polymer is not charged.

Then, in this case, it can be considered that the flocculation of charged particles of the dispersed phase, for example, by cationic polyelectrolytes, mainly occurs due to the compensation of their charge by adsorbed macromolecules of the polymer. The possibility of forming bridge bonds is allowed only with significant ionic forces, in highly concentrated dispersions or at high pH values of the medium, when the polymer macromolecule is not charged.

In this regard, of interest, by way of example, is the effect of the molecular weight (MM) of the cationic active flocculant polydimethyldiallylammonium chloride (PDMDAAH), which has a high positive charge density, on the flocculation efficiency, electrokinetic behavior and kineticsof the sulphate lignin (SL) was used over a wide range of changes in pH. An example of this study shows how to find aboutpthymal conditions. the use of PDMDAAH in the process of bleach-containing wastewater of sulfate-cellulose production and, in addition, to clarify the mechanism of flocculation, as well as to determine the optimal dose of polymer (ODP) used as a flocculant.

The data obtained indicate the absence of the contribution of bridge formation to the process of FLOCCulation of SL when adding PDMDAAH.

In this regard, the correspondence of the RBP of all flocculant samples studied to the value of the ζ potential of the SL particles close to zero suggests that at ODP approximately the same number of positively charged units of the polyelectrolyte is adsorbed on the SL particles, regardless of the length of its polymer chain.

The data obtained are in agreement with the electrostatic model of flocculationof the individuallycharged dispersion with a cationically active polymer. The increase in ODP with a decrease in mm flocculant is associated with a decrease in the adsorption capacity of polyelectrolit as its MM decreases.

Consider the properties of some new flocculants. For example, the flocculant VPK-402 is a high-molecular compound of a linear-cyclic structure. Empirical formula of the unit cell VPK-402 C8H16NCl. Structural formula of the unit cell VPK-402;

The molecular weight of the unit cell VPK-402 is 161.7 according to international atomic masses.

VPK-402 is infinitely soluble in water, lower alcohols, acid and alkali solutions. The properties of some polymeric flocculants are presented in Table 4.1.

Table 4.1. X characteristics of individual cationic flocculants

(according to Gandurina L.V., Burtseva L.N., Selezneva L.V.)

Flocculant	THE	Presentation	Jetty. mass	Charge, mV	Functional group
VPK-101	6-05-231-140-81	20% aqueous solution	6· 104	+37	+ -N(CH3)3Cl-
PEI	02-2-187-71	25% aqueous solution	3· 104	-	≡N, =NH, -NH2

PPP	6-14-22-103-73	50% aqueous solution	1·106	+47	+ ≡N(CH3)(CH3SO4-)
VPK-402	605-231-188-78	28% aqueous solution	3·105	+41	+ =N(CH3)2Cl
PDMAEMA	-	% aqueous solution	2·106	-	+ -NH(CH3)2(C2H5COO-)
OKF	-	2% aqueous solution	6·105	+16	+ -NH(CH3)2Cl- -CONH2-CONH-COOH

It should be noted that thevalue ofthe loculant shown in Table 4.1 was estimated by the maximum value of the ζ potential of quartz particles with flocculant macromolecules adsorbed on them. In this regard, the dependence of the flocculation effect of pollution particles on the properties of polymeric flocculants is of interest.

In Table 4. Fig. 2 shows the values of the lightening effect from the properties of flocculants.

Table 4.2. Dependence of the optimal dose value, the lightening effect and the particle potential on the type of flocculant

Flocculant	Dose, mg/l	Suspended solids, mg/l		ζ-the potential of particles at the optimal dose of flocculant, mV
		before cleaning	after cleaning	
VPK-101	7-10	34-107	7-9	-(2,5-8,5)
VPK-402	5	I06-116	14-16	-(S-7)
PPP	5-7	23-107	7-12	. -(3-9)
PDMAEMA	5	23-107	6-18	-(3-6,5)
PEI	2-15	23-107	4-8	-(7-12)
Source water	-	-	-	-(14-18)

From the above data it follows that the ζ-potential of the particles of the dispersed phase in the purified water is -(11 - 18) mV. With an increase in the dose, and consequently, in the amount of flocculant adsorbed on the particles, a monotonous decrease in the ζ potential of the particles to zero is observed. The exception is the flocculant OKF, with the addition of which the potential remained negative. Then, as the flocculant content in the wastewater increases, the ζ potential becomes positive as a result of superequivalent adsorption of the polycation.

The optimal dose of flocculant corresponded to a certain negative value of the ζ potential, which ranged from -2 to -12 mV, depending on the type of flocculant and the composition of the wastewater. At the isoelectric point, when the ζpotential of the particles decreased to 0, the flocculation efficiency decreased.

High molecular weight flocculants (PPS, PDMAEMA) reduce the electrokinetic potential at a higher rate than low molecular weight potential (VPK-101, PEI).

These results are consistent with the data obtained by adding high molecular weight polyelectrolytes to a quartz suspension. With an increase in the molecular weight of flocculants, their adsorption capacity increases, as the number of contacts of macromolecules with the surface of the particles increases.

The nature of the ionogenic groups, as well as the charge of the flocculant of the eye, call for an effect on the aggregation effect and the ζ-potential of the particles of the dispersed phase. The weakly cationic flocculant OCF, which contains, in addition to the positively charged ammonium groups, carboxyl, amide and imide groups (see Table 4.2) has less efficiency and does not compress the ζ potential of the particles up to 0.

It should also be noted the effect of the small molecule electrolyte (sodium chloride) contained in wastewater on the dependence of the ζ potential on the dose of flocculant. With an increase in the sodium chloride content to 1.5 g / l, there is a sharper decrease in the negative value of the ζ potential when flocculant is added. A further increase in the sodium chloride content in wastewater is accompanied by a slowdown in the decrease in the ζ potential, an increase in the optimal dose of flocculant and a deterioration in the purification effect. This is the circumstance is a consequence of a decrease in the degree of dissociation of ionogenic groups of flocculant, coagulation of macromolecules and a decrease in their total positive charge.

An example of activated sludge thickening intensification is the pretreatment of an activated sludge suspension with reagents, in particular industrial cationic flocculants of Praestol 644 and 852 brands. These are flocculants with high molecular weight, which are synthetic high-molecular compounds based on polyacrylamide. They adsorb contaminant particles in the dispersed phase and combine their flakes. As a result, at the stage of flocculation, large flakes are formed, which leads to compaction of the sediment.

Of great importance when using reagents is the method of their preparation in the form of a solution, the choice of the mode of mixing the reagents with the wastewater sediment and the type of mixer.

Proper organization of the process of preparing reagents allowsyou to get the maximum effect in the process of treating wastewater sediment with minimal consumption. The quality of the prepared solutionsis not only the efficiency of the coagulants, but also the operation of the equipment of this unit. The greatest use as coagulants was given to aluminum sulfate, hydroxochlorideand aluminum (III) chloride. . On a somewhat smaller scale, ferrous sulfates, mixed coagulants in the form of aluminum and iron salts, are used. Noticeably in smaller quantities, alumina ammonium and aluminum-potassium alum are used. The use of coagulants, primarily iron and aluminum, obtained by electrochemical means, is increasing. In this case, their properties as coagulants are dramatically improved.

Reagents in both solid and concentrated solutions must be brought to an operating concentration (5-15%). In this regard, it is necessary to analyze the dissolution of salts and primarily salts of aluminum and iron. Knowing the basic laws of the process of dissolving reagents in water, you can choose the optimal mode of dissolution of reagents in water and choose the necessary equipment for this.

The efficiency of wastewater treatment using coagulants and flocculants largely depends on the accuracy ofthe observance of the main parameters. Themain control parameters are the pH of the treated wastewater sludge, electrical conductivity, turbidity, redox potential.

In the practice of sediment treatment, various automatic control systems (CAP) are widely used to control the processes of reagent treatment. Increasing the level of automation of these processes allows to reduce the cost of reagents.

In the practice of wastewater sludge treatment, as a rule, volumetric dosing systems are used. Basically, the ATS of supplying solutions of coagulants and flocculants are built on this principle.

Dispensers usedin the SAR of regional treatment of wastewater sediment must also work reliably when supplying solutions containing suspended particles, sediments, sludge, since lime slurries and waste from various industries are often used as reagents.

When using pre-clarified solutions of reagents, plunger dosing pumps with manual or automatic capacity control can be used.

For the normal functioning of the reagent treatment unit using plunger dosing pumps, preliminary cleaning of reagent solutions is necessary. Otherwise, the dosing pump is clogged with suspended particles, and, therefore, it is necessary to stop and rinse it.

For the treatment of sediments, the rational use of reagents is of great importance, since the annual consumption of flocculants alone is hundreds of tons. Determining the optimal dose of reagents is very difficultto give, since in the practice of wastewater sludge treatment, a number of factors can simultaneously change, for example, the composition and amount of solid phase of sediment.

The efficiencyof sediment treatment processes in all types of equipment is due to the strength and density of the coagulation structure.

A simultaneous increase in the strength and density of the coagulacin structure can be achieved by a combined effect on the structure by hydrodynamic mixing conditions and the dose of the coagulant. The choice of the optimal water purification mode using reagents is possible on the basis of a chain-cellular model of the coagulation structure.

Of interest is the determination of the optimal dose of the reagent when it is added to the water electrochemically. In this case, it is most easy to optimize the process by changing the current density and duration of treatment depending on the quantitative composition of the wastewater.

Applying the known methods of mathematical modeling, it is possible to determine the optimal mode of electrochemical processing. Existing devices for automatic dosing of reagents make it possible, as a rule, to maintain only their flow rate, established on the basis of preliminary studies. Maintaining the optimal dose of reagents to comply with the basic qualitative parameters of the coagulation process is still difficult.

Usually, the prepared solution is introduced into the water through the dosing device and the mixer. Mixing of water with reagents should be carried out in two stages, and the first stage should be carried out in a mode approaching the ideal mixing mode, and the second - in the mode of ideal displacement in the liquid phase. This is due to the fact that in the first stage a uniform distribution of the reagent over the entire volume of treated wastewater should be ensured, and on the second - the creation of conditions that exclude the decay of the formed agglomerates of pollution particles. The first mode can be carried out, for example, in a device with an intensively rotating agitator, and the second - in a layer of suspended sediment.

As the results of many studies show, the process of mixing water with reagents, in particular with inorganic coagulants, must be carried out at maximum speed. Optimizing the mixing mode of the coagulant with water can lead to more efficient use and, in some cases, a reduction in coagulant consumption.

The effectiveness of instant mixing is to change the degree of dispersion of the products of hydrolysis of coagulants absorbed on the surface of the contaminant particles. With more intensive mixing, the probability of sorption on the surface of particles of contaminants of small particles of hydrolysis products of coagulants increases, which leads to coagulant savings and a simultaneous increase in the bond strength of particles in microhlops.

When choosing the mixing mode of the coagulant, it is necessary to take into account the composition and physicochemical properties of wastewater, as well as the injected reagents. The importance of determining the optimal parameters of the mixing regime is also due to the large role of the orthokinetic stage of coagulation in the processes of aggregation of contaminant particles. The probability of collisions between coagulating particles increases with increasing mixing intensity. However, when a certain high-speed gradient is reached, the resulting flakes begin to collapse. For the coagulants used, the value of the velocity gradient is approximately 20-70 $^{s-1}$. As a criterion assessment of the process of mixing reagents with water, along with the velocity gradient, also used the product of the latter multiplied by duration of displacement introduced by Camp (Camp criterion).

In the direction of intensification of mixing water with reagents, the development of mixers is also developing. It is recommended that when choosing the type, design and mode of operation of mixing devices at the stages of rapid mixing of water with reagents and slow mixing of water in flaking chambers, it is recommended to take into account the patterns of coagulation structure formation that determine the initial values of the velocity gradient, the need for gradual mixing and the concentration of solid and liquid phases on the interface surface.

Rapid mixing of reactants with water can be achieved in mixers with a fluidized nozzle and pre-treatment of the mixture.

Electromagnetic mixers should be used, first of all, when contacting water with electrolyte solutions, for example, with solutions of acids, alkalis, salts. However, it is possible to mix non-electrically conductive reagents, for example, polyacrylamide with water, in electromagnetic mixers with a fluidized or magnetized nozzle.

The simplest in the equipment design are mixers containing an electrical processing chamber, in which two or more electrodes are installed. As a result of the electric field on electrolyte solutions, there is an effective mixing of water with a coagulant, which can significantly reduce the mixing time, as well as the consumption of reagents for wastewater treatment. Electrolysis is carried out, as a rule, in modes without noticeable release of gases (oxygen and hydrogen) Another simplest option for electromagnetic mixing is the use of magnetic field generators installed on the section of the pipe where water and a solution of a coagulant (electrolyte) are simultaneously supplied. Such mixers are very simple and easy to install on almost any part of the technological line. In addition, faucets using permanent magnets can be installed in rooms of any category.

High cleaning intensity is achieved in electromagnetic mixers with a magnetically illuminated nozzle consisting of ferromagnetic particles.

In cases where contamination of the purified water with iron impurities is unacceptable, electromagnetic mixers of the stator type of an asynchronous motor can be used instead of mixers with a magnetically lit nozzle using a multi-axis rotor with moving elements as a nozzle.

The author has developed a mixer with a fluidized nozzle and preliminary electrical treatment for the introduction of a coagulant in the zone of action of an electric field and a flocculant in the layer of a fluidized nozzle into the sludge mixture sequentially (Fig. 4.2).

In this case, efficient and rapid mixing of reagents with sludge suspension can be achieved.

Electromagnetic mixers should be used, first of all, when contacting a suspension of activated sludge with electrolyte solutions, for example, with solutions of acids, alkalis, salts. However, it is possible to mix non-electrically conductive reagents, for example, polyacrylamide with a suspension of activated sludge, in electromagnetic mixers with a fluidized or magnetized nozzle.

The most simple in the equipment design of mixers containing an electrical processing chamber, in which two or more electrodes are installed. As a result of the electric field on electrolyte solutions, the activated sludge with the coagulant is effectively mixed, which can significantly reduce the mixing time, as well as the consumption of reagents. Electrolysis is carried out, as a rule, in modes without noticeable release of gases (oxygen and hydrogen) Another simplest option for electromagnetic mixing is the use of magnetic field generators installed on the section of the pipe where water and a solution of a coagulant (electrolyte) are simultaneously supplied. Such mixers are very simple and easy to install on almost any part of the technological line. In addition, faucets using permanent magnets can be installed in rooms of any category.

High mixing intensity is achieved in electromagnetic mixers with a magnetically heated nozzle consisting of ferromagnetic particles.

In cases where it is unacceptable to contaminate the sludge suspension with iron impurities, electromagnetic mixers of the stator type of an asynchronous motor can be used instead of mixers with a magnetically activated nozzle using a multi-axis rotor with moving elements as a nozzle.

In the domestic practice of processing sediments, this stage is not given special importance. It is known that in some cases devices with agitators are used for these purposes, and sometimes a solution of the reagent is introduced into the line (more often into the pipe) of sediment or activated sludge. In the latter case, mixing occurs only due, as a rule, to a slight turbulence that occurs during the pumping of sediment or sludge.

The author has developed a mixer with a fluidized nozzle and pre-treatment for the introduction of a coagulant in the zone of action of an electric field and a flocculant in the layer of a fluidized nozzle into the sludge mixture sequentially (Fig. 4.2).

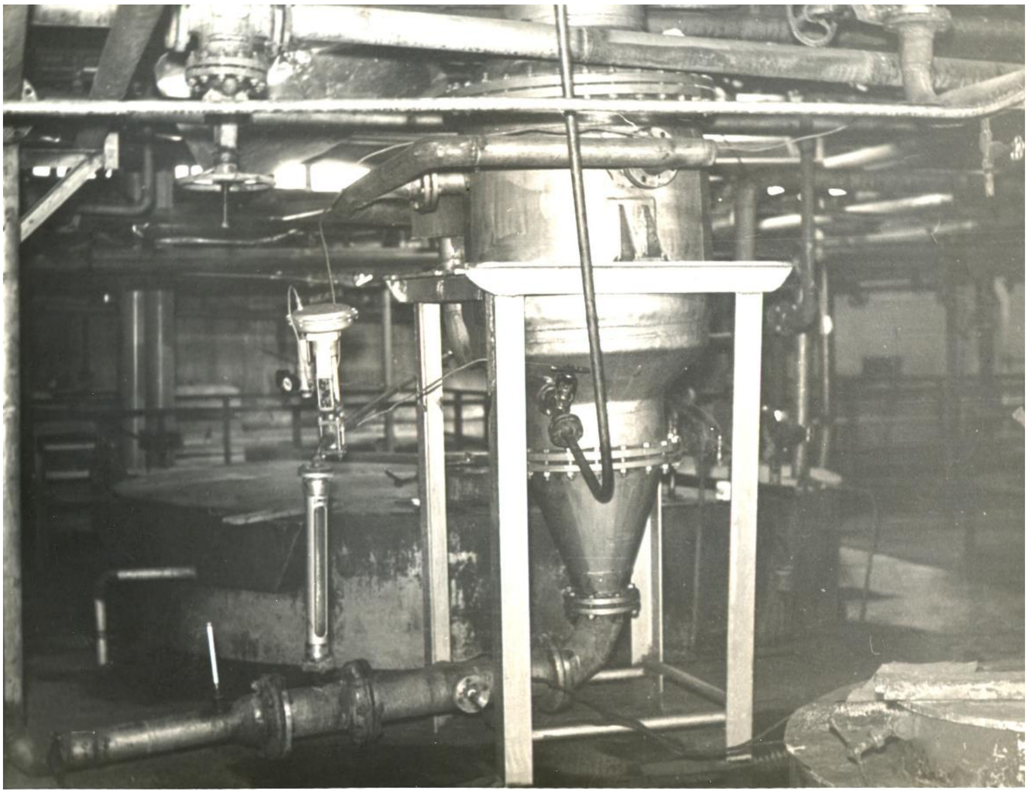


Fig. 4.2. – Mixer with fluidized nozzle and pre-treatment (author's development)

The coagulant is introduced and mixed with the sludge is at the bottom horizontal of the mixer, and the flocculant is contacted in the conical part of the mixer, where a fluidized layer is created using an inert nozzle, for example, from polymer balls.

It should be noted that instead of an electric mixer, it is possible to use a magnet mixer. These methods of administration and contact of coagulants with sludge suspension are presented in Fig. 4.3. Initially, magnetic- and electric mixers were developed only for the introduction and contact of coagulants with water. Then, in the process of conducting experimental studies, the author was convinced that they could also be used to mix coagulants with sludge sediments with their low concentration in the suspension, for example, no more than about 3 - 4% for absolutely dry substances (ADM).

Such mixers are characterized by very small dimensions and mixing efficiency.

The principle of operation of these mixers is based on the use of the mixing or "absorbing" effect of the electromagnetic field when applying it to the non-equilibrium coagulant system - water or coagulant - sludge precipitate. This effect was established by the author in 1974 (Ksenofontov B.S. et al. Reports of the Academy of Sciences of the USSR, 1974, vol. 215, No. 4; 1976, vol. 227, No. 1).

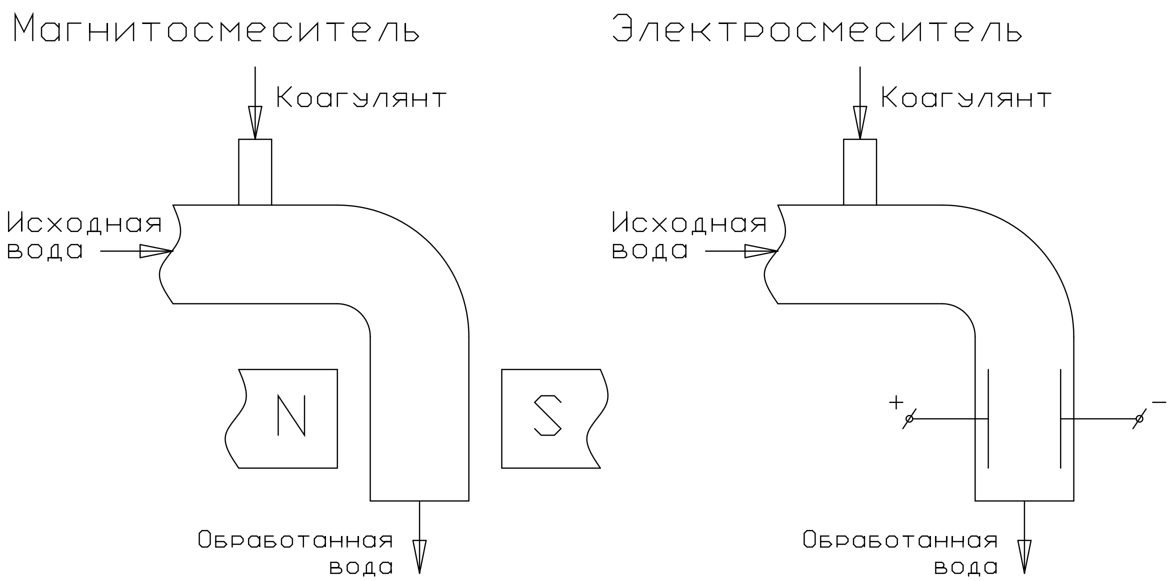


Fig. 4.3. Schemes of magnetic and electric mixers

Of course, in the case of high-viscosity sludge suspensions (more than 4% ADM), preference should be given to other methods and apparatus, for example, the use of an apparatus with a stirrer.

Taking into account the above features, experimental data were obtained on the effect of some flocculants on the process of flotation thickening of the suspension of activated sludge, which are given in Table. 4.3.

Table 4.3. Averaged data on the effect of the amount of cationic active flocculants on the efficiency of flotation thickening of activated sludge

Flocculant type	Flocculant dose, kg/t	Concentration of activated sludge in the foam, % of mass.	Concentration of activated sludge in the liquid phase, % by weight.
Praestol 644	1,5	3,1	0,13
Praestol 644	2,5	3,5	0,11
Praestol 644	5,0	4,3	0,10
Praestol 644	7,5	4,5	0,8
Praestol 644	10,0	4,6	0,8
Praestol 852	1,5	3,4	0,11
Praestol 852	2,5	4,2	0,09
Praestol 852	5,0	4,8	0,07

Praestol 852	7,5	4,9	0,03
Praestol 852	10,0	4,9	0,03

Analysis of the results (Table 4.3) shows that at the same doses, the use of the cationic flocculant Praestol 852 is more effective than the flocculant Praestol 644. Therefore, flocculant Praestol 852 can be recommended for further use for flotation thickening of activated sludge suspension.

Thus, the conducted studies have shown that in the practice of flotation thickening of activated sludge, it is possible to use the cationic flocculant Praestol 852.

In recent years, complex reagents consisting of polymeric flocculants and inorganic electrolytes have been increasingly used for wastewater treatment of various compositions. The results of experimental studies have shown that in all cases of the use of complex flocculation additives, both synergistic and antagonistic effects are observed.

In connection with the search for additional options for intensifying the wastewater treatment process using activated sludge, experiments were conducted on the effect of iron sulfate additives ($FeSO_4$) and cationic flocculants based on polyacrylamide of the brands fennopol (Fennopol) and VPK-204 on the process of thickening of activated sludge. The work was carried out on samples of activated sludge when mixing it with additives of reagents. Then the treated suspension of active sludge with reagents was mixed with working fluid (dispersion water) in a ratio of 1: 1.

In Table. 4.4 shows the conditions for the treatment of sludge suspensions with reactants and the effect achieved in this case of separation of the sludge suspension. The impact of reagents was assessed by the height of the foam layer formed during flotation, the turbidity of the liquid phase, as well as by COD (chemical oxygen demand, which characterizes the total amount of polluting organic substances in water).

Table 4.4. Influence of reagent treatment on the separation of the sludge suspension by flotation (flotation time 10 min)

No p/n	Activated sludge suspension quality	Number of reagents to be added		Ph Active Sludge	Separation efficiency		
		0.05% solution $FeSO_4$ ml	Fennopol 0.01% solution, ml		Height of the foam layer, cm	Turbidity %	COD (mg/L) liquid phase
1	Activated sludge after stabilization for 1 hour	-	-	6,93	5,0	48	170
2	Activated sludge after a 6-hour stay in anaerobic conditions	-	-	6,94	5,2	45	260
3	Activated sludge after hour-long aerobic stabilization	0,08	-	5,20	3,0	43	80
4		0,08	1,0	5,10	3,2	42	65
5		0,08	2,0	4,68	3,0	22	-
6		-	-	6,95	-	-	-
7		1,0	-	5,1	4,5	30	-
8		0,25	-	6,0	4,0	28	-
9		0,10	-	6,5	4,0	25	-

Presented in Table. 4.4. the data indicate the effectiveness of the reagents used.

The results of studies of the effect of iron sulfate, sulfuric acid and flocculant MIC-402 on the process of thickening of activated sludge are given in tables 4.5 and 4.6.

Table 4.5. Effect of iron sulfate on the thickening process of the suspension of activated sludge by settling for 1 hour at different pH values (concentration of ADM (absolutely dry matter) in the initial suspension 0.92%)

No p/n	Activated sludge suspension treatment modes		Pre-acidification of activated sludge suspension with sulfuric acid (pH)	Microbial biomass concentration (% ADM)	
	Consumption 0,05% ferrous sulfate, %	Mixing		In sediment	In clarified liquid
1	-	-	6,9	1,44	0,41
2	0,01	agitator 5 min	6,9	1,62	0,22
3	0,05	agitator 5 min	6,9	2,03	0,18
4	0,1	agitator 5 min	6,9	2,32	0,12
5	0,01	pneumatic for 5 min	6,9	1,56	0,37
6	0,05	pneumatic for 5 min	6,9	1,98	0,20
7	0,10	pneumatic for 5 min	6,9	2,36	0,12
8	0,01	pneumatic for 5 min	5,0	1,58	0,36
9	0,05	pneumatic for 5 min	5,0	2,10	0,22
10	0,10	pneumatic for 5 min	5,0	2,38	0,11
11	0,01	pneumatic for 5 min	4,0	1,64	0,33
12	0,05	pneumatic for 5 min	4,0	2,16	0,20
13	0,10	pneumatic for 5 min	4,0	2,40	0,11
14	0,01	pneumatic for 5 min	3,5	1,60	0,32
15	0,05	pneumatic for 5 min	3,5	2,15	0,18
16	0,10	pneumatic for 5 min	3,5	2,44	0,10

Table 4.6. The effect of cationic flocculant VPK-402 on the separation of the suspension of activated sludge by settling for 1 hour (the initial concentration of activated sludge in the suspension is 0.84%).

Nop/n	Concentration of reagents			Microbial biomass concentration (% ADM)	
	0,05% $FeSO_4$ Flow rate (%)	70%, H_2SO_4 mg/l	0,01% VPK-402, mg/l	In sediment	In clarified liquid
1	0,05	-	4	2,21	0,18
2	0,05	-	8	2,24	0,13
3	0,05	-	12	2,27	0,12
4	0,05	-	16	2,19	0,07
5	0,05	-	20	2,18	0,07
6	-	0,6	4	2,63	0,10
7	-	0,6	8	2,54	0,10
8	-	0,6	12	2,48	0,09
9	-	0,6	16	2,50	0,06
10	-	0,6	20	2,52	0,06

The presented data on the compaction of the foam layer formed during the flotation of activated sludge with the addition of iron sulfate and phennopole show (Table 3, 4) that at the concentration of iron sulfate of 0.25-0.35 mg / l and the concentration of phennopole (1-10 mg / l), the volume of the foam layer (height) decreases by 1.5-2.0 times compared with the control without the addition of reagents.

The use of flocculants for thickening activated sludge and clarifying wastewater has become very widespread in world practice. However, the mechanism of interaction of flocculants with contamination particles and, consequently, the possibilities of their more complete use, in particular the combination of simultaneous use of various flocculants, have not yet been fully disclosed. Samples of activated sludge samples were taken both at city and factory (biochemical plant treatment plants) treatment facilities. Such selection made it possible to immediately assess possible differences in the behavior of active sludges selected from various structures.

The study of the effect of reagents on the thickening process of the sludge sludge was carried out using a pressure flotation unit and settling in the cylinders, which made it easier to interpret the data obtained.

Iron sulphate ($FeSO_4$) and phennopole supplements were tested on samples of activated sludge selected at local treatment plants by stirring and then the reactive sludge suspension was mixed with the working fluid (dispersion water) in a 1:1 ratio. Iron sulfate ($FeSO_4$) in the form of a liquid was used as a coagulant. The impact of reagents was assessed by the height of the foam layer formed during flotation, by COD and the turbidity of the liquid phase.

In Table. 4.7 shows the conditions for processing the suspensions of activated sludge with reactants and the effect of separation of the sludge suspension achieved in this case.

Table 4.7. Influence of reagent treatment on the separation of activated sludge sludge (urban treatment plants) by flotation (flotation time 10 min, activated sludge: dispersion water ratio 1:1)

No p/n	Activated sludge suspension quality	Number of reagents to be added		pH of activated sludge suspension	Separation efficiency		
		$FeSO_4$ in the form of a solution, ml	Fennopol 0.01% solution, ml		Foam layer height, cm	Turbidity	COD (SODTOT) (mg/L) liquid phase
1	Activated sludge after	-	-	6,93	5,0	48	170

	stabilization for 1 hour						
2	Activated sludge after a 6-hour stay in anaerobic conditions	-	-	6,94	5,2	45	260
3	Activeatedsludge after hour-long aerobic stabilization	0,08	-	5,20	3,0	43	80
4		0,08	1,0	5,10	3,2	42	65
5		0,08	2,0	4,68	3,0	22	-
6		-	-	6,95	-	-	-
7		1,0	-	5,1	4,5	30	-
8		0,25	-	6,0	4,0	28	-
9		0,10	-	6,5	4,0	25	- (*)

- (*) – data not received

Analysis of the data presented in Table 4.7 shows that the addition of reagents in combination with iron sulfate leads to quite satisfactory results.

As a result of studies conducted on samples of a suspension of activated sludge selected at the factory treatment facilities, it was established that one of the effective reagents is the cationic flocculant VPK-402, added in combination with ferric sulfate or sulfuric acid. The results of the research are given in Table. 4.8 and 4.9.

Table 4.8. Effect of iron sulfate on the condensation process of the suspension of activated sludge by settling at different pH values (concentration of ADM (absolutely dry substances) in the initial suspension 0.92%)

No p/n	Activated sludge suspension treatment modes		Pre-acidification of activated sludge suspension with sulfuric acid (pH units)	Microbial biomass concentration (% ADM)	
	Consumption of ferrous sulfate, %	Mixing		In sediment	In clarified liquid

1	-	-	6,9	1,44	0,41
2	0,01	agitator 5 min	6,9	1,62	0,22
3	0,05	agitator 5 min	6,9	2,03	0,18
4	0,1	agitator 5 min	6,9	2,32	0,12
5	0,01	pneumatic for 5 min	6,9	1,56	0,37
6	0,05	pneumatic for 5 min	6,9	1,98	0,20
7	0,10	pneumatic for 5 min	6,9	2,36	0,12
8	0,01	pneumatic for 5 min	5,0	1,58	0,36
9	0,05	pneumatic for 5 min	5,0	2,10	0,22
10	0,10	pneumatic for 5 min	5,0	2,38	0,11
11	0,01	pneumatic for 5 min	4,0	1,64	0,33
12	0,05	pneumatic for 5 min	4,0	2,16	0,20
13	0,10	pneumatic for 5 min	4,0	2,40	0,11
14	0,01	pneumatic for 5 min	3,5	1,60	0,32
15	0,05	pneumatic for 5 min	3,5	2,15	0,18
16	0,10	pneumatic for 5 min	3,5	2,44	0,10

Table 4.9. Effect of cationic flocculant VPK-402, iron sulfate and sulfuric acid on the separation of the suspension of activated sludge (factory treatment plants) by settling for 1 hour (initial concentration of activated sludge 0.84% of absolutely dry substances - ADM)

Nop/n	Concentration of reagents	Microbial biomass concentration (% ADM)

	Ferrous sulfate, %	Sulfuric acid, mg/l	VPK-402, mg/l	In sediment	In clarified liquid
1	0,05	-	4	2,21	0,18
2	0,05	-	8	2,24	0,13
3	0,05	-	12	2,27	0,12
4	0,05	-	16	2,19	0,07
5	0,05	-	20	2,18	0,07
6	-	0,6	4	2,63	0,10
7	-	0,6	8	2,54	0,10
8	-	0,6	12	2,48	0,09
9	-	0,6	16	2,50	0,06
10	-	0,6	20	2,52	0,06

The data presented in Tables 4.7 – 4.9 indicate the advantages of using flotation for sludge thickening compared to settling.

In the case of flotation, the intensification of the process depends both on the optimal regime determined by kinetic constants and on the use of reagents.

The basic kinetic constants of the flotation process can be determined from the following relations:

the constant *K_1,* which determines the intensity of the formation of flotation complexes, can also be found from the ratio: ($K_1 = \frac{1.5qE}{k_0\overline{D}}$ I), where q is the amount of gas (V) released from the liquid on the unit surface (S) of the flakes of activated sludge per unit time (t) and at the same time q = V / S t; *E* - the probability of the formation of gas bubbles on the flakes of activated sludge; - the average diameter of the bubbles formed on the flakes of activated sludge; $\overline{D}$ *to_0* is the mass ratio of the solid and gas phases. Most often, the value of this constant is taken to be 10-3-10-4 $^{s-1}$.

The movement of the particle-bubble fleets from the liquid to the foam layer is characterized by a constant (2), where $K_3 = \frac{\upsilon_{под}}{h}$ *υ_{sub}* is the rate of lifting of the flotation complex; *h* is the distance from the aeration zone to the foam layer (depth of the flotation chamber). In most cases, the value of this constant is taken to be about 10-3 $^{s-1}$. Taking into account the specified values of kinetic constants, the mode of flotation thickening of activated sludge was used, which also includes the addition of reagents.

The obtained data on the compaction of the foam layer formed during the flotation of activated sludge with the addition of iron sulfate and phennopole show (Fig. 1, 2) that at the concentration of iron sulfate of 0.25-0.35 mg / l and the concentration of phennopole (1-10 mg / l), the volume of the foam layer (height) decreases by 1.5-2.0 times compared to the control (without adding reagents). At the same time, the value of the turbidity of the clarified liquid phase is also reduced by 3-5 times, which indicates a decrease in the content of suspended and dissolved substances in the liquid phase. The latter is confirmed by measuring chemical oxygen consumption (COD), which decreases by 2-3 times or more.

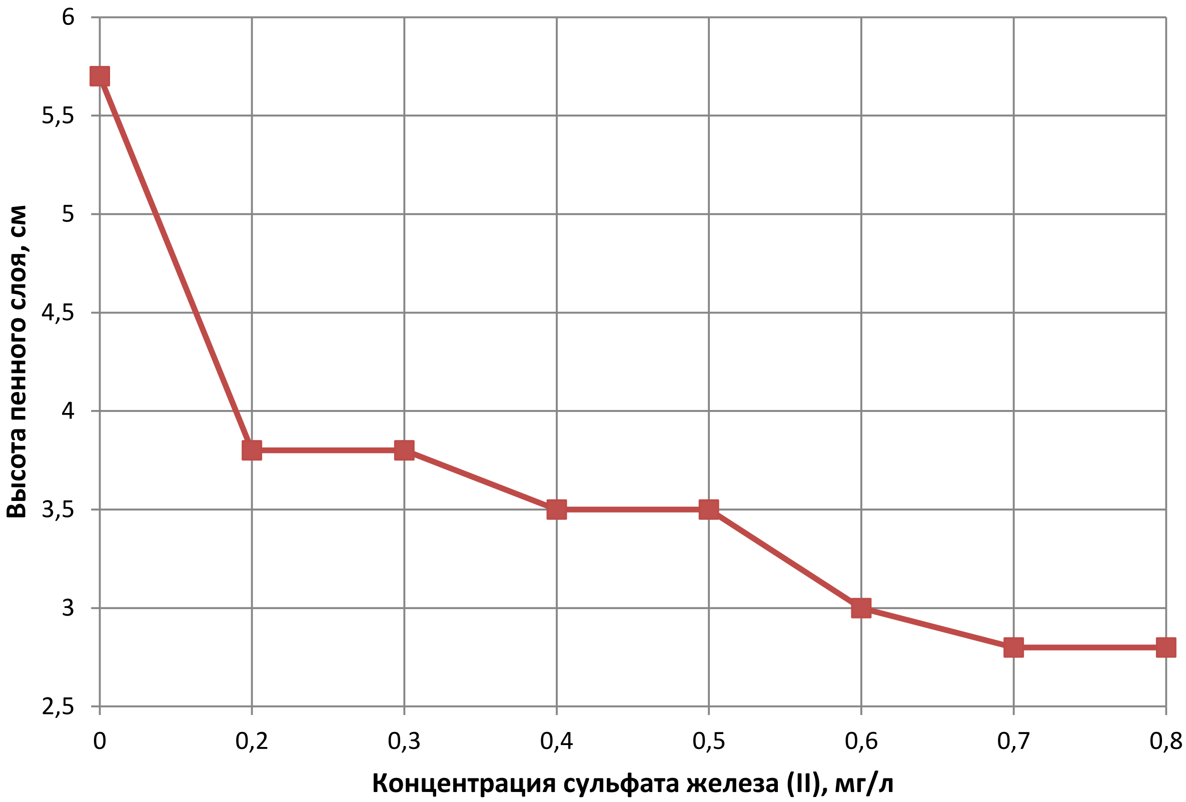


Fig. 4.4. Dependence of the height of the foam layer of the fleeted activated sludge on the consumption of the added ferrous sulfate

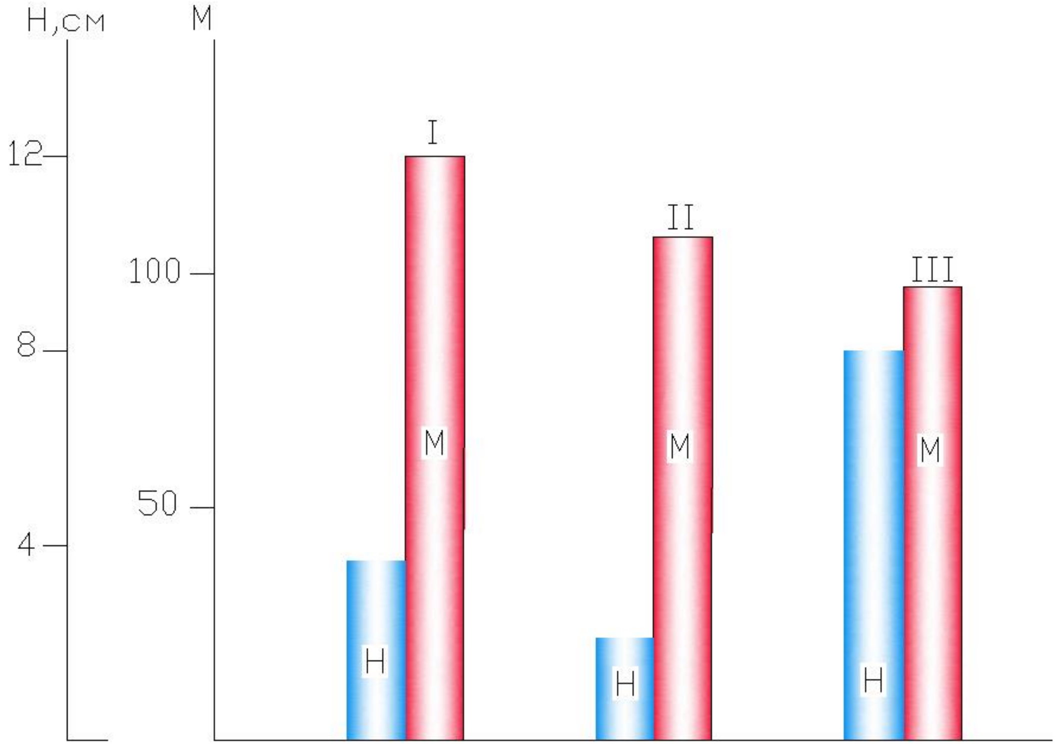


Fig. 4.5. Influence of phennopol in combination with ferrous sulfate on the efficiency of flotation separation of activated sludge

At concentrations of iron sulfate ($FeSO_4$) of more than 0.3-0.4 mg / l, an even more pronounced effect of compaction of the foam layer is achieved, but at the same time the turbidity value increases, which is undesirable and economically, apparently impractical, since this significantly increases the consumption of iron sulfate.

It is of practical and scientific interest to compare the efficiency of processing a suspension of activated sludge with iron sulfate in combination with phennopol and sulfuric acid (Fig. 4.6 – 4.7).

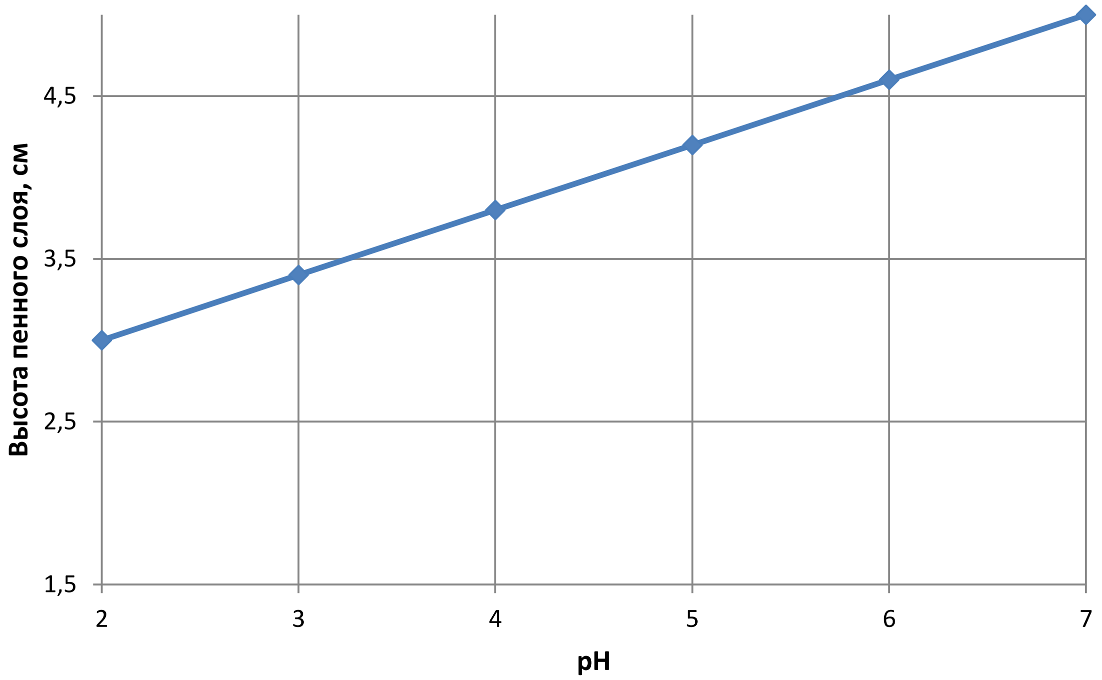


Fig. 4.6. Dependence of the height of the foam layer of the floated activated sludge on the pH value

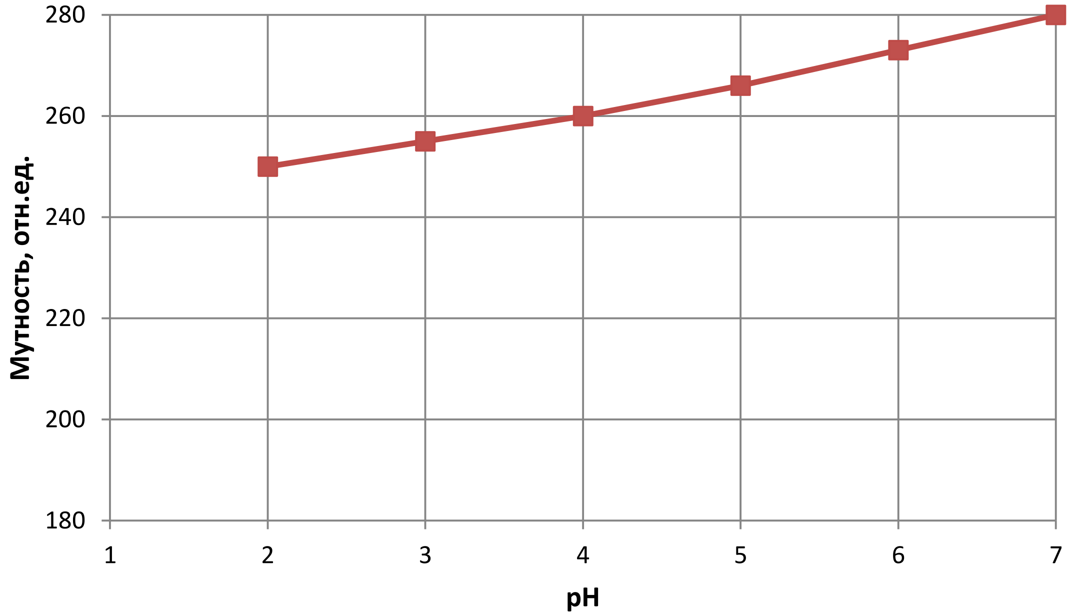


Fig. 4.7. Dependence of the turbidity of the clarified liquid after the separation of the activated sludge by flotation on the pH value of the liquid phase

Treatment of activated sludge with sulfuric acid leads to coagulation of activated sludge particles and to an improvement in the separation of the suspension into a foam layer and a liquid. In this case, the foam is obtained 2.0-2.5 times denser at a pH of 2.5-4.5 than at a pH of 6.6-7.0 (without adding acid). At pH values of 2.5-4.5, the turbidity of the clarified liquid is reduced by 4-5 times compared to the turbidity of the liquid obtained by separating the sludge suspension by flotation without adding sulfuric acid.

The results obtained on the effect of phennopol on the process of flotation of activated sludge correlate with the data obtained in the study of VPK-402 on the process of settling activated sludge. In both cases, the effectiveness of these cationic flocculants increases with the additional use of coagulants - ferrous sulfate and sulfuric acid. It is known that the macromolecules of both flocculants carry positively charged groups, in particular, the micromolecules of VPK-402 include groups N + (CH3) 2Cl, allowing to achieve a sufficiently high charge value of about 40 mV. The presence of a charge of this magnitude indicates the possibility of interaction of cationic flocculants with organic substances dissolved in water, for example, anion-active collectors such as carboxylic acid soap. The choice of anion-active collectors as the object of research is due to the fact that they, along with cationic active flocculants, can potentially be used in the flotation processes of activated sludge. The joint addition of cationic-active flocculants and anion-active collectors the suspension of activated sludge requires study from the interaction in aqueous media. To this end, studies were conducted to elucidate the interaction of cationic flocculants MIC-402 and phennopole with anion-active collectors on the example of technical fatty acids (TFA) and crude tal oil (CM). At the same time, a different amount of MIC-402 and fennopol was added to an aqueous solution of saponified technical fatty acids and crude thalic oil with a concentration of 60 mg / l. The study of the properties of solutions of TFA and STM with flocculants additives was carried out by measuring optical density. The results of studies show that with an increase in the concentration of flocculant, there is first an increase in optical density, and then its decrease. At the same time, the most dramatic increase in optical density is observed in stM solutions, and the maximum is noted with the addition of VPK-402 with a flow rate of 3 mg / l, and with the introduction of phennopol with a consumption of 2 mg / l. A less pronounced effect of increasing optical density was observed when adding flocculants to the solution of technical fatty acids. The increase in optical density is associated with an increase in the number of intermolecular bonds between the macromolecules of cationically active flocculants and anion-active collectors, and a further decrease is due to the sediment of the formed complexes into the sediment.

The data obtained indicate the possibility of joint addition of activated sludge of TFA and cationic active flocculants to the suspension.

Thus, studies have shown that the addition of cationic active flocculants leads to their interaction not only with the cells of activated sludge microorganisms, but also with some dissolved organic substances. In this case, it is possible to add activated sludge to the suspension along with cationically active flocculants of saponified fatty acids.

Thus, with a certain ratio of the coagulant $FeSO_4$ and the flocculants used, it is possible to obtain the maximum concentration of the solid phase in the thickened suspension of activated sludge and the minimum in the clarified liquid. The results obtained make it possible to recommend options for reagent treatment of activated sludge. In this case, the volumetric costs of the reagent are reduced by 1.5-3 times.

4.3. Thermostatic treatment of activated sludge

The use of thermoagent treatment can significantly intensify the process of thickening of activated sludge by separation or centrifugation. Under the guidance and with the participation of the author, experimental and industrial tests of the technology of thickening the suspension of activated sludge using thermoagent treatment of thickening of activated sludge were carried out. Heat treatment was carried out with a sharp steam, and diluted sulfuric acid and a protein solution were used as a reagent.

In Fig. 4.8 shows a scheme of pilot tests of the technology of thickening the suspension of activated sludge using thermoagent treatment of thickening of activated sludge.

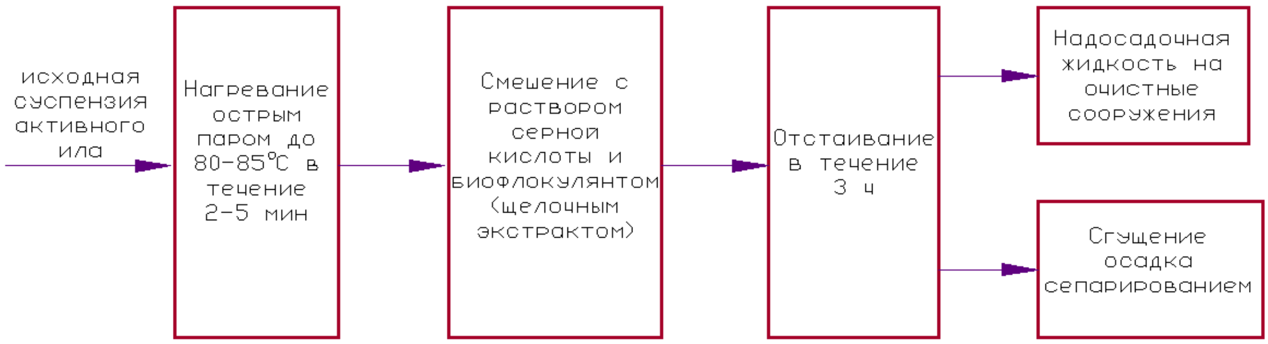


Fig. 4.8. Schematic technological scheme of pilot tests of thickening of activated sludge suspension with pre-thermoresagent treatment

According to the above condensation scheme (Fig. 4.4), a suspension of excess activated sludge with a concentration of 0.8-1.2% of ACB is fed for heat treatment (85 ° C) to intensify the flocculation process that occurs under the combined effects of thermal and physicochemical effects.

After treatment, sulfuric acid is added to the suspension to change its pH from 6.8-7.5 to 3.5-4.0 and a protein solution obtained by extraction treatment of the yeast suspension is added as a flocculant, as well as the yeast suspension itself.

A suspension of activated sludge with a floculated dispersed phase is fed into the settling tank, where it is pre-condensed to 2.5-4.0% ADM, and then to separation and then to the spray dryer.

Heat treatment is carried out with sharp steam using an ejector installed in the supply line of the suspension of activated sludge. Reagents (sulfuric acid and protein extract, yeast or waste culture liquid) are introduced into the mixer. At this stage, the following is determined and controlled: ADM of the initial sludge suspension, %; pH of the suspension in the mixer; suspension temperature before and after the mixer; the amount of reagents supplied.

The suspension of activated sludge after thermoreagent treatment is sent to the settling tank, where within 3 hours it settles and compacts the formed sediment. Condensed to 2.5-4.0% ADM suspension is sent for separation, and the clarified liquid is discharged into the sewer.

From the analysis of the results obtained (Table 2.10), it follows that after a single separation with preliminary heat treatment, the degree of thickening is 6-10, and the loss with fugate is up to 0.2-0.4% ACB.

Table 2.10 – Results of pilot tests of thickening of activated sludge suspension

Thermostatic treatment mode			Time spent in the sump, h	Biomass concentration, % ADM				
temperature after ejector, oC	pH after mixer	flocculant		In the original suspension	After the sump		After separation	
					In sediment	In the plum	In a condensed product	In fugate
85	4,2	Alkaline Yeast Processi	2,5	1,32	3,8	0,4	8,05	0,15

		ng Extract						
85	3,5	Ditto	3,0	0,98	4,05	0,38	10,5	0,2
85	3,5	Yeast (pH 10.5)	3,0	0,95	3,85	0,38	7,8	0,21
Without heat treatment (22)	7.2 (no acid added)	Not added	3,0	0,95	1,85	0,42	4,4	0,23
Without heat treatment	7.1 (no acid added)	Ditto	-	1,2	-	-	3,6	0,45
85	6.8 (no acid added)		3,0	1,1	2,5	0,48	6,2	0,3
85	5,6	Waste culture fluid up to pH 5.6	3,0	0,98	2,6	0,5	7,6	0,26

Tests of the process scheme of thickening of activated sludge with pre-thermoreagent treatment also showed that the process parameters significantly depend on the state of the initial sludge suspension. Pre-treatment not only improves the condensation process of the suspension, but also dramatically slows down the decay of microbial biomass.

The developed method was used in the industrial practice of thickening the activated sludge production of fodder yeast.

5. Mechanical dewatering of wastewater sediment

5.1. Screw thickeners

Traditional mechanical equipment for the dewatering of wastewater sediment at treatment plants are screw thickeners, vacuum filters, filter presses (frame, chamber and belt), centrifuges. As a rule, the processes of mechanical dehydration are carried out using flocculants, which can significantly increase the productivity of the dehydration process.

In recent decades, screw dehydrators have been used, which give a good technological effect.

The compact design of the screw dewaterer on a single frame includes everything you need: a receiving tank, a flocculation tank with a stirrer, a dehydrating drum with a flushing system and a pallet for collecting and removing leachate. In Fig. Figure 5.1 shows a diagram of such a screw dehydrator.

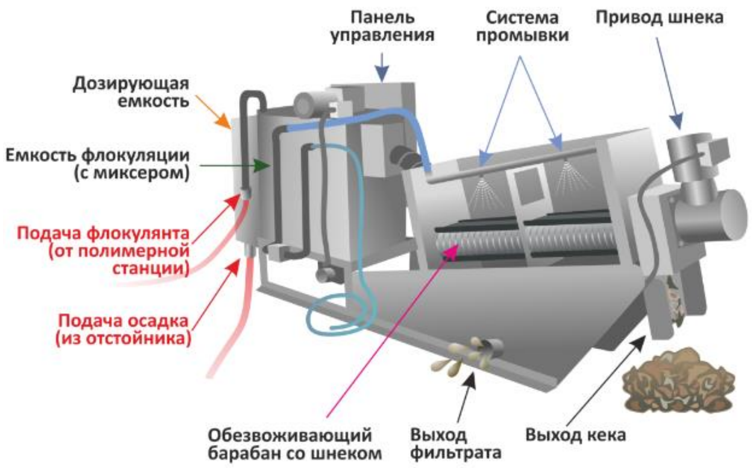


Fig. 5.1. Scheme of screw sediment dehydrator

The principle of operation and arrangement of the dehydrating drum of the screw sediment dehydrator is presented in Fig. 5.2.

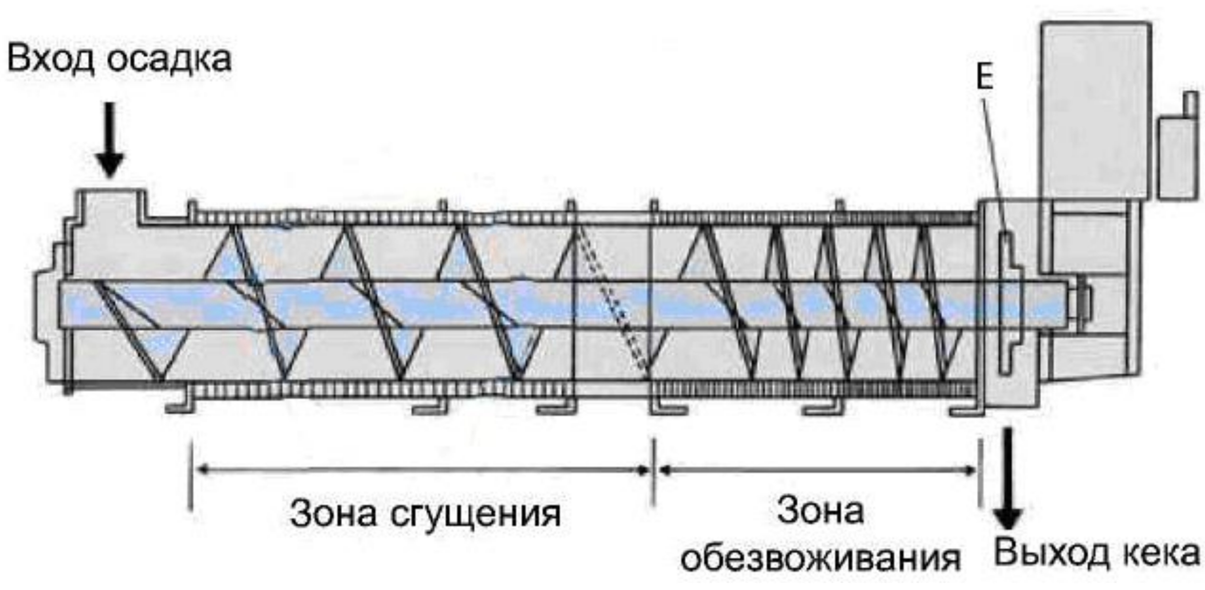


Fig. 5.2. Installation of dehydrating drum of screw sediment dehydrator

The dehydration drum consists of an auger rotating at a constant speed, with its outer surface bounded by fixed and moving rings with fixed gaps between them. The speed of rotation of the screw is regulated by a frequency converter, which allows you to change the performance of the dehydrator.

Sludge dehydration begins with the automatic pump supply of sediment from the secondary sump to the receiving tank. In this container, the required amount of condensed sediment enters the flocculation tank through overflow. Excess sediment is sent for recycling. At the same time, a flocculant solution is supplied at the same time. The precipitate is mixed with the flocculant using a stirrer. The treated precipitate is then redirected to a dehydrating drum. The speed of rotation of the agitator is adjusted using a frequency converter to adjust the optimal flak formation for different concentrations of sediment.

In the first part of the drum, the sediment undergoes mechanical thickening with the separation of the free liquid through the gaps between the movable and stationary rings, the sediment is propelled by the auger along the drum under the excess pressure created by the pressure plate and dehydrated. In this case, the filtrate flows through ring gaps, the width of which is 0.5 mm in the thickening zone and from 0.3 mm at the beginning and 0.15 mm at the end of the dehydration zone. The pitch of the screw turns is also reduced, creating pressure in the dehydration zone. At the end of the screw there is a pressure plate that regulates the internal pressure in the drum. After pressing, the sludge is reloaded into the collector, and the filtered water is returned back to the head of the treatment facilities along with other return flows. Rotating, the screw changes the position of the moving rings, which leads to constant friction of the surfaces of the rings, thereby ensuring the inoclubility of the filter gaps of the screw drum of the dehydrator. After spinning, the cake, depending on the capacity of the installation, is either collected in a bag container or sent by a screw conveyor to the collection hopper, after which it is taken to the sediment disposal sites.

As special advantages of the device, the following should be noted.

The device has a built-in thickening zone, which prevents the need for additional equipment for thickening the sediment and allows you to dehydrate the sediment with a low concentration of suspended substances.

The device can dehydrate sediments with a concentration of suspended particles from 2 g / l to 35 g / l, which allows you to work with any concentration range and allows changes in inlet concentrations during the operation of the equipment.

The dehydrator is characterized by a low level of noise and vibration. It does not require a special foundation, noise-proof casing, etc.

Screw sediment dehydrators are considered the most universal, since they can be used to dehydrate all types of wastewater sediment - household, agricultural, surface, industrial, etc. The screw dewaterer of the sludge works on the principle of a manual screw juicer. The filtered liquid flows out along the entire length of the casing, collected from loose ring elements, and the sludge as the screw rotates with an inter-turn distance decreasing to its end, is compressed, collected at the outlet in the container and then used for its intended purpose - disposed of, processed or taken to the fields.

Existing analogues of screw thickeners have similar designs and the same principle of operation.

The most common in the world are screw dehydrators of the Japanese company AMCON (Fig. 5.3-5.4).

Figure 5.3 – general view of the screw dehydrator of the Volute Dehydrator series from AMCON

The compact design on a single frame includes everything you need: a receiving tank, a flocculation tank with an agitator, a dehydrating drum with a flushing system and a pallet for collecting and removing leachate. The unit is available in 2 series: VT series – used to seal sludge mixtures with initial humidity ... 99,6-99,2% to humidity 96-97%; ES series - used for compaction and dehydration of sludge mixtures with a starting humidity of 94.0-99.8% to a humidity of 80% or less. The units differ in that the drum of the VT series unit does not contain a pressure plate at the outlet of the thickener.

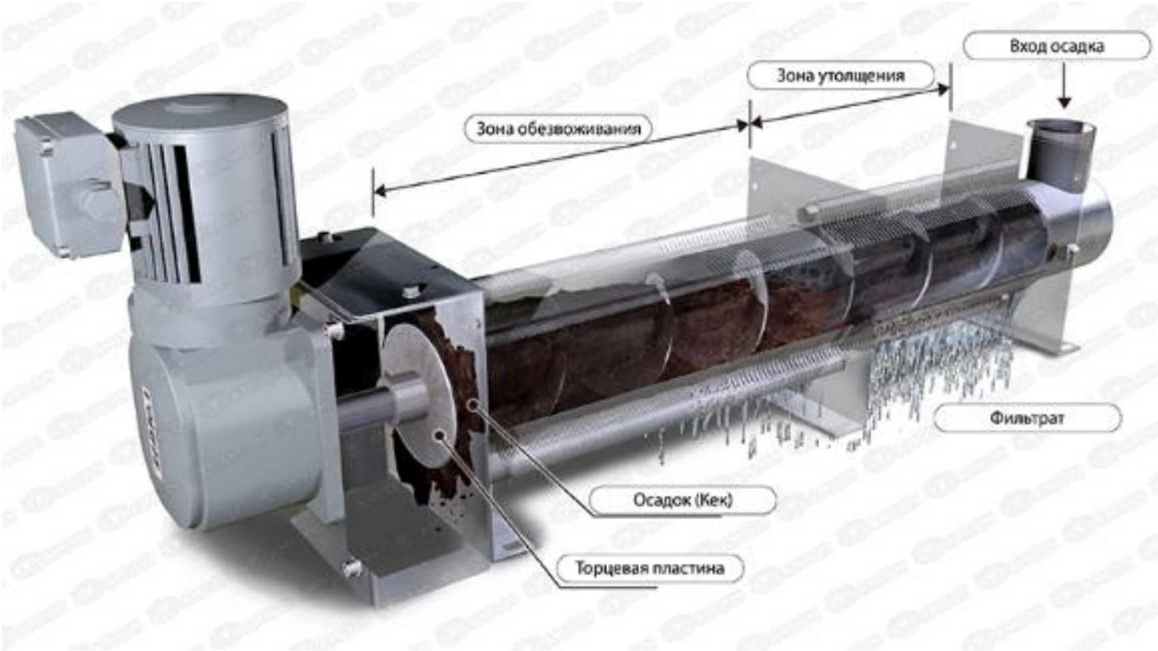


Fig. 5.4 – general view of the AMCON dehydrating drum

Due to their advantages, screw dehydrators quickly became widespread and are used in practice in many countries of the world. Russian production offers sediment dehydrators N-Auger of JSC "NOOSPHERE" (Fig.5.5).

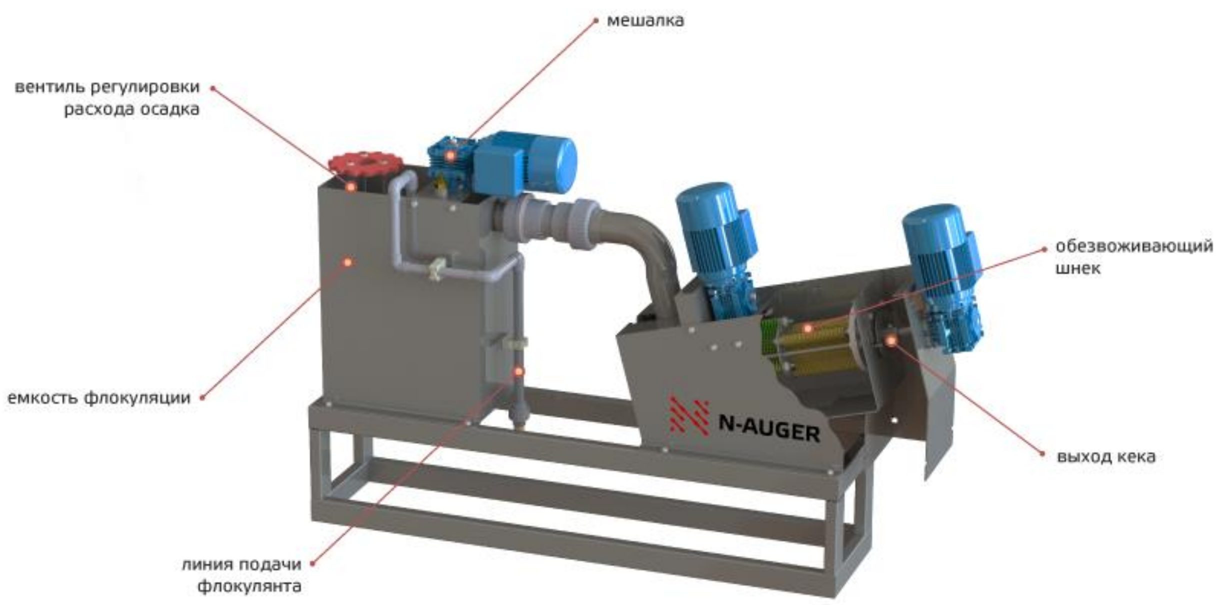


Fig. 5.5. N-Auger sediment dehydrator device of JSC "NOOSPHERE"

A distinctive feature of the dehydrators of this company is the presence of a special design to prevent clogging of the gap between rotating and floating rings, sediment particles and, as a result, a decrease in the productivity and efficiency of the dehydrator. At the heart of this design is the possibility of radial displacement of floating rings relative to rotating ones. Thus, complete cleaning of gaps is achieved, which prevents disruption of the functioning of the sludge dehydrator. This system does not require additional external flushing of the screw housing with water supplied from the outside. Only the water that is released from the sediment in the process of dehydration is enough.

An example of the calculation of a screw sediment thickener is presented in Annex 1.

For the initial data: performance - Q and concentration of solid phase in the sediment Сисх

$Q = 15\frac{m^3}{\mathrm{h}};$

$C_{исх} = 15\frac{\mathrm{g}}{\mathrm{l}}.$

Let's get the basic parameters of the screw thickener

Options	Designation	Meaning
Diameter, mm	D	650
Screw shaft length, mm	L	1095
Screw inclination angle, deg	B	20

5.2. Condensation of wastewater sediment and excess activated sludge using hydrocyclones and centrifuges

The suspension of activated sludge, as is known, refers to hard-to-thicken systems, which is explained by the weak water transfer of the biomass of activated sludge. At the same time, the thickening process is hampered by the presence of a large number ofabrasion impurities. According to a number of developers, in the absence of these impurities and when using fresh biomass of activated sludge, the problem of thickening of activated sludge would be solved. similarly, as for most suspensions of various industrial microorganisms. Asshown by the studies conducted by the author at several biotechnological enterprises, the suspension of fresh activated sludge with pre-heat treatment thickens well, for example, on separators COC 501 T-2. The disadvantage of this method is the frequent shutdown of separators for washing due to the presence of abrasive impurities in the thickened suspension, in particular sand particles.

In recent years, in the practice of dewatering sludge formed during the treatment of wastewater (urban), the method of centrifugation, which is one of the most effective, has been widely used.

In domestic practice, sedimentary horizontal centrifuges with screw discharge of sediment (OGSH type) have become widespread. Their advantage is compactness, ease of maintenance. They provide dehydrated sediment of low humidity, require relatively low costs for processing the sediment.

A diagram of a horizontal sedimentation centrifuge is shown in Fig. 5.6.

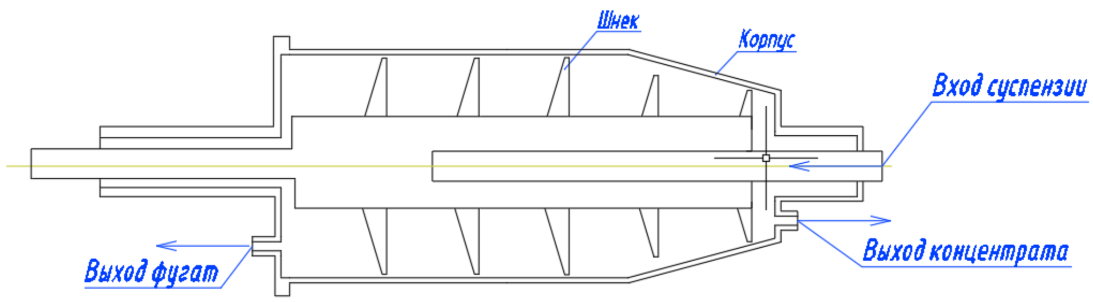


Fig. 5.6. Scheme of horizontal sedimentation centrifuge

As an example, we give the technicalcharacteristics of some types of domestic centrifuges.

Technical characteristics of domestic centrifuges of OGSH type

	OGSH-501K-10	OGSH-1001K-01
Inner diameter of the drum, mm..................	500	1000
The ratio of drum length to diameter.......	3,6	3,6
Maximum drum speed, min-1.......	2650	1000
Torque transmitted by the gearbox, kgf/m.....	600	4500
Power of the main electric motor, kW....	75	100
Gauge, mm...	3880x2510x1340	6590x3550x2080
Mass, kg....	7145	13800

To thicken excess sludge formed in the process of biological wastewater treatment, the SDS-631K-04/3/13 separator is designed, consisting of a bed with a drive mechanism, a rotor, a receiver-output device and a sludge receiver.

The separator has a recirculation system to increase the degree of sludge thickening and increase the CIP period of operation, equipped with an automatic separation and thickening control system.

The separator can be used at aeration stations with a capacity of 20-300 thousand m3 / day.

Technical characteristics of the separator SDS-631K-04.

Capacity for the original active sludge, m3/h.................... 25-30

Drum diameter, mm.... 630

Drum speed, min-1........... 5000

Electric motor power, kW.... 75

Gauge, mm... 2290x1140x2385

Mass, kg......... 3600

Service life of separators, years.... 5

Centrifugal thickening of excess activated sludge has become widespread in many countries of the world. At the same time, research in the direction of improving and creating new designs of centrifuges for thickening activated sludge continues.

Comparative characteristics and performance indicators of centrifuges for thickening activated sludge are given in Table. 5.1 (according to Agranonics R.Y.).

Table 5.1 Comparative characteristics and performance of centrifuges for thickening activated sludge.

Centrifuge type	Drum diameter, mm	Drum length, mm	Partition factor, F	Capacity, m3/h	Condensed sludge terminal, %	Effectiveness of dry matter	Naming of the facility where

						retention, %	the centrifuge tests are performed
OGSH-501 K10	500	1800	1500	10 16	7,5 7,0	93 85	Šiauliai (Lithuania)
A X-417 of the company "Alfa Laval" (Sweden)	355	1400	2000	6 12	5,5 4,5	91 74	Tampere (Finland)
RM-35000 by Penvalt (Great Britain)	425	1260	2360	6 13	8-7	82 73	Tver
Humboldt S2-1	450	1350	700	5-7	7-6	50-70	Hanno-ver (Germany) Stoke-golm (Sweden)

For the dewatering of industrial wastewater and municipal sludge, Humboldt designed and developed a centrifuge design in which deposition takes place in a direct joint flow of solid and liquid phases (Figure 5.7).

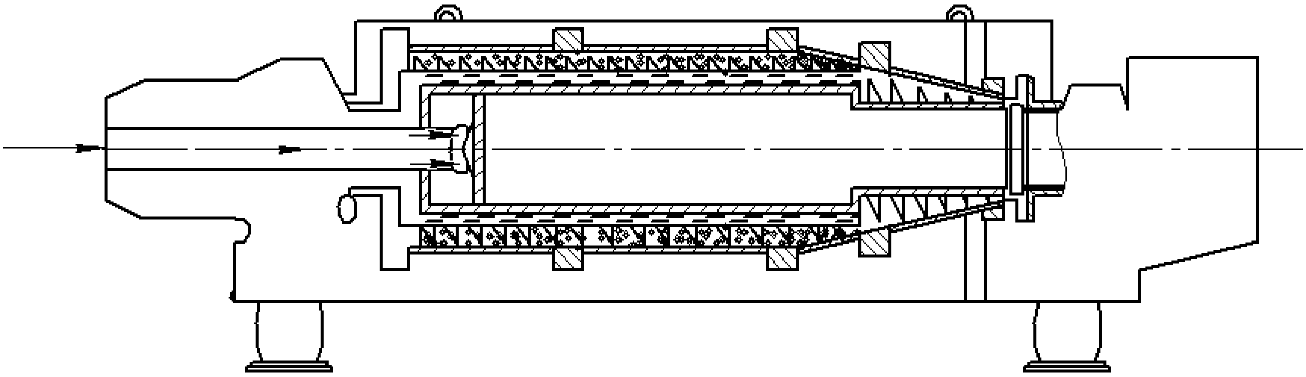


Fig. 5.7. Centrifuge for condensation of wastewater sediment by "Humboldt Wedag"

In a conventional centrifuge with a solid shell, the separated suspension is assembled in the middle of the drum. There, as a result of the counterflows of the solid and liquid phases, as well as as as a result of the return of the solid phase to the same place, the deposition process isdisturbed by turbulent flows, which, however, in the usuallyprecipitated solid phase process practically does not disrupt the separation process. In a straight-flow centrifuge, the deposition process, and with it the deposition zone, begins immediately at the suspension in front of the back wall of the drum.

In this case, the deposition process has a longer duration in time, which makes it possible to deposit even the smallest particles, which causes a large compaction of the solid phase, a smaller percentage of humidityin it and the production of a sufficiently well-purified fugatea (centrifuge).

The centrifuge is poured out after the cleaning process is completed through the valve. The optimal value of the liquid depth in the drum is carried out by adjusting the threshold of the drain valve.

For the treatment of loose sludges, a leading auger is used at a greater depth of liquid in the drum, which causes a particularly favorable process flow, less effort, a high output of the solid phase with a negligible degree of humidity.

For the treatment of highly concentrated sediments, a hydrocyclone with tympanic discharge of sediment is intended. A feature of the design is the presence in the chamber of the condensed product of two drums rotating from the flow of condensed suspension. When the drums rotate, the sediment is squeezed and its concentration increases.

The use of hydrocyclones with self-pulsating sand nozzles is promising. A distinctive feature of such a hydrocyclone is the use of a sand nozzle made of elastic material, for example, soft rubber, and its installation with a gap in the fixing washer. During the operation of the hydrocyclone, the condensed flow at the exit from the apparatus causes oscillations of the sand nozzle, which, in turn, are transmitted to the condensed flow, contributing to the additional pressing of the condensed phase. Comparative tests have shown that the degree of thickening of the solid phase when using hydrocyclones with self-pulsating sand nozzles increases by 2 to 4 times.

In some cases, hydrocyclones began to be used instead of centrifuges and filters for washing the solid phase of the suspension. Battery hydrocyclones with a diameter of a single cell of 60 and 100 mm and a totalcapacity of 120 - 150 m3 / h instead of OGSH-120 centrifuges have been developed. The battery hydrocyclone is rationally arranged from single elements along the perimeter of the circle, during operation each element can be turned off. Single hydrocyclones are equipped with circulation tubes, as a result of which stagnant zones in the branch pipes are excluded during battery operation with partially switched off cells.

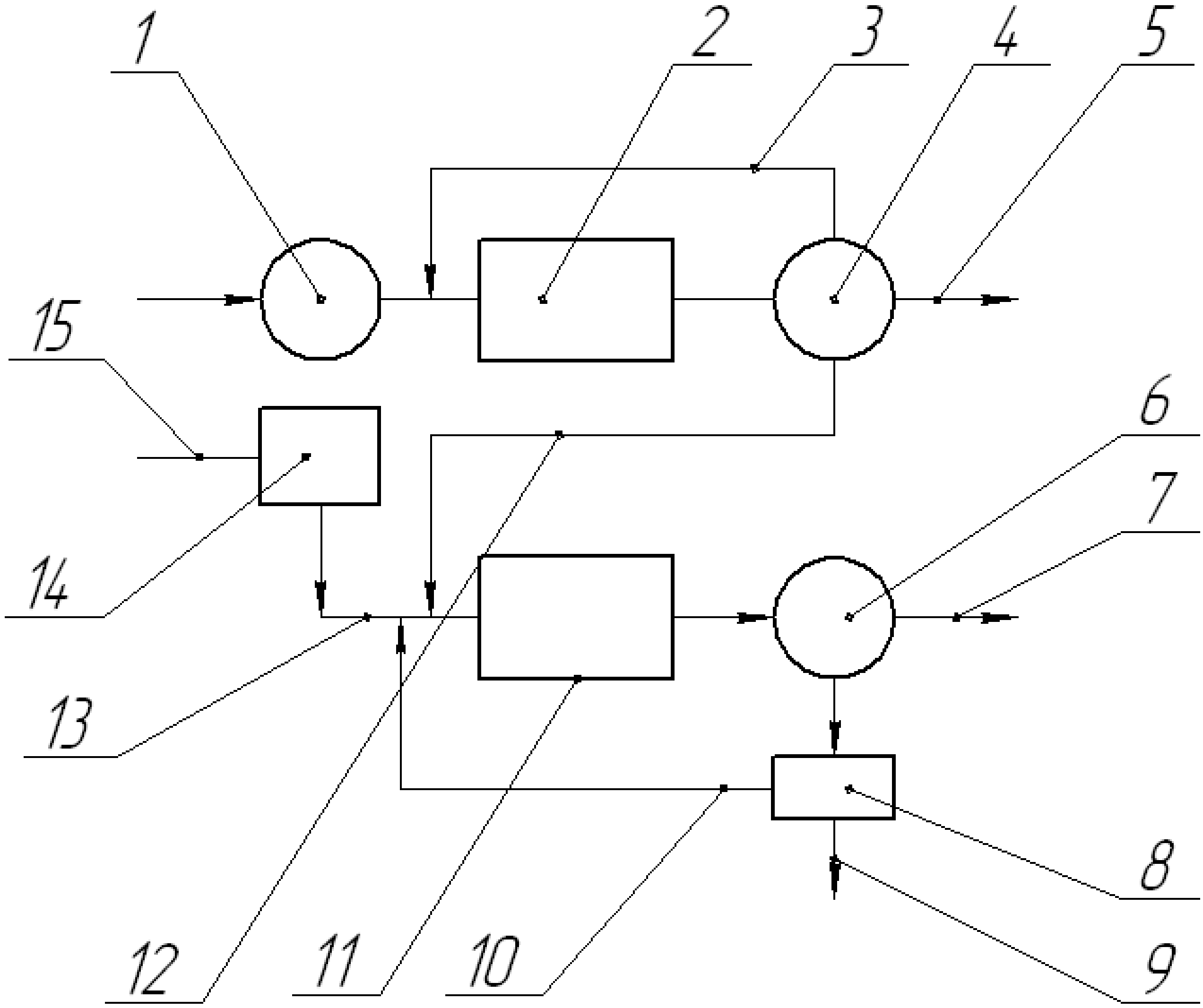


Fig. 5.8. Schematic diagram of dewatering of sedimentation of primary sedimentation tanks:

1 - primary settling tank; 2 - aerotank; 3 - supply of circulating activated sludge to the aeration tank; 4 - secondary settling tank; 5 - purified wastewater; 6 — sludge compactor; 7 - discharge of the drain fluid from the seal into the primary settling tanks; 8 - centrifuge; 9 - dehydrated precipitate for heat treatment; 10 - return of fugate to the mineralizer; 11 - mineralizer; 12 - supply of excess activated sludge to the mineralizer; 13 – supply of compacted sediment of primary settling tanks to the

mineralizer; 14 – sediment compactor of primary sedimentation tanks; 15 – sediment of primary sedimentation tanks.

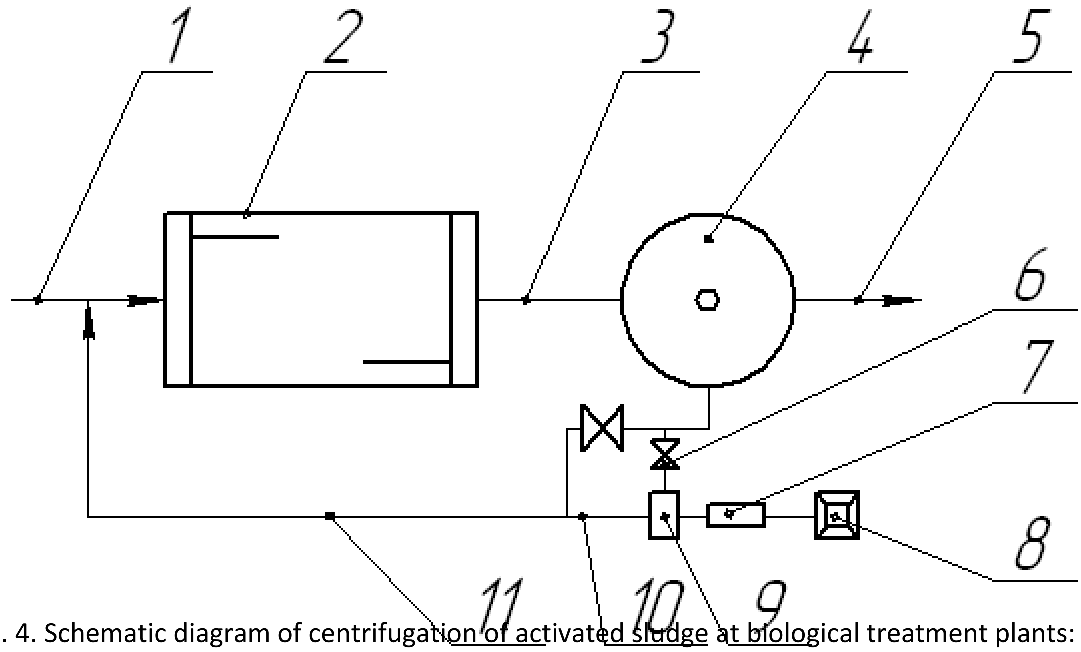


Fig. 4. Schematic diagram of centrifugation of activated sludge at biological treatment plants:

1 - supply of wastewater to the aeration tank; 2 - aerotank; 3 - inflow of sludge mixture into the secondary settling tank; 4 - secondary settling tank; 5 - discharge of purified wastewater; 6 - supply of activated sludge to the centrifuge; 7 - heat treatment of dehydrated sludge; 8 - sludge hopper; 9 - centrifuge; 10 - fugat; 11 - supply of fugate mixture with circulating activated sludge into the aeration tank

Fig.5.9. Schematic diagram of activated sludge dewatering (position numbers as in Fig. 5.8)

Technological schemes of centrifugal dewatering of sedimentation of primary sedimentation tanks and activated sludge are given respectively in Fig. 5.8, 5.9. Compared to other methods, this method of sediment treatment has a number of significant advantages: compactness of installations, ease of maintenance, economy and favorable sanitary conditions. The experience of using centrifuges and separators in technological schemes of sediment treatment revealed one of their significant drawbacks - waterjet wear of devices for removing dehydrated sludge (screws for centrifuges and nozzles for separators).

The maincause of waterjet wear is sand and mineral impurities contained in the sediment. In addition, the presence of sand and mineral impurities causes clogging of nozzles and inter-plate space of separators, which prevents their normal operation. Operating experience

shows that the screws of serial centrifuges made of steel

I2X18H10T, fail after 1500 - 3000 hours of operation of centrifuges. Auger cladding with stellite increases its service life to

5000 - 7000 h, and spraying the screw turns with tungsten carbide - up to 10,000-12,000 h. The cost of such a screw is about 30% of the cost of the centrifuge.

The efficiency of solid and ash emission during the treatment of activated sludge on a hydrocyclone with a diameter of 75 mm was 9 - 12 and 10 - 17%, respectively, At the same time, the degree of extraction of sand, which is an abrasive, reached 80%.

The results of the conducted studies allow us to conclude that hydrocyclones can be successfully used in technological schemes of centrifugal dewatering of wastewater sediment to isolate abrasive impurities from the sludge before feeding them to centrifuges and separators, increasing the durability and reliability of the latter. Let's consider in more detail the design and principle of operation of hydrocyclones.

In a hydrocyclone, the contents rotate in a fixed housing. Structurally, the hydrocyclone is much simpler than a centrifuge, since there are no moving elements in it. The hydrocyclone is also used for descaling, thickening of sludge and flotation products, clarification of circulating water. Principle

The action of hydrocyclones is based on the separation of solid phase particles in a rotating fluid flow (Figure 5.10). Separation rate

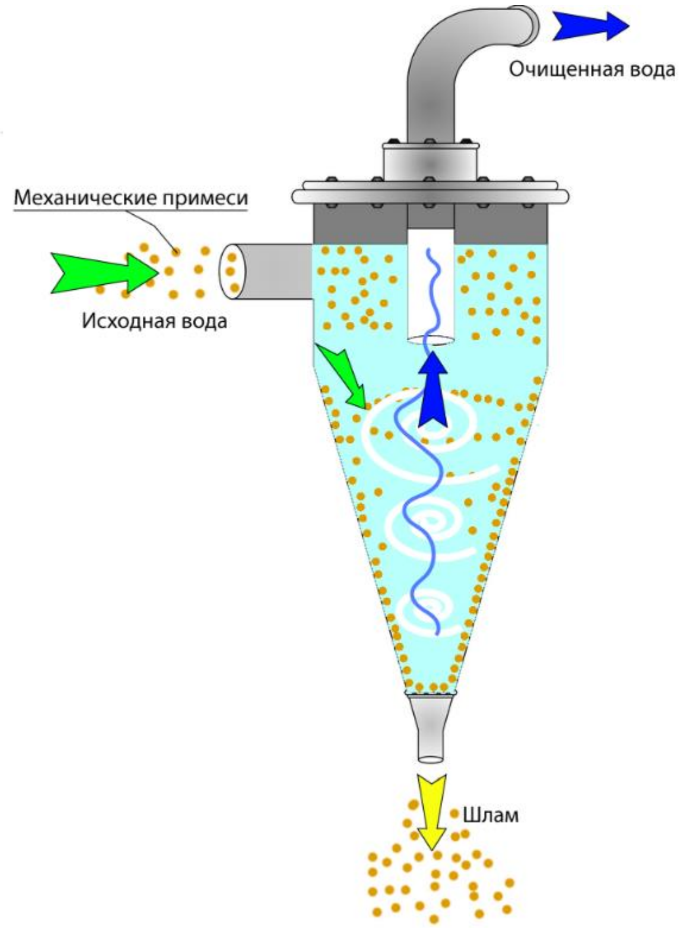


Fig. 5.10. Diagram of the hydrocyclone

hastics in the centrifugal field of a hydrocyclone can exceed the rate of deposition of similar particles in the gravitational field by hundreds of times. The moisturecontent of the sediment after the hydrocyclone in some cases can reach 60-70%.

In the practiceof condensation and dewatering of sediments at the treatment facilities of small and medium-sized industrial enterprises, the most common are hydrocyclones, which are used, as a rule, in combination with sludge compactors located below. In a hydrocyclone, sediment thickens, and in a compactor bunker - its further dehydration by compaction occurs.

The sedimentary mixture is fed with the help of a suspension pump into pressure hydrocyclones, from which the dehydrated sediment is sent to the inside of the hopper body, and the clarified water is sent for additional purification. The sedimentary mixture is kept in a bunker, as a result of which it is compacted. The water released during the settling process is diverted to the receiving tank. After filling the hopper with sediment and compacting it, unloading is carried out.

The disadvantage of the primary stage of sediment treatment is a significant (up to 50%) entrainment of finely dispersed particles of the solid phase with water. Therefore, it is advisable to use centrifuges, as the second stage of thickening, which are highly resistant to erosional wear. Such a scheme (Fig.5.11) provides the humidity of the concentrated solid waspof the dock (cake) at the outlet of no more than 35-45%.

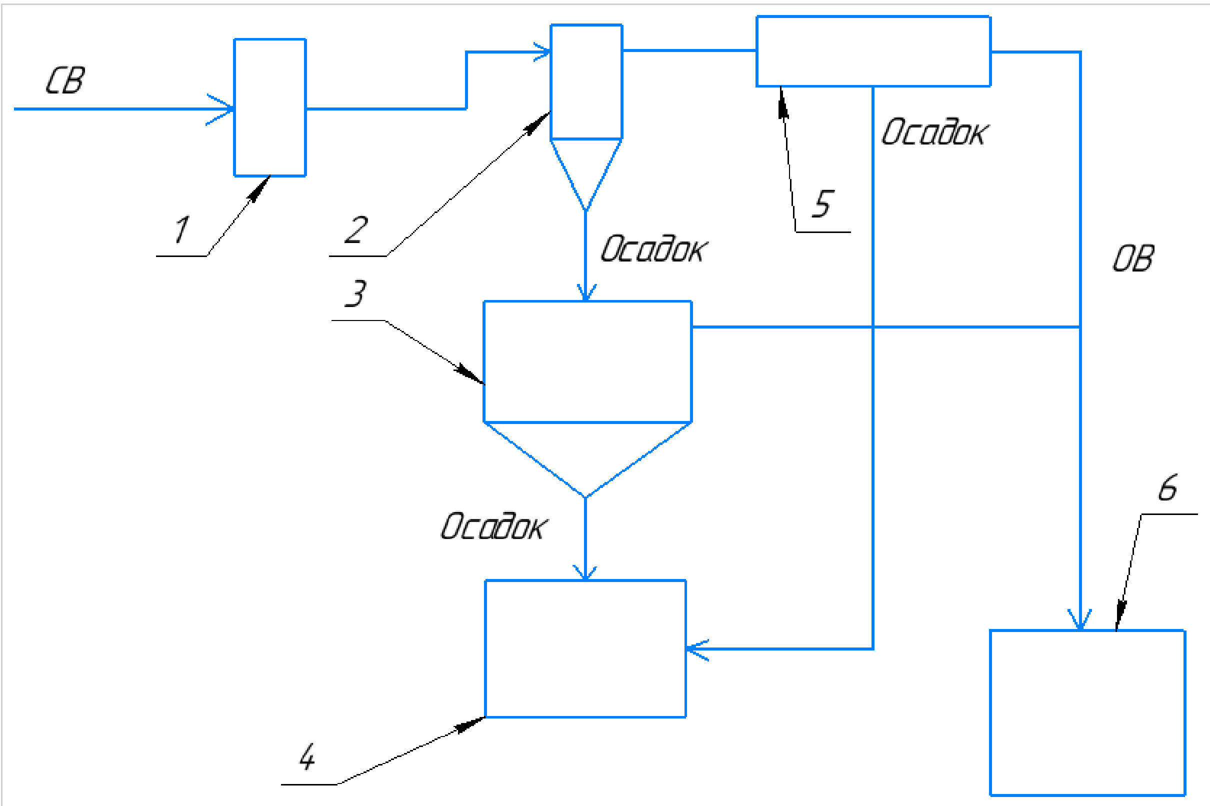


Fig. 5.11. Scheme of condensation of sediment, including hydrocyclones and centrifuges:

1 – grille; 2 – hydrocyclone; 3 – hopper-compactor; 4 – capacity; 5 – centrifuge; 6 – pure water tank; NE – wastewater; OV – purified water.

The calculation of equipment for this treatment scheme at wastewater consumption Q= 100 m3 / h, wastewater concentration Stv.b = 25 g / l, hydraulic particle size u_0 = 5 mm / s2 is given in Annex 1, which indicates the need to use centrifuges OGSH-631K-2 in the amount of 3 pcs.

5.3. Use of filter presses

Filters are also widely used to thicken wastewater sediment and activated sludge. The sludge of activated sludge under static conditions is filtered at a low rate. An increase in the filtration rate can be achieved by mixing the sludge of activated sludge with the sediments of the primary sedimentation tanks. The filtration process is especially effective when mixing activated sludge with the sediment of primary sedimentation tanks containing a significant amount of mineral particles. At the same time, the optimal ratio of active sludge to precipitate, as a rule, is approximately 1: 1. Mineral particles, most often sand, present in the sediment contribute to the formation of a porous structure when mixing sediment with activated sludge, which leads to a significant increase in the filtration rate and the formation of a cake with a humidity of 70-80%. This allows in some cases to abandon expensive drying and remove dehydrated sediment with active sludge into the dump or use it as a fertilizer. In practice, sometimesthe original compact device of the filter of the bag type is also made, in which the filter bag is wound on a perforated rotating drum, and the filter is pressed by a special clamping roller device that allows you to work at different thicknesses of the sediment entering the bag filter.

For many years, filter presses have been usedfor dewatering wastewater sludge, which are available in two versions: chamber and frame, which make it possible to obtain products with a high degree of dehydration. Due to their significant size and heavy associated devices, the use of such filter presses is unprofitable at small and medium-sized treatment plants.

Pressure filtration is a cyclic process in which the operations of filling and pressing sediments are sequentially repeated with simultaneous sediment of squeezes. The technological simplification associated with the use of belt filters and belt filter presses is cumulative in the following.

First, water is removed from the sludge, and then 60 to 80 percent of it is removed from the tape with a scraper. It falls on the pressing tape. After achievingthe required consistency and moisture content, the sludge is sent for final dehydration at high pressure.

In recent decades, the mechanical dewatering of sediment on filter presses has become more common than vacuum filters and centrifuges. Such filters have a number of advantages that reduce costs and increase the efficiency of mechanical dewatering of sediments.

It should be noted that oilpressesare devices not only for dewatering sludge fromwastewater and industrial effluents, but also for various wastes from chemical, coal, hydrometallurgical, oil, mining, ceramic, food and other industries. Usually, filter presses are periodic devices.

For the dewatering of wastewater sediment, the following types of filter presses are used:

-Frame;

-Chamber;

-Tape.

The main advantages of chamber filter presses over other types of equipment for sediment dewatering (vacuum filters, centrifuges, belt and frame filter presses) are:

1. Deep degree of dehydration;

2. the lowest specific productivity related to the unit area of the filtering surface;

3. Low specific energy intensity;

4. Possibility of carrying out the dehydration process in automatic mode.

However, given the developed filtration surface of chamber filter presses and their design features, in terms of productivity related to the production area, in many cases they are comparable to vacuum filters.

Disadvantages of chamber filter presses are:

1. Relatively high cost;

2. Greater labor costs when unloading the sediment;

3. Unpleasant smell in the operating room.

Modern chamber filter presses are divided into diaphragm and diaphragm-free. The main structural elements of such filter presses are plates equipped with a filter partition, clamping and opening mechanisms for plates, devices for unloading dehydrated sludge, communications and fittings for supplying sediment, compressed air and filter drainage. In diaphragm filter presses, plates are equipped with rubber diaphragms (membranes) for additional dehydration of the filtered sludge.

Consider the most common designs of chamber filter presses.

In domestic practice, FPAKM diaphragm chamber filter presses with a filtering surface of 2.5; 5; 12.5; 25 m and chamber filter presses without diaphragms FK1Mm 52-800; FKV-500; FK1Gpm 600-1428 with a filtration surface of 52, 500 and 600 m, respectively, are known.

Diaphragm filter presses have approximately 1.5 times the capacity of diaphragm-free chamber filter presses at the same humidity values of the discharged sludge, but they are more complex to operate and require special preparation of the sludge before feeding for dewatering: grinding or removing particles larger than 3 mm from the original sludge. Therefore, FPACM chamber diaphragm filter presses are not recommended for dewatering the sludge of the primary sedimentation tanks of urban wastewater. Waters. Chamber diaphragmatic filter presses have a large diameter of supply communications, so when they are used, it is not necessary to grind large particles of sediment.

In Fig. Figure 5.12 shows the FPAKM filter press diagram. The filter consists of a set of horizontal rectangular plates. Between the plates zigzag stretched an endless tape of filter fabric. The filter plates can be moved up or down four rails by a hydraulic actuator. The filter has a supply manifold for supplying the initial sludge and air to the chambers, a diverting collector to remove the filtrate and a collector for supplying water to the diaphragms when the sludge is pressed and for the release of water after the end of the spin. The filter belt on which precipitate forms in the chambers is driven by the actuator after the filter is opened. The dehydrated sediment is removed from the tape with knives and removed to the hopper. In the process of movement, the filter belt passes through the regeneration chamber, where it is washed with water.

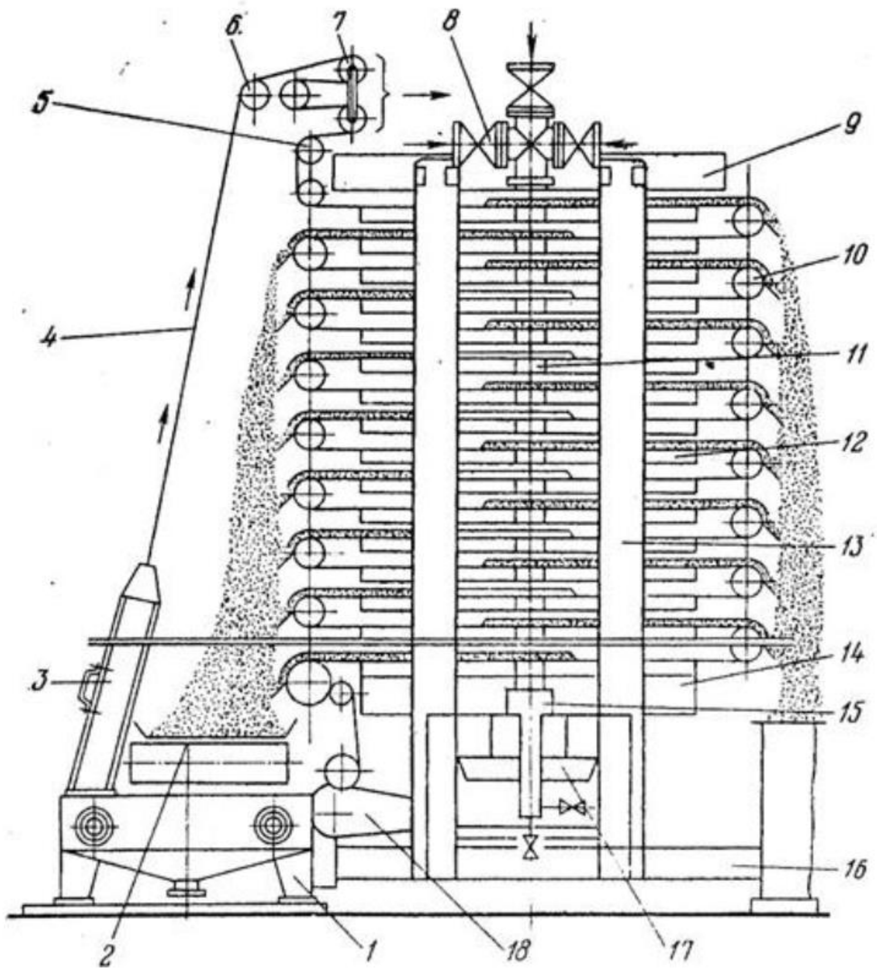


Fig. 5.12. FPACM filter press scheme: 1 – frame; 2 – receiving tray; 3 – regeneration chamber; 4 – filter fabric; 5 – top roller; 6 – roller for adjusting the position of the

fabric; 7 – tensioning device; 8 – supply manifold; 9 – upper resistant plate; 10 – fabric roller; 11 – pressure collector; 12 – filter plate; 13 – screed; 14 – pressure plate; 15 – drain unit; 16 – base plate; 17 – hydraulic clamping mechanism; 18 – fabric mover drive

In Fig. Figure 5.13 shows the filter press scheme PKIMm 52-800/33U.

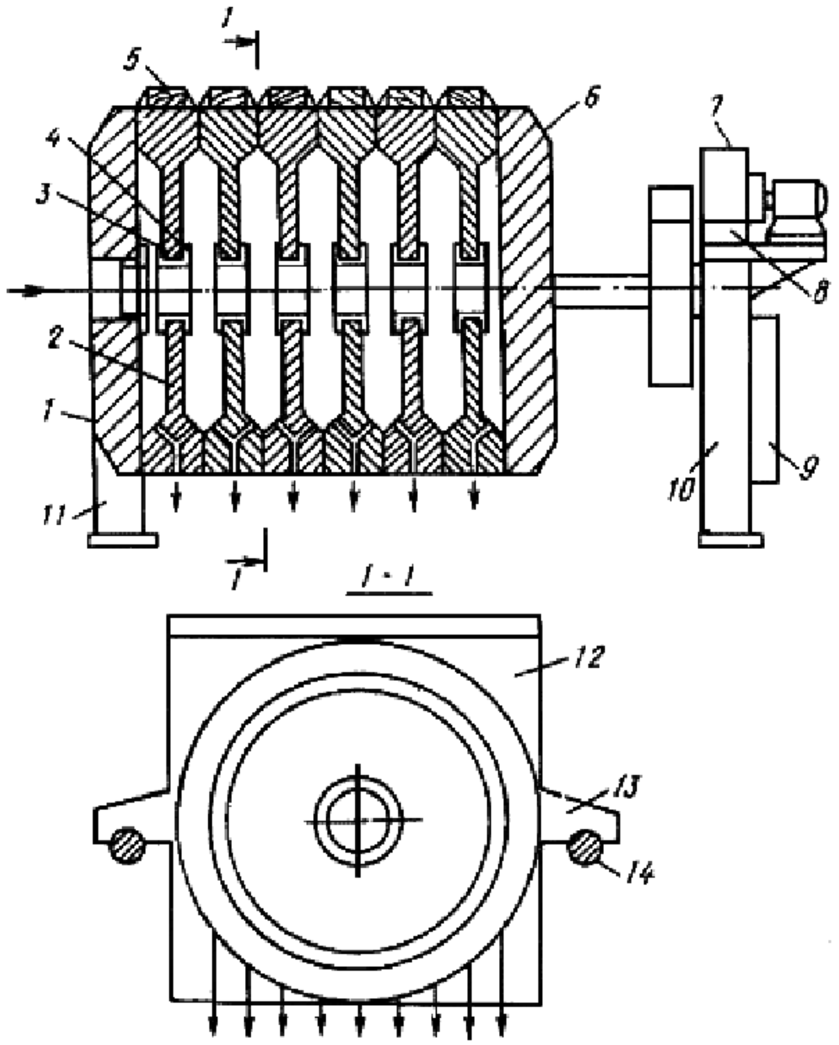


Fig. 5.13. Scheme of filter-press chamber type PKIMM 52-800/33U:

1 – resistant plate; 2 – filter (intermediate) plate; 3 – bushing;

4 – screw; 5 – bar for installation of the filter cloth (napkins);

6 – pressure plate; 7 – clamping mechanism; 8 – control panel; 9 – control station; 10, 11 – racks; 12 – filter napkin; 13 – plate handle; 14 – support beam

Chamber diaphragmatic filter presses consist of a set of vertically arranged filter plates on which napkins made of filter fabric are fixed. When the plate is compressed, filter chambers are formed. The plates rest on two parallel beams connecting the clamping mechanism and the thrust plate. The plates are moved along the beams by means of a plate moving mechanism when the sludge is unloaded or by means of a clamping mechanism when preparing the filter press to feed the initial sludge into it. The precipitate is fed into the press through a hole in the thrust plate and distributed over the filter space of the chambers through the holes in the middle of each intermediate plate.

Table 5.2 shows the main technical characteristics of the most widely used domestic chamber filter presses.

Indicators	Filter press			
	FPAKM-25	FCIMM 52-800	FKV-500	FKIGPM 600-1428
Filter surface area, m2	25	52	500	600
Operating pressure, MPa	1.2	1	1	1
Sediment thickness, mm	5-35	35	30	30
Chamber volume, m3	1	0.9	7	9
Number of filter plates, pcs.	16	60	115	116
Plate dimensions, mm	1100x1800	d800	1500x1700	1400x1900
Fabric width, mm	1100	900	1600	1600

Installed power of electric motors, kW	31,5	4,5	14,8	10
Pipeline diameter, mm, for:				
- suspension supply	100	70	150	150
- Air drying supply	65	-	65	65
- Air supply for regeneration	-	-	65	65
- Leachate drainage	125	-	150	-
- Suspension discharge	50	-	100	100
- water supply to diaphragms	65	-	-	-
- water drainage to diaphragms	65	-	-	-
Width of conveyor belt for sediment, mm	1000	1000	1200	1200
Dimensions, mm:				
-length	3780	6300	16050	12150
-Width	2150	1350	3325	2350
-height	4240	1900	2185	2450
Weight, kg	14970	8930	100930	58400
Filtrate outlet type	Closed	Open	Closed	Open

In the practice of sediment treatment, the possibility of using modernized chamber diaphragm filter presses KMP (chamber, mechanized with movablefabric), which will be usedinstead of FPAKM filter presses with approximately the same range of filter areas, are being considered.

Consider the working cycle of a chamber filter press, which consists of the following operations:

1. Closing cameras;

2. Loading of chambers with sediment and filtration;

3. Squeezing (for diaphragm press) of filtered precipitate with diaphragm or pressing sediment into chambers after filling them with sediment (for chamber diaphragmatic filter press);

4. Diaphragm blowing and sediment drying (for diaphragm filter press), purging of communications (for diaphragm-free filter press);

5. Unloading of the filter press, which for the FPAKM chamber diaphragm filter press is carried out by opening the chambers and stretching an endless filter belt, and for a diaphragmatic filter press - by opening the chambers and unloading the sediment under its own weight;

6. Regeneration of the filter partition and closure of the filter press chambers.

Operations (2) and (3) are the primary operations whose duration determines the actual filtering time, and operations (1), (4), (5), and (6) determine the time spent on ancillary operations.

An example of the filter press calculation is given in Annex 1.

Chamber filter presses are used both for dewatering wastewater sediment and in chemical, oil, coal and other industries.

The operation of chamber filters can be automated. Control of the filter can be both remote (from the buttons on the control panel) and automatic using a time relay and an electro-hydraulic system. This allows you to significantly reduce operating costs and limit access to the production room with an unpleasant odor.

6. Thermal dewatering

6.1. Dehydration using vacuum evaporation

For preliminary dewatering, the sludge of activated sludge enters the vacuum evaporators. At the same time, the evaporation is carried out under vacuum at a temperature not exceeding 80-85^{0}C. In order to save heat, evaporation is carried out on two- or three-body vacuum evaporator batteries, the concentration of activated sludge increases from 5-7% to 10-12% for abs. dry substances.

The scheme of two- or three-body evaporation makes it possible to reduce the consumption of steam for evaporation of moisture during evaporation of sludge. To prevent the formation of sediment, it is necessary to ensure intensive circulation of the evaporated suspension in evaporators, as well as in other apparatuses and communications. When evaporating viscous suspensions, evaporators with forced circulation of liquid are effective.

The design of devices with a remote heating chamber is widespread, as it has a number of advantages over evaporators with tubular heaters built into the body. Devices with remote heaters and forced circulation provide better conditions and higher speeds of circulation of evaporated liquid, and therefore a higher heat transfer coefficient and the possibility of free access to the tubular heater for cleaning or repair. The principle of operation of evaporators with natural circulation, due only to the difference in the specific gravity of the liquid in the evaporator and the heater, has great application when evaporating the residuex liquids. Thus, f

or the technological scheme of thickening of the activated sludge, we choose an evaporator with forced circulation and with a remote heating chamber.

6.2. Drying of wastewater sediment and activated sludge

For drying excess activated sludge and wastewater sediment, mainly oncoming jet dryers, drum type, sprayers and fluidized bed dryers are used.

The advantage of spray dryers is a very short residence time of the dried material in the chamber, usually not exceeding I min, which is very important for such heat-sensitive materials as biomass of microorganisms, including active sludge.

In addition to the temperature difference between the initial and spent coolant, the efficiency of the drying process of the suspension of microorganisms, including activated sludge, is greatly influenced by the value of the biomass concentration in the initial suspension, as well as its physicochemical properties, for example, viscosity.

Given the high viscosity of the concentrated suspension suspension, it is advisable to pre-heat it before drying. In the case of obtaining biomass of activated sludge with its further use as a feed additive, the stage of heat treatment of the suspension of activated sludge (plasmolysis) is necessarily used, and at low concentrations of biomass in the initial suspension along with plasmolysis and evaporation.

Quite simple and reliable is the technological scheme for dewatering the sludge of activated sludge, including flotation, plasmolysis, evaporation and drying. At the same time, after flotation, the concentration of biomass in the suspension usually reaches 3-5% of the active solids (AS), and after evaporation 7 -12% of the DIA.Achieving higher values of the biomass concentration in the suspension is hardly advisable, since the fluidity of the concentrated suspension of activated sludge decreases sharply and, in addition, an increase in its viscosity can significantly worsen the process of spray drying.

After plasmolysis or evaporation, the suspension of activated sludge is dried in spray dryers, e.g. CPC type (Figure 6.1).

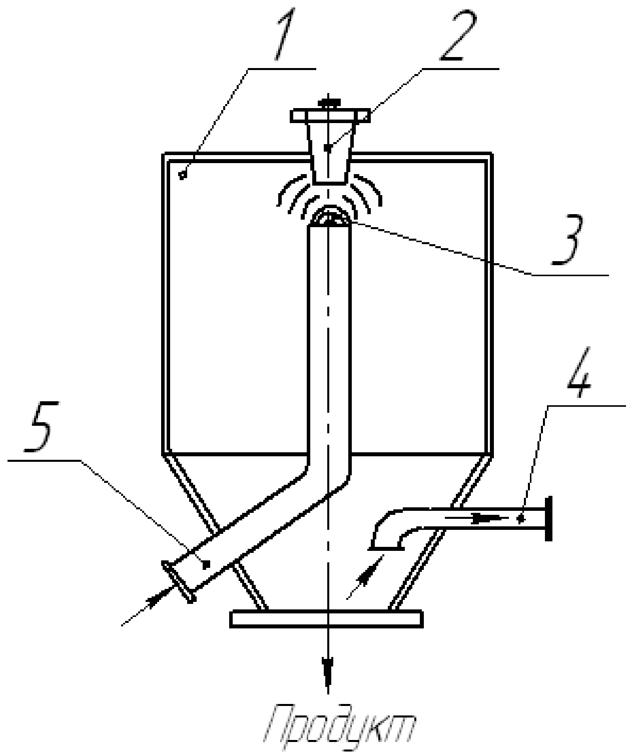


Fig. 6.1. Scheme of spray dryer type SRC:

1 — drying chamber; 2 — centrifugal spraying mechanism; 3 — guiding apparatus; 4 — gas exhaust; 5 — gas pipeline

The sludge is supplied through the spraying mechanism 2 to the drying chamber 1. With the help of a centrifugal disk, the suspension is sprayed to small particles. At the same time, with a decrease in the viscosity of the initial biosuspension and an increase in the circumferential velocity of the spray disc, the dispersion of the sprayed suspension increases and, consequently, the operation of the drying chamber intensifies.

A significant proportion of the dried biomass of activated sludge is collected in the lower cone part of the drying chamber, and the rest is captured in cyclones.

The biomass of activated sludge from the bottom of the drying chamber is captured in the cyclone and then pneumatically transported to the package. The finished biomass product is obtained in the form of a gray powder with a humidity of 5-10%.

The following factors have a significant impact on the spray drying rate:

degree of dispersion of the suspension;

increase in the temperature of the coolant at the entrance to the drying chamber;

increase in the relative speed of the coolant and the dried material;

improvement of mixing of the sprayed suspension with the drying agent.

The choice of dryers for the required performance is carried out on the basis of their technical characteristics, a detailed description of which can be found in the special literature.

Technical characteristics of the dryer SRP-10/550NK

Capacity for evaporated moisture, kg/h.... 7500

Coolant temperature, °C

at the entrance to the drying chamber............ 300

at the exit from the drying chamber.... 90

Vacuum in the drying chamber, Pa......... 6666,10

Coolant flow rate, kg/h.... 100000

Centrifugal spraying mechanism:

rotational speed, min-1.... 8050

disk diameter, mm.............. 330

circumferential velocity of the disk, m/s....... 140

Technical characteristics of the dryer SRC-12,5/1500 with upper and lower gas supply

Capacity, kg/h.

on the original product.... 19860

by evaporating moisture........... 15000

Coolant flow rate, kg/h.... 200000

Coolant temperature, °C

at the entrance to the drying chamber............ 300

at the exit from the drying chamber.... 90

Vacuum in the drying chamber, Pa......... 6666,10

Volume of the cylindrical part of the chamber, m3...... 1500

Centrifugal spraying mechanism:

rotational speed, min-1.... 8050

disk diameter, mm.............. 330

circumferential velocity of the disk, m/s....... 140

A significant drawback of products obtained by spray drying is their dusty shape.

In the case of dehydration of very thick pastes, suspensions that are dried in spray dryers, it is possible to structure these dispersed systems, which complicates the drying process. The granule obtained in this case can be processed in a fluidized bed. In comparison with spray drying, specific energy costs are markedly reduced.

a number of advantages have spray drying in a fluidized bed, combining the advantages of drying in a fluidized bed and the possibility of spray drying. This method is carried out using a carrier substance on which the starting material can be sprayed in liquid form. In some cases, this carrier substance can be extracted on subsequent use. In this case, it is possible to use the dried product in a finely dispersed form.

In the process of agglomeration, such structures are obtained that consist either of individual particles of the same substance, having almost the same or different grain size, or of many substances.

The main purpose of agglomeration is not only to combine particles into a sufficiently strong compound, but also to give the product certain agglomeration properties. In any case, a sufficiently high strength is required. In addition, it is necessary to provide other properties corresponding to the purpose of subsequent use of the product.

The developed methods of drying the suspension of activated sludge in the fluidized bed make it possible to obtain the finished product of the biomass of the activated sludge in granular form.

For dehydration of sludge with coagulants, it is recommended to use a dryer with a suspended layer of inert bodies.

The process is as follows:

The dehydrated product first enters the vacuum filter and then into a twin-shaft mixer, where it is mixed with the dried material at a 1:1 rate. The moisture content of the mixture is 45-50%. The longer mixture is fed into a vortex layer dryer filled with an inert nozzle, which is used as pebbles or cement clinker with particles of 5-6 mm in size.

The coolant and fluidizing agent are air-diluted flue gases with a temperature of 5000C. The flue gas generator is a furnace in which either fuel oil or natural gas is burned.

The temperature of the fluidized bed is maintained at the level of 100-1200 C^o. The wet material comes into contact with intensively moving particles, is dehydrated, crushed and, together with the exhaust gases, is sent to the cyclone system. After the first and second stages of purification in a straight-flow cyclone, the dry product enters the twin-shaft mixer, and the rest, together with the dry particles from the battery cyclone, is fed into the finished product collection. The flue gas pressure under the gas distribution grate is maintained at about 4-5 kPa.

The amount of loading sludge approximately corresponds to the mass of the inert particles. The working load when drying pastes in an apparatus equipped with an agitator is 6-8 kg / h; humidity of the suspension of activated sludge after drying is about 3-5%; suspension loss in a fluidized bed dryer of about 4% and in a spray dryer of 9%.

Granulators with a fluidized bed have a number of advantages, for example, a large developed phase contact surface, a high intensity of heat and mass transfer processes, the possibility of obtaining a granular product of high quality, etc. Significant disadvantages of granulators with a fluidized bed are relatively high energy costs, a fairly narrow interval of stable operation modes, etc.

It should be noted that thermal drying and granulation are appropriate for the utilization of activated sludge biomass, which can significantly increase the shelf life of the product and increase the safety of working with it.

7. Disposal of wastewater sediment

7.1. Disinfection and detoxification of sediment

Disposal of sediment to a large extent in most cases is inhibited by both a large contamination of sediment and the presence of various toxicants in them.

Methods of disinfection of wastewater sediment can be divided into three main groups:

· thermal (including biothermal);

· Chemical;

· physical (including microwave exposure, ultrasound, etc.).

Thermal methods consist in heating the sediment at sufficiently high temperatures for a certain time. For example, when sediment is heated to a temperature of about 100 C^0 and a time of several tens of minutes, the death of helminth eggs and the death of pathogenic microorganisms occur in them.

In the case of composting of wastewater sediment, biothermal heating of the sludge occurs, which contributes to the death of helminth eggs and various pathogenic microorganisms.

Thermal methods are reliable and effective ways to disinfect wastewater sediment.

In the case of using chemical disinfection, it is advisable to use it when using sediment in agriculture as an organomineral fertilizer. In these cases, lime, ammonia water (25% aqueous solution of NH4OH, urea, etc. Contained in the sediments, these substances contribute to the death of helminth eggs and pathogenic microorganisms.

Various physical methods of sediment disinfection, including microwave exposure, ultrasound, etc., are practically used only as research methods and are not used in the practice of sediment treatment.

To detoxify sediment, various methods are taken to extract heavy metals from them, for example. We conducted research on the acid treatment of wastewater sediment in order to cure heavy metals. Positive results were obtained when acidifying the sludge of activated sludge to pH 1-4. However, it has not yet been possible to use this technological technique in practice. The scientific search in this direction continues.

7.2. Use of wastewater sediment and excess activated sludge as fertilizers

The technological and environmental properties of wastewater sediment (SALT) largely determine the conditions for their disposal. At the same time, the main environmental criteria are their decontamination, as well as the absence of an excess content of heavy metals (TM) in them. When using SALT as an organomineral fertilizer in agricultural landscapes, it is necessary to proceed from the forecast of their expected effect on the chemical composition of the soil, which can be determined for a period of 10-15 years. In conditions of low content of TM in SALT, the dose of their application is determined based on the need of crops for mineral nutrition elements. In a number of regions, there are production and environmental features, which is reflected in the proposed ways of use in agricultural production.

The use of SALT in the landscaping of cities is one of the promising areas for their disposal. Organizations engaged in landscaping and landscaping need large quantities of fertile soil. Often, for these purposes, a fertile layer of virgin soils is removed. There is a violation of land and their withdrawal from agricultural circulation. In the future, they must be remediated, which is associated with significant material costs. In addition, very significant financial resources are spent on transporting soils to the place of direct use.

In our country, only about 5% of sediment is used in the aggregate in the aggregate. Taking into account the current economic situation and with a sharp shortage of mineral and organic fertilizers, it is advisable to use SALT in agriculture, in landscaping cities, for the reclamation of disturbed lands and dumps.

The properties of sediment as potential fertilizers are determined by a whole range of characteristics, among which humidity, the content of phosphorus, nitrogen, potassium, and heavy metals are of fundamental importance. There are no precise criteria for the qualification and rationing of sediment as a fertilizer, since fluctuations in the composition of sediment, in particular the content of nutrients phosphorus, nitrogen, potassium in them, vary greatly depending on the type and origin of sediment.

During fermentation, there is a significant decrease in the nutrient content in the solid component of the sludge. The nitrogen content, for example, can be reduced by 30 to 40% due to its conversion to ammonia or ammonium salts soluble in the aqueous phase. The same thing happens with phosphorus. Thus, if the sediment is introduced into the soil in a diluted form, the amount of nutrients in it is much higher than when using dehydrated sediment.

In Table. Figure 7.1 shows the composition characteristics of some types of sediment.

Table 7.1.

Nutrient content in different types of sludge at wastewater treatment plants

Type of sediment	Nitrogen, %	Phosphorus,% P_2O_5	Potassium, % K_2O
Primary	2,4 – 2,9	1,1 – 1,6	-(*)
Sediment condensed on the filter	2,9	2,8	-
Activated sludge	3,0 – 5,6	2,8-7	0,56
Sediment after fermentation, mixed	1,8 – 5,8	1,2-3,3	0,14 – 0,4

(*) – data not available.

The data presented in Table 7.1 indicate good properties of sediment as potential fertilizers.

However, the presence of heavy metals in sediment makes it difficult to use them as fertilizers.

Heavy metals can not only cause intoxication of bacteria in the process of sediment stabilization, but also have a toxic effect. In this regard, the use of wastewater sediment as a fertilizer makes it necessary to stricter adherence to sanitary standards for monitoring the composition of both the applied sediments and the composition of the soil. In order to ensure the safety of the use of wastewater sediment as a fertilizer when it is applied to the soil, the regulations in force, for example, in the EU countries, do not allow grazing of livestock on pastures for 6 weeks from the date of introduction of wastewater sediment into the grass stands. The use of sediment in most cases significantly increases the yield of grass, legumes, corn, cabbage, cereals. Wastewater and the sediments generated during its treatment can be used in forestry and forest park management, and also taking into account strict control over the presence of toxic ingredients in them.

Severe bacterial contamination of wastewater sediment, including excess activated sludge, can be reduced by heat treatment or by special methods, for example, by adding chemical reagents to the sludge, as well as by exposure to electromagnetic or radioactive radiation.

As practical directions confirming the effective use of wastewater sediment as a fertilizer, consider the experience of using excess activated sludge (microbial biomass) of microbiological industries, in particular plants for the production of protein-vitamin concentrates (PVC).

At the BVK plants at the stage of wastewater treatment, the bulk of waste is generated in the form of excess activated sludge (microbial biomass) in the amount of 6-9% of the volume of PVC production, which is characterized by the practical absence of heavy metals in the composition of microbial biomass.

Such microbial biomass is obtained in the process of PVC production by growing a biocenosis on metabolites of hydrocarbon-oxidizing yeast. Studies of the chemical composition of microbial biomass show that this product contains valuable substances and is a multicomponent system.

Analysis of the chemical composition of dry microbial biomass (MB) is given in Table. 7.2.

Table 7.2. Chemical composition of dry microbial biomass

Composition of microbial biomass	Content, % on ADM
Moisture	5-10
Total sediment	40-60
Lipids	2-8
Carbohydrates	8-17
Nucleic acids	1,5-5,0
Ash	10-35
Potassium	0,2-2,0
Magnesium	0,3-0,4
Calcium	0,5-1,5
Iron	0,7-3,0

Phosphorus	2,0-3,0
Zinc	600-22000
Manganese	300-600
Copper	30-220
Cadmium	1-3
Lead	10-13
Molybdenum	4-50
Strontium	3-55
Cobalt	0,1-4,0
Nickel	10-30
Chromium	5-30
Mercury	n/prom.

The effectiveness of using microbial biomass as a fertilizer is determined not only by the content of nitrogen, phosphorus and potassium, but also by trace elements. The presence in microbial biomass of a high content of ash elements, in particular such trace elements as, for example, boron, molybdenum, copper, manganese, zinc, is very important for plant growth.

When obtaining fertilizers based on microbial biomass, along with the qualitative characteristics of the composition, its physicochemical properties are important, in particular the ability to caking, scattering, hygroscopicity. These indicators should be taken into account during storage, transportation, dosage of the product in the process of preparing fertilizer.

Research conducted by us on possible methods of utilization of wet microbial biomass led to the development of a method for obtaining organic fertilizer based on condensed activated sludge (microbial biomass) and peat.

The essence of the proposed method is that a suspension of activated sludge with a biomass concentration of 0.5 - 5.0% ADM is mixed with peat in the ratio of active sludge: peat from 5: 1 to 1: 8, respectively. Mixing sludge with peat leads to effective adsorption interaction of microorganisms of activated sludge and mineral elements on peat particles, which reduces energy costs for dehydration of the peat - active sludge mixture and improves the quality of fertilizer obtained on its basis.

One of the main requirements in the production of peat-sludge fertilizers is high-quality mixing of components, which ensures an even distribution of moisture and minerals in the total mass, which contributes to the active activity of microflora during the fermentation of the mixture in the shoulders.

For the preparation of peat-sludge mixtures, the most suitable are vane mixers of continuous action SMK-126. The capacity of the mixer is 30 - 60 t/h, the energy consumption per 1 ton of the mixture is 0.2 - 0.4 kW/h.

After mixing, it is necessary to strictly observe the composting technology.

There are two ways to compost:

1. Composting in piles is a natural way of bio-oxidation.

2. Composting in bioconvectors - composting with forced aeration.

In world practice, both the first and second methods are used. When composting in bioconvectors, the composting time is reduced to 2 - 3 weeks, and in the best case to 3 - 7 days. In the case of composting in piles, the maturation time of the compost is calculated in months up to a year. The duration of this process primarily depends on the ambient temperature.

The cost of electricity for the preparation of 1 ton of compost is approximately 20 -190 kW, depending on the conditions of its preparation.

The most interesting are technologies that create conditions for the rapid development of microorganisms, which are secreted in the form of metabolic products substances that suppress the development of other microorganisms.

The process of fermentation of peat-sludge mixtures into fertilizer consists in the rapid development under favorable conditions first of mesophilic microorganisms (t_{min} = 10 - I5 ° C, t_{max} = 35 - 47 ° C, t_{opt} = 30 - 45 ° C), and then thermophilic microorganisms (t_{min} = 40 - 45 ° C, t_{max} = 80 ° C, t_{opt} = 55 - 75 °C). When composting under conditions of forced aeration, it is possible to create conditions for the predominant development of actinomycetes, which secrete antibiotics that suppress many bacteria, including putrefactive and microbacteria.

The increase in temperature inside the burt deprives the weed seeds in the mixture of germination and largely kills the pathogenic microflora, larvae, helminth eggs, fly pupae. Composting time – 5 - 8 months.

However, the solid-phase fermentation process can be accelerated by storing the shoulders under a canopy or indoors, as well as by mixing the compostable mass as the process attenuates, or by an enhanced aeration device. Selective cultures of microorganisms can be used to intensify the process. For example, a culture of thermophilic actinomycetes is grown in the laboratory on an environment of approximately the following composition: 1 liter of tap water is added in grams KNO3, - 1; (NH4)2SO4 – 1; Na2 HPO4 – 1; MgSO4 – 0,5; FeSO4 - 1; chalk - 4; starch - 20; agar - 20 at a pH of the medium 7.2 - 7.5. The resulting biomass is introduced into the embedded burt, for example, 2.5 - 3.0 m high, at least 4 m wide and of arbitrary length with a minimum weight of the shoulder of 200 tons. Such dimensions and weight make it possible to reduce the influence of ambient temperature on the compost maturation process. To intensify the maturation of the compost, perforated pipes are laid inside the shoulder, through which compressed air is supplied using a compressor or fan.

For the normal course of biothermal processes, it is necessary to observe the following conditions:

the amount of dry substances - 30 - 40%;

humidity - not more than 70%;

соотношение C:N = 20:1 - 30:1;

The pH of the medium is 6.0 - 8.0.

If these requirements are met, the temperature inside the burt rises to 55 - 60 ° C and above up to 70 ° C. After two weeks, the burt must be mixed to achieve a biothermal process in all layers of the compostable mixture.

Composition of compost on a peat basis (peat-sludge mixture):

moisture 70%; the proportion of phosphorus is not less than 0.5%.

The angle of the natural slope of the shoulder is 36 - 43 °.

So that the compostable mass does not freeze in winter, each stack in winter is laid for as short a time as possible (1-2 days) and covered with a layer of peat 30 cm thick.

Preparation of peat-sludge compost in the field can be carried out using the following technology (Fig.7.1). The dehydrated sediment is piped by a screw or screw pump 2 from the card along with ammonia water to the mixer 6. A powdered peat crumb with a layer of mineral additives is fed by a belt conveyor 5 to the mixer 6.

From the mixer, the peat-sludge mixture is fed by a scraper conveyor 7 to the storage hopper 8. As the mass accumulates in the bunker, it is unloaded into mobile vehicles and placed in shoulders.

The mixture in the shoulders for 30 - 45 days is mixed several times (after 6-8 days). The temperature in the shoulder should not exceed 60 - 65 ° C.

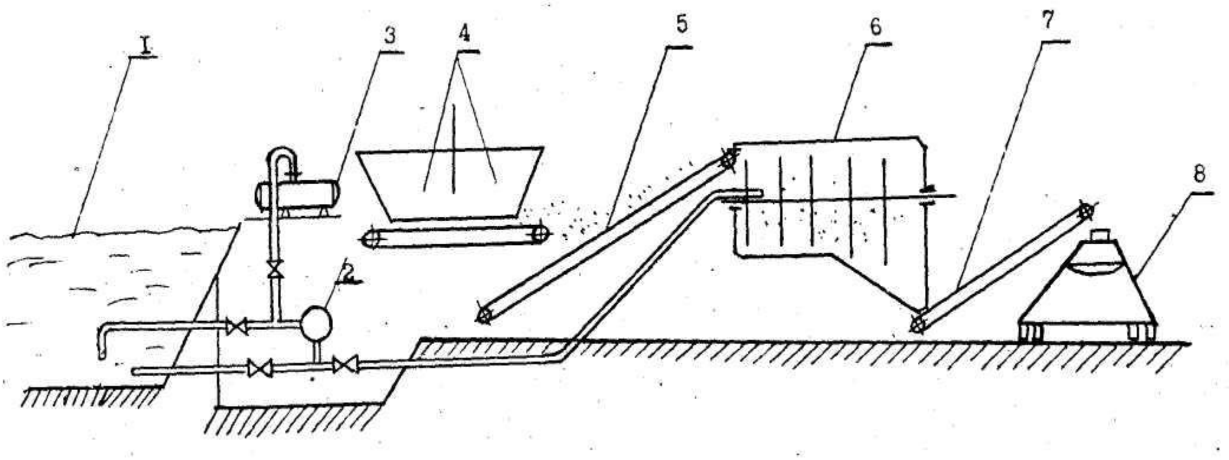


Fig. 7.1. Technological scheme of fertilizer preparation using sludge from cards: I – dehydrated sludge; 2 – pump; 3 – ammonia water tank; 4 – mineral fertilizer dispensers; 5 – loading conveyor; 6 – mixer; 7 – mixture unloading conveyor; 8 – hopper-accumulator.

When applying fertilizers based on wastewater sediment, the content of heavy metals in the soil is of particular importance.

The maximum permissible concentrations (MPC) of heavy metals in the soil have the following values, mg/kg: for lead 20 (above background 12); cadmium 5, arsenic 2; nickel 35; zinc 85; hexavalent chromium 0.05; trivalent chromium 100; mercury 2.1; antimony 4.5; manganese 1500; copper 10 (above the background); Vanadium 150; manganese + vanadium 1000 + 100, superphosphate (P_2O_5) 200.

Regulation of the values of the concentration of ash elements, including heavy metals, in the proposed method makes it possible to maintain the MPC of heavy metals in the soil established by the Ministry of Health of the Russian Federation.

For the agrochemical evaluation of the effectiveness of the use of compost based on wet microbial biomass and peat, experiments with potatoes were laid.

The repetition of experiments was fourfold. The total area of the plots was 56 m2. The soil before the experiments was brought to a homogeneous state and at the same time was with low acidity, a high degree of saturation with bases and a high content of phosphorus. All fertilizers were applied in the spring for the main tillage of the soil.

Scheme of fertilization for potatoes with the following options:

1. Control (without fertilizers);
2. $N_{146} P_{140} K_{2}$*
3. MB 300 kg;
4. MB 600 kg;
5. MB 300 kg + $P_{33} K_{228}$;
6. Straw 5 t / ha;
7. Straw 5 t/ha + $N_{146} P_{140} K_{277}$;
8. Straw 5 t/ha + MB 300 kg;
9. Straw 5 t/ha + MB 600 kg;
10. Straw 5 t/ha + MB 300 kg + $P_{22} K_{226}$;
11. Transition peat 58 t/ha (19t of dry matter) + $N_{146} P_{140} K_{277}$;
12. Peat-sludge compost 50 t/ha (19t of dry matter) + K_{223}

* - values of subscripts - the amount of element in kg per 1 ha.

The yield of potatoes and the starch content in the tubers are given in Table 3.

From those given in Table. Figure 7.3 shows that peat-sludge compost at a sufficiently low cost can have a greater effect on increasing yields.

These data also indicate that when using wet microbial biomass as a fertilizer, additional income can be obtained by increasing the yield.

Table 7.3. Yield and starch content in potato tubers depending on the fertilizer used

№ p/n	Experience option	Average yield, c/ha	Increase		Starch content,%
			c/ga	%	
1	Control	62,3	-	-	17,09
2	NS146 P140 K277	103,6	40,4	63,9	17,90
3	MB 300 kg	87,9	24,7	39,1	16,42
4	MB 600 kg	96,2	33,0	52,2	18,05
5	МБ 300 kg + P33 K228	109,9	46,7	73,9	18,70
6	Straw 5 t / ha	79,6	16,4	25,9	19,51
7	Straw 5 t/ha + N 146 P140 K277	115,5	52,5	83,1	14,00
8	Straw 5 t/ha + MB 300 kg	89,2	26,0	41,1	12,31
9	Straw 5 t/ha + MB 600 kg	98,7	35,5	56,2	17,09
10	Straw 5 t/ha + MB 300 kg + P22 K226	80,3	17,1	27,1	17,76
11	Transitional peat 58 t/ga + N 146 P140 K277	101,9	38,9	61,2	17,76
12	Peat-sludge compost 50 t/ga + K223	97,2	34,0	58,3	14,80

Thus, the results of the tests showed that the microbial biomass produced by BVK is a valuable component of fertilizers for various crops.

Composting activated sludge can give good results not only with peat, but also with lignin.

Processing of lignin and condensed sediments into composts is a promising way to sell solid waste and the most rational in creating an environmentally friendly technological scheme. In addition to composts, on the basis of solid waste hydrolysis production, it is possible to obtain organomineral fertilizers without the composting process. Mixtures of lignin and condensed sediments containing about 70% of humic substances (total nitrogen 3-4%, P2O5 - 1.5-2%) can be used as a fertilizer. To do this, heat treatment of condensed sediments is carried out by extrusion or treatment with caustic and mixed with lignin. In order for the content of endogenous elements to be high enough, the following ratio of the main components is recommended: lignin 50-40% and sediment 50-60%.

7.3. Vermiculation

Of all municipal waste, the most important is the wastewater sediment of treatment plants. Activated sludge, along with cattle manure, is one of the most valuable substrates for vermicomposting. According to a number of developers, the use of SALT as a raw material for vermicomposting has great prospects. In a mixture with household garbage, it is widely used for processing into vermicompost abroad, but in our country this method has not yet found wide application, although such work is being carried out in a number of regionalinnovations of the Russian Federation. So, in the Moscow region, since 1995, In sludges mixed with manure, aculture of compost earthworms is added, which process this substance into biohumus. The process takes place in special containers in strict accordance with the regulations OPR 23433262-02-95, developed by the Department of Environmental Biotechnology of the Research Center tbp (Serpukhov), and gives the urban green economy 7-10 thousand tons of fertilizer annually. There is also a positive experience of such work in the Tver region.

For example,in the production of microbiological preparations, a large amount of organic waste is generated (wastewater sediment, post-yeast residue or brazhka, biosurst, hydrolysis lignin, substandard biological preparations, etc.), the use of which in agriculture is difficult due to the unfavorable properties of these wastes: they are strongly seeded with microbes, have a specific unpleasant odor, etc. It is proposed to process this waste with the help of earthworms. it is possible to obtain valuable, environmentally friendly organic fertilizer from the waste of the microbiological industry. To do this, various wastes of the microbiological industry are mixed with pig manure, moistened, pre-fermented for 12 days and populated with worms. A culture of worms adapted to wastewater sediment formed at local treatment facilities of enterprises is used. Worms have been found to grow and reproduce best on a substrate consisting of: wastewater sediment (40%), bioshrite or corn husks (30%), pig manure (20%) and substandard bakpreparations (10%). Processing is carried out for 6 months, providing watering and regular feeding of worms. During vermicomposting, the organic matter of the waste is decomposed, and the waste is disinfected, enriched with enzymes and easily digestible minerals for plants.

One technologically acceptable species of worm is the red California worm. It has the ability to reproduce in closed greenhouses and gives a large reproduction.

California worms eat twice as much food per day, theyweigh themselves. They grow quickly. In about two to three weeks, they reach sexual maturity and begin to breed in closed greenhouses. These worms are very voracious and prolific. In the summer, California worms can simply be settled in a compost heap, where they will multiply intensively. Comfasting thanks to them quickly ripens. Worms process decaying organic matter well. In this case, bacteria, mold fungi and other microorganisms are also involved in the decomposition process.

Vermiculture is more focused on obtaining a mass of earthworms for their subsequent use as a feed additive in the diets of birds and pigs, in pharmaceuticals, as well as in technologies for neutralizing soil pollution, restoring soils and increasing their fertility. A method of bioremediation, which uses the ability of earthworms andother representatives of the soil fauna to loosen the soil, thereby facilitatingthe pressing of water and the penetration of gases.

Another purpose of vermicomposting is the processing of organic substrates for the production of fertilizer composts (biohumus) and the restoration of soil fertility, the neutralization of household waste, wastewater sediment, and other waste that is difficult to recycle.

Earthworms have become the object of close scientific attention and practical activities in the field of agriculture, fodder production and ecology due to their unique properties: unpretentiousness to food and maintenance conditions, rapid increase in biomass and high protein content in their body. They are currently considered as one of the priority means of conducting environmentally friendly agricultural production, processing of various organic waste.

In the USSR, the first experiments on the influence of earthworms on the harvest began to be carried out in the 70s. The twentieth centuryhas shown that the introduction of earthworms into the soil several times increases the yield of crops such as barley and clover. Of particular note are the results of research on the cultivation of worms, which were launched at the Vladimir State Pedagogical Institute under the leadership of A. M. Igonin. In 1985-86, he obtained the first domestic lines of worms for the industrial processing of organic waste and carried out the first large-scale experience of introducing vermiculation technology in the greenhouse plant "Vesna" near Uzhgorod (Ukraine). However, in industrial vermiculture in the USSR began in 1989, when selective cultures of worms from Poland and Hungary were imported. In 1991, there were already more than 100 laboratories dealing with the problem of breeding worms and obtaining biohumus.

Tests conducted under the guidance and with the participation of the author on the use of such worms in the processing of a mixture of activated sludge with a sediment of primary sedimentation tanks of microbiological production gave positive results. However, due to the closure of most microbiological production facilities in our country in the 90s, this experience could not be implemented in industrial practice.

Vermiculture has been created and is being successfully developed in many countries. It is known from the literature that about 1,000 large biofactories for growing worms and obtaining biocomposts are operating abroad. The most widespread vermiculture and vermicomposting were in the USA, Canada, China, India, South Korea, Australia, Italy, Mexico, and Cuba.

According to some reports, the Russian market also shows an increase in the number of taller vermicompost farms.

It should be noted that in Russia the need for biohumus is several million tons and in this regard there is a need to increase the mass of worms. Work of both scientific and practical profile in this direction is carried out in a number of regions of the Russian Federation. As a result of numerous scientific studies and practical work, the properties of the biomass of the resulting worms, the conditions for their breeding, processing of various wastes were clarified.

Earthworms are invertebrate animals that are among the oldest inhabitants of the Earth. The name "earthworms" is a collective, applied to all more or less large members of five different families of the type annelid worms, a class of oligochaetes that live in the soil. The most important feature of the structure of oligochaetes is the correct repetition of individual segments (rings) along the axis of the worm-like body of the animal. When reproducing, earthworms lay eggs in a cocoon. Usually in each cocoon there is only one egg, less often two or three.

With external similarity with each other, earthworm families are distinguished mainly by the structural features of the internal organs, in particular the reproductive organs, by the location of the belt, bristles and other signs.

Worms feed on dead decaying plant tissues entering the soil in the form of litter, root and crop residues, as well as animal remains. Together with them, they swallow various representatives of the soil microflora: bacteria, algae, fungi and their spores, protozoa and nematodes. Some of the species of earthworms are typical consumers of humus and prefer the top layer of soil (humus consumers, epigeal worms), others live in the middle layers of the soil, and some live at depths of up to 2 m. Species and populations of worms found in manure and other non-humified organic substrates are humus-forming.

The color of the worms is different. The red-colored genera include Lumbricus, Dendrobaena, and Eisenia, which live primarily in litter and upper, humus-rich horizons; representatives of the generaAllolobophora, Octolasium and Eiseniella have a color from gray to greenish.

The biomass of earthworms in the soil accounts for 50–72% of the total biomass of the soil mesofauna. In natural habitats of earthworms (meadows, pastures, arable land), their total number in the soil can reach 106–107 individuals /ha, and biomass 103–104 kg/ha.

With insufficient nutrition, the growth and development of worms are greatly slowed down, and they die. Earthworms need primarily nitrogen-containing organic matter, the reserves of which in the soil are limited. In this regard, the highest number, rates of individual growth and fertility of worms are usually observed in places of localization of organic substrate rich in nitrogen (on pastures, near the excrement of herbivores, etc.). Nitrogen contained in the soil microflora and microfauna ingested and digested by worms is almost completely absorbed by them. The optimal C:N ratio in the organic substrate should be close to 20. In addition to nitrogen-containing substances (proteins, amino acids), processed organic materials should contain carbohydrates, a variety of minerals, vitamins, as well as fiber or other substances, the absence of which complicates digestion. They should also contain a mineral inert filler, sand or soil.

Substrate humidity in the range of 60-80% is optimal. By the way, the humidity of wastewater sediment after centrifugation or pressure filtration is also approximately within these limits.

It should be noted that after rains, when there is a lot of water in the soil, earthworms crawl to the surface.

In the case of progressive drying, the worms move to wetter zones. If the moisture content in the soil for a long time is below 30-35%, then the number of worms decreases. It should be noted that worms can lose up to 50-60% of their water from body weight without damage. With soil moisture, 22% of the worms die within one week. When growing earthworms in the laboratory, their maximum weight and fertility reach at substrate humidity of 70–85%, which is close to the water content in the body of the earthworm.

Optimal for worms is a temperature of about + 15-25 °C and a habitat pH of about 7.0-7.6. In fields without vegetation and food, worms die at temperatures close to zero. Worms are saved from the cold by going into deeper soil horizons. In the same way, they avoid high temperatures. Earthworms do not live in environments with a pH of <5.0 or a pH of >9.0.

In temperate latitudes in the warm season, the active activity of earthworms lasts up to seven months. In winter, earthworms hibernate. When the temperature drops below +10 °C, they begin to go into a state of rest and at +6 ° C they stop eating, and at +4 - +5 °C, the contents of the digestive tract are released. With the onset of frost and freezing of the upper soil horizon by 5-6 cm, they go into the deep layers of the soil. In spring, with the onset of thaws, the worms go into an active state 10-15 days before the disappearance of the frozen layer of soil, and they can crawl even on the snow.

Many worms are afraid of light and ultraviolet rays. To find a sexual partner, they crawl out of their burrows only at night, so their habitat should not be illuminated by either natural or artificial light sources.

Species of worms suitable for vermiculture, in natural conditions, live mainly in the surface well-aerated layer of soil. They are extremely sensitive to the release of gases formed during the decay process: ammonia, hydrogen sulfide, methane. The permissible level of ammonia content is 0.5 mg / kg of substrate. With a higher gas content, the worms die. Therefore, in industrial vermiculture plants, they try to avoid the formation of stagnant zones and maintain an oxygen content in the gas phase of at least 15%, and carbon dioxide - no more than 6%.

The reproduction of worms is adversely affected by the overpopulation of the processed substrate. In this case, the worms are stressed and excited. Under these conditions, cases of cannibalism are possible. Therefore, population density is an important monitored indicator.

Since field conditions are characterized by cyclicality, impermanence and suboptimal conditions for the growth of worms, the tasks of industrial methods of vermicomposting and vermiculture are the creation of highly productive and adapted to various substrates worms, maintaining optimal conditions for their detention in laboratory and industrial cultivators, leading to an increase in the growth rate and reproduction of worms. In relation to the processed substrates, worms should not only have an increased ability to consume the substrate and a high rate of their decomposition, but also quickly adapt to the change of substrate and be resistant to diseases.

Of all the variety of earthworms, only a few species are suitable for vermiculture:

muckworm Eisenia foetida;

subspecies E. foetida foetid, foetida andrel;

common earthworm (or great red crawler)

Lumbricus terrestris;

the lesser red worm (small crawler) Lumbricus rubellus;

several other species (dendrobaena dendrobaena, etc.).

The most widely used in vermiculture is the dung (compost) worm E. foetida. This worm is widespread in the world, including in the North and central Russia: near human housing, in clusters of manure, rotten straw, in greenhouses, where their number often reaches 1000 pcs. / m2.

E. foetida is a relatively small worm 6–10 cm long. The color of its segments is dark red or reddish-brown, with lighter grooves separating the segments. Under natural conditions, each sexually mature individual. E. foetida produces 1–2 cocoons weekly, of which 2 to 20 juvenile worms are hatched in about 3 weeks, of which an average of about 4 individuals survive. After 3 months, the worms hatched from the cocoons become sexually mature. On average, 1 worm gives offspring of 200-400 individuals per year. Young individuals when reaching sexual maturity weigh up to 0.5 g. Adults live 10-15 years, reaching a length of up to 8-10 cm with a mass of up to 1.0 g.

In the late fifties of the last century in the United States in the state of California, a hybrid of the dung worm E. foetida, called the red California worm (Eisenia foetida red hybrid of California), was bred. This worm is characterized by a high intensity of nutrition and the rate of utilization of the original substrates. Under favorable conditions, organic waste is processed in 1-2 months. At the same time, up to 10 cocoons per week are deposited (up to 70 cocoons per year, taking into account the breeding cycle). E. foetida produces 4–5 generations per year with a high reproduction rate (1:1500 throughout the year) and has a longer lifespan (up to 15–16 years). The maximum size of individuals of the red California worm (KCH) is reached at seven months of age, when their mass is an average of 2.4 g. An important feature of the KCC is the loss of the instinct to leave their habitat under adverse environmental conditions. Therefore, it can be bred in open-air beds without fear of population loss. It reproduces well in captivity on various wastes - all types of manure, straw, waste paper, leaf litter, household garbage, activated sludge, etc. The red California worm is currently most widely used in many countries in industrial vermicomposting and vermiculation.

The disadvantage of KCC is its tropical origin and, as a result, warmth. Therefore, in the conditions of the temperate climatic zone characteristic of Russia, it can be grown only indoors or greenhouses. Promising for use in open ground are worms of other species, for example, local races of dung worms, forest dendrobenes.

In the course of research on obtaining a technologically acceptable strain of compost worms, it was found that technological worms for the industrial processing of any organ-containing waste can be obtained from local wild populations in any agricultural area. Comparative studies of ordinary earthworms and red California worms did not reveal any differences between them on 14 traits.

Technological worms always react negatively to the replacement of one substrate by another, which is accompanied by a sharp decrease in their productivity and even death.

To process a large amount of organic waste, the company needs to create its own population of technological worms, adapted to process a specific type of waste. To do this, you need to find a colony of worms around the source of this organic matter and transplant it into a cultivator. Worms should not be cultivated in compost piles. The process of composting in the piles goes with the heating of the compostable mass and the release of biogas (CO_2, CH_4, NH_3), which destroy the population of worms.

Cultivation of worms is technologically possible only in semi-transpired compost in the original layer with a thickness of 40-50 cm. As the compost is processed by worms, it is layered periodically, while the worms move from the lower layer to the upper fresh nutrient substrate.÷

It is established that the worm on average consumes an amount of compost per day equal to its own mass. This is limited by the limit of population density, upon reaching which the colony stops its development. The optimal seeding dose when populating a cultivator with a substrate with worms is their biomass of 0.3 kg / m2 (1500 individuals). During the cultivation cycle (160 $\pm$ 20 days), the population will increase by an average of 50 times in terms of the number of individuals and biomass. An increase in the sowing dose leads at the end of the cultivation cycle to overcompaction of the population, individuals become small and the total yield of biomass decreases.

Vermicomposting of various plant substrates can be significantly accelerated by their pre-treatment: steaming, partial hydrolysis with chemical reagents or treatment with cellulolytic microorganisms or enzymes. Pre-treatment also makes it possible to make substrates such as tree bark, lignin, active sludge available for vermicompostation. It is believed that "softened" waste is better digested and absorbed by earthworms, without exerting a toxic effect on them. However, in relation to such a cheap product as vermicompost, the pre-treatment of the substrate is economically unprofitable due to the high energy intensity and laboriousness of the operation. As another option for accelerating vermicomposting, the use of microbial preparations that activate the growth of worms is proposed.

It should be noted that although the technologies of vermiculturation and vermicomposting are developing in the Russian Federation at a relatively weak pace, but in general, this problem, in our opinion, has passed the stage of accumulating reliable data and is on the way to improvement. With the increasing pace of agricultural development in our country, we can hope for a more successful development of vermiculture and vermicomposting technologies using wastewater sediment as a substrate. Sometimes opinions are expressed that vermiculture and vermicomposting are technologies of the XXI century. In our opinion, this is partly true, but at the same time it is necessary to have an idea that in the practice of processing wastewater sediment, other methods, in particular conventional composting, will be actively improved in this direction.

7.4. Possibilities of using biomass of excess activated sludge of food and feed production as a feed additive

The biomass of excess activated sludge is a valuable protein-vitamin supplement. Its use in the diets of farm animals can balance feed in both protein and vitamins. The toxicity of this biomass is important. The experience of research of GosNIIsintezbelok on the use of activated sludge biomass as a feed additive gives positive results in most cases.

The developers have determined the optimal conditions for obtaining a protein preparation from activated sludge. The most appropriate mode for isolating protein from the biomass of activated sludge is a heat treatment temperature of 130 - 135 °C; heat treatment time is 20 - 30 minutes; pH 9.0. Inthe course of protein, it is 65%.

Activated sludge was tested as a feed additive on gobies aged 6-7 months. Activated sludge was introduced into rations in an amount of 20% of protein or 400-500 g per head per day (7 - 6% of the dry matter of the feed) or 25 - 30% of the mass of concentrates. It has been established that active sludge can be used as an energy, protein, mineral and vitamin supplement in the diets of growing young animals.

According to a number of developers, active sludge is a promising addition to animal feed and in the future will be widely used as a feed additive.

For feeding chickens in the process of pilot tests, active sludge was used after cleaning the effluents of yeast production. The composition of the sludge included: crude protein 42.8%, fat 2.5, ash 21.7, calcium 2.3, phosphorus 1.7% (by dry matter), little sulfur contentof ache amino acids, vitamin B12 - 25 mg / kg. Active sludge additives were equal to 2 and 8% of the feed ration. Biomass of activated sludge partially replaced a yeast and soybean flour, which served as control samples of the feed additive. In experiments on pigs, 2.4, 8% of activated sludge was added to the feed. Sludge supplementation of up to 2% gives an increase in mass, and more than 2% gives a significant deterioration in feeding rates. Thus, for pigs, the addition of sludgeto feed should not exceed 2%.

Experiments were also conducted on pigs of 2.5-3 months, grown to a live weight of 95 - 100 kg on feed with dietary supplements. The results of the experiments showed that the complete and partial replacement of fodder yeast with wastewater sediment (7.5 - 12.5%) in feed reduced the increase in live biomass by 6.1 - 19.3% and increased feed consumption by 3.0 - 19.2%. The addition of activated sludge alone in the amount of I - 5% to the feed increased the average daily increase in the live weight of pigs by 18.1 - 20.3% and reduced feed costs by 1 kg of growth by 6.0 - 9.6%.

Technical specifications (TU) and recommendations for the use of microbial biomass in the diets of growing and fattened pigs were developed in GosNIIsintezbelok. Of particular interest is the use of excess activated sludge as an additional substrate in the fermentation of fodderyeast of the genus Candida.

Based on the initial data of gosNIIsintezbelok, a project of acid hydrolysis of activated sludge was carried out with the supply of the obtained hydrolysate to the fermentation stage.

It is known from the literature that wastewater sediment is harmless after gamma irradiation and can be used in the feeding of farm animals. They are characterized by a high content of ash (42.1%, including 26% soluble in acid). In organic matter, which is 57.9%, crude protein accounts for 26.7%, fiber and lignin 23.0 and 6.3%. The content of trace elements ranges from 847 mg / kg (Na) to 917.5 mg / kg (Ca), trace elements from 5 mg / kg (Cd) to 5840 mg / kg (Fe). In most experiments conducted on ruminants, the digestibility of nutrients and nitrogen was 60 and 70%. In terms of digestibility, the wastewater sediment approaches cotton meal. The inclusion of wastewater sediment or meal in the diet of cows increases the birth rate of calves from 66% to 84% when using wastewater sediment and up to 80% when adding meal. With this diet, the mass of cows increased from 2 to 12% and from 7 to 20%, respectively.

Active sludge is mainly formed by the biomass of unicellular organisms. In terms of protein content, it is close to protein-vitamin concentrates (BVK) obtained by culturing yeast of the genus Candida on various substrates. (Table 7.5)

Table 7.5. Component composition of activated sludge and some feed preparations, %

Components	Activated sludge	BVK	Preparation KMB-12	Meat and bone meal	Fish low-fat flour	Podsolnechnikovый шрот	Pea	Barley
Dry matter	85,1	87,3	92,2	91,3	94,3	87,5	87,6	87,3
Organic matter	60,7	81,1	53,1	58,1	68,2	81,7	84,7	84,2
Protein	50,3	54,2	31,8	37,4	59,1	38,4	21,5	10,5
Fat	2,1	1,3	0,9	14,7	1,7	2,6	1,1	5,3
Cellulose	8,7	2,2	6,2	8,9	7,8	15,1	4,2	5,1
Nitrogen-free extractive substancesa	38,1	52,3	61,9	47,2	38,3	42,7	72,3	78,9
Ash	19,5	11,8	38,1	32,1	25,4	6,5	2,4	3,5

Table 2.2 shows the composition of the activated sludge during the trial cultivation. Compared to the biomass of fodder yeast, active sludge contains less carbohydrates, fat-like substances, slightly more ash. A comparative analysis of sludges cultured on wastewater of different origins showed that the composition of bacterial biomass is practically constant and changes slightly under different modes of aerobic treatment. The conflicting data in the literature are explained by the ingress of suspended particles from the treated wastewater into the active sludge, which changes the chemical composition of the sludge, but not the composition of the bacterial biomass contained in it. According to Table 2.2, the active sludge or bacterial biomass of the aerobic community differ little in composition from BVK (protein-vitamin feed), in any case, in the content of the main component - protein. In terms of dry matter concentration, active sludge is similar to fodder yeast and plant feeds. In terms of protein content, sludge exceeds meat and bone meal by 12.5%; sunflower meal by 10.8; peas on 28; barley by 38.8; BMF by 18.8%. The fat content in sludge is close to the fat content in fish low-fat flour, peas. The amount of nitrogen-free extractive substances (BEV) in sludge is somewhat inferior to barley, peas and fodder yeast.
The criterion of the biological value of feed is not only its chemical composition, but also the usefulness of protein, the presence and concentration of vitamins, macro- and microelements. Bacterial protein is a complete product in terms of amino acid set. In Table. Figure 7.6 shows the amino acid composition of active sludge, fodder yeast and beef meat. The comparison shows an almost complete correspondence of the content of essential amino acids in active sludge and meat.
Table 7.6. Amino acid composition of active sludge, fodder yeast and beef meat, % to protein

Amino acids	Activated sludge	Fodder yeast	Beef meat
Alanya	5,89	3,2	6,1
Arginine	6,06	3,6	6,7
Aspargarine	7,44	4,1	8,2
Valyan	5,76	1,8	6,1
Histidine	1,93	2,5	3,3
Glycine	4,97	1,9	6,9
Glutamine	12,11	3.9	14,30

Isoleucine	4,20	6,2	5,20
Leucine	6,30	9,8	8,90
Lysine	7,20	5,9	8,80
Methionine	3,10	1,	2,70
Series	6,32	5.3	3,60
Tyrosine	3,10	1,6	3,40
Threonine	3,35	2,9	4,10
Tryptophan	1,42	1,7	1,40
Phenylalanine	4,34	1,5	4,30
Cysteine	1,41	1,4	1,6

According to other sources, 1 g of dry matter of sludge (25-47% protein) accounts for up to 4.2 mg of cysteine, 22.4 mg of lysine and histidine, 14.6 of arginine, 31.4 mg of aspartic acid, 50.1 mg of glycine and glutamic acid, 10.8 of tyrosine, 27.8 of methionine and valyl, 26.5 mg of phenylalanine.
The content of vitamins, especially vitamin B12, in dry active sludge is quite high and in some respects exceeds their content in fodder yeast (Table 7.7).
A complete amino acid and rich vitamin composition of activated sludge indicates its suitability for use as a feed additive.

Table 7.7. Vitamin composition of active sludge and fodder yeast μg from 1 gram of absolutely dry matter (ADM)

Vitamins	Activated sludge	Fodder yeast
Thiamine B1	5-10	10-25
Riboflavin, B2	5-90	40-120
Pyridoxine, B4	6-20	10-20
Cyanocobalamin, B12	7-18	0,05-0,1
Niacin, PP	20-60	200-250
Folic acid, B9	10-40	5-40

Activated sludge formed during the treatment of food production effluents can contain 40 - 55% of the protein in dry matter, and in amino acid composition it is close to meat and soy muke. Animals absorb up to about 80 % of the substance of activated sludge, their weight gain is the same as when using traditional protein feed. The use of sludge in an amount of 3-5% to the diet of cattle can provide weight gain of up to 20%.

Activated sludges formed during artificial biological treatment of food industry effluents are to a certainextent guaranteed against a significant content of hazardous substances. Nevertheless, their direct use as feed components should be carried out under careful sanitary and veterinary control.

Thus, the prospects for the use of activated sludge as a feed additive are highest for activated sludges formed at local treatment facilities of food enterprises and production facilities for the production of feed additives, including fodder yeast.

In general, it should be noted that the efficiency of the use of wastewater sediment increases with the simultaneous solution of several tasks. On the basis of such treatment facilities, for example, with the help of anaerobic digestion, biogas and high-quality fertilizers are produced. The biogas obtained in this way contains 62 - 63% methane, 35 - 36% carbon dioxide and 1-3% impurities of nitrogen, hydrogen, ammonia, hydrogen sulfide. The calorific value of this biogas is 21 - 26 MJ/m3. The fertilizers obtained along with biogas contain a dry residue of 31%, nitrogen 0.6%, phosphorus 0.6%.

7.5. Disposal of water sediments: experience of JSC Mosvodokanal

Water sediment is formed during the production of drinking water due to the sediment of mineral and organic contaminants present in the water of surface sources by aluminum salts. Sediment disposal is the final stage of industrial wastewater treatment.

At three Moscow water treatment plants, water sediment is discharged into the city sewerage system for its further treatment at treatment facilities together with wastewater sediment. And only at one station (Vostochnaya) until recently, the treatment of water sediment was carried out due to natural drying on artificially created maps (sludge sites), followed by the removal of clarified water into natural reservoirs and the placement of dehydrated sediment at deposition sites. However, this method of sediment treatment was ineffective, as it depended on the composition of the water sediment, weather factors, changes in the groundwater regime in the adjacent territories, and the need for the alienation of significant land. At the same time, the humidity of the sediment remained quite high, which made it difficult to remove it.

In accordance with the concept of development of the system of utilization of industrial wastewater of water treatment plants and in order to eliminate the negative impact on the natural environment and increase the efficiency of water sediment treatment, in 2010 facilities for its mechanical dewatering were put into operation at the Eastern Water Treatment Plant. The operation of these structures is based on the principleof continuous thickening - at the first stage in gravity seals, and then on drum thickeners and mechanical dewatering on centrifuges to an estimated humidity of 80%. At all stages of processing, flocculant is injected. As a result, a precipitate is formed, ready for transportation and disposal.

The main components of the sediment are mineral substances - clay particles, fine sand, carbonate rocks, insoluble or poorly soluble salts and organic substances formed by phyto- and zooplankton, waste products of aquatic organisms and plants, colloids of humic and fulvic acids. The sediment of water treatment plants is an analog of natural sapropel, containing up to 40% of fertile humus, which was removed from the natural cycle due to leaching from the soil by atmospheric sediment.

The chemical composition of the tap sludge is determined by seasonal changes inthe surface of the water source and the current dose of the coagulant - sulfate or aluminum oxychloride. Plumb precipitate is a non-toxic biologically inert suspension with a low content of sedentary forms of nitrogen and phosphorus, with a high content of aluminum hydroxide - from 8-12% to 18-20% Al in dry matter for low-color and high-color waters, respectively. Sediment contains an average of about 20% aluminum, 0.7% nitrogen and 0.4% phosphorus. Acidity according to the pH of the water extract is 7.4, according to the pH of the salt extract - 6.9. The potassium content is about 0.1% (according to K2O).

The humus and nutrients contained in the sediment make it possible to use it to obtain biomass used in urban greening and the production of industrial crops. The high content of aluminum allows us to consider the sediment as a secondary resource for obtaining building materials.

The analysis of the world experience in the secondary industrial use of water sludge conducted by the specialists of JSC "Mosvodokanal" made it possible to identify the following main areas: in construction in the production of cement and bricks, foam glass granulate, material for road surfaces; in the manufacture of paints and mastics; in the production of soil.

Recycling in construction allows you to assimilate part of the water sludge and create on its basis materials with useful properties. However, due to the unstable composition, the use of water sediment as a building material is very limited. For megacities, where the problem of technogenic soil degradation is extremely relevant, this direction cannot be considered as the main one. In cities, under the influence of intensive anthropogenic pressure, not only soils disappear and become polluted, but also the possibilities of natural formation and maintenance of soil cover are destroyed.

In natural ecosystems that are not exposed to anthropogenic influences, nutrients (nitrogen, phosphorus, potassium) and soil organic matter are continuously replenished. However, human activity, especially in the past century, has profoundly altered the biogeochemical flows of energy bound in organic matter and the cycle of elements involved in the exchange of organisms and the environment. Urbanized areas have become zones of accumulation of organic raw materials and food, household, physiological and industrial organic waste. Waste removed from the natural cycle is, on the one hand, a source of environmental pollution, and on the other hand, causes a deficiency of humus and nutrients in the soil. The disappearance of humus from the top layer is the cause of the loss of soil fertility. Moscow is no exception in this case.

At the same time, in Moscow, the problem of depositing sediment is very acute, since the landfills are overcrowded. The current situation with the burial of water sludge - the most important source of organomineral fertilizer against the background of widespread soil depletion should be changed. The way out of the ecological impasse is the production of fertile soils and their use to restore the fertility of urban soils.

Specific requirements are imposed on urban soils: they must have increased buffering, resistance to adverse factors. When the fertile layer is irreversibly polluted, it is necessary to completely replace it with natural or artificial soils. The experience of reclamation of urban soils has shown that peat-mineral mixtures without the addition of other organic components are characterized by rapid drying, potential flammability on the lawns of the city, dusting and a low content of easily accessible mineral salts, since peat contains mainly hard-to-oxidize organic matter.

Water sediment has agrochemical properties that make it possible to attribute it to sapropels: a sufficient content of organic matter, nitrogen, phosphorus, potassium, a favorable pH range, but is characterized by unfavorable agrophysical properties (lack of soil structure, unfavorable water-air regime for seeds and roots, the ability to crack when drying out, etc.). Therefore, the opportunity to use in the green economy appears only in a mixture with other soils. Plumbing sludge, being a source of food available to plants, stimulates the microbiological decomposition of peat, which increases the nutrient content in the soil, maintaining it at the required level for several years without the addition of mineral fertilizers. The precipitate contains a significant amount of aluminum salts and hydroxides, which have amphoteric properties, which allows the soil to show high buffering in relation to highly acidic or highly alkaline surface waters of the urban environment. The harmlessness of sediment in soils is explained by the absence of salts of heavy metals and organic toxicants in them.

In terms of the content of toxic elements, pesticides, radionuclides, 3.4 benz(a)pyrene, petroleum products, the water sediment meets the requirements of GN 2.1.7.020-094, GN 2.1.7.2042-06, GN 2.1.7.2041-06, and also meets the requirements of SanPiN 2.1.17.1287-03 "Sanitary and epidemiological requirements for soil quality". A typical sediment composition of the Eastern Water Treatment Plant is shown in Table 7.8.

Table 7.8. Typical composition of the water sludge of the Eastern Water Treatment Plant (according to JSC Mosvodokanal)

Index	Units. ism.	Meaning
Humidity	%	81,2
Organic matter	%	49
Nitrogen	%	0,8
Ph		7,14
P2O5 common	%	0,40
P2O5	mg/kg	150
K2O general	%	0,04
K2O	mg/kg	40
Chlorides	mmol/100g	1,09
Aluminium	g/kg	173

Iron	g/kg	3,5
Cadmium	mg/kg	0,04
Copper	mg/kg	21
Arsenic	mg/kg	16
Cobalt	mg/kg	<4
Nickel	mg/kg	8,2
Mercury	mg/kg	0,03
Lead	mg/kg	1,8
Strontium	mg/kg	100
Chromium	mg/kg	5,6
Zinc	mg/kg	34
Petroleum products	mg/kg	62
Benz(a)pyrene	µg/kg	<1
Aldrin	mg/kg	<0,001
Hexachlorobenzene	mg/kg	<0,001
Dieldrin	mg/kg	<0,001
Eldrin	mg/kg	<0,001
Heptachlor	mg/kg	<0,001

Soil composition:

50% peat,

35% of water sludge,

15% sand.

Let's calculate the amount of soil using the above recipe.

Source data:

500 m3~360 tons of water sludge

When adding:

$$\frac{15 \cdot 360}{35} = 155 \text{ tons of sand},$$

$$\frac{50 \cdot 360}{35} = 515 \text{ tons of peat}$$

Get:

$$360 + 155 + 515 = 1030 \text{ tons of soil}$$

Experiments of the engineering and technological center of JSC "Mosvodokanal" showed that mixing the water sludge of the Eastern water treatment plant with peat and sand makes it possible to prepare a fertile soil that is close in composition and properties to natural soil.

The soil is prepared as follows. Peat, tap sediment and sand are moved to the concrete surface from the storage site of the initial components in accordance with the recipe. Mixing of the mixture of raw materials is carried out by a front loader with a hinged bucket by repeatedly gripping and tipping the mixture.

Mixing is carried out until the raw materials are completely mixed, the completeness of mixing is determined visually. Mixing and crushing of the soil obtained after the primary mixing of the starting materials is carried out by passing it through a bucket crusher installed on a front loader. Then the finished soil is moved to the storage site.

The author has developed a more highly efficient method of mixing using a rotary mixer. This development is still at the stage of pilot tests.

The finished soil has high fertility, which has been repeatedly confirmed in vegetation experiments with various crops (lawn cereals, flower and tree crops), has an attractive appearance for the consumer. Utilization of 0.35 m3 of water sludge in the composition of 1 m3 of soil makes production economically profitable and environmentally sustainable for JSC "Mosvodokanal". The soil is balanced in terms of mineral nutrition elements and granulometric composition. The soil contains 17-20% organic matter; 0.4-0.6% of total nitrogen; 200-250 mg/kg of mobile potassium (K2O); 100-150 mg/kg of mobile phosphorus (according to P2O5); 15-17% of particles smaller than 0.01 mm. According to the chemical and sanitary-epidemiological condition, the soil complies with the requirements of GN 2.1.7.020-094, GN 2.1.7.2042-06, GN 2.1.7, SanPiN 2.1.17.1287-03.

Soil based on water sludge is used to create and repair lawns, landscaping road slopes. Soil can be in demand for growing ornamental plants and woody crops, used in landscaping various territories - sports and children's playgrounds, recreation areas. Soil expands the range of plant nutrient soils used in Moscow, has high anti-erosion properties, as well as high buffering in relation to adverse conditions of the urban environment. The use of soil based on water sludge contributes to the improvement of the natural environment of the capital and will make our city even greener and more comfortable.

7.6. Improvement of the method of using activated sludge as a flocculant in wastewater treatment technology

It is well known to use activated sludge as a flocculant (the term biocoagulant is sometimes used in the literature) when supplying it to primary sedimentation tanks. However, its effectiveness can be markedly increased when used in combination with chemical regents (coagulants and flocculants).

It is known that the flocculating properties of activated sludge are due to the presence of a polysaccharide layer around the microorganisms included in its biocenosis.

On the other hand, it is also known that when using flocculants, various mechanisms of this process are considered, namely: compression of the double layer, chemical interaction, the mechanism of bridge formation (the formation of polymer bridges between the particles of the suspension due to the fixation of molecular chains on the surface of the particles).

Based on the comparison of the above data, it can be assumed that the most likely flocculation mechanism in the case of active sludge is the adsorption-bridge mechanism.

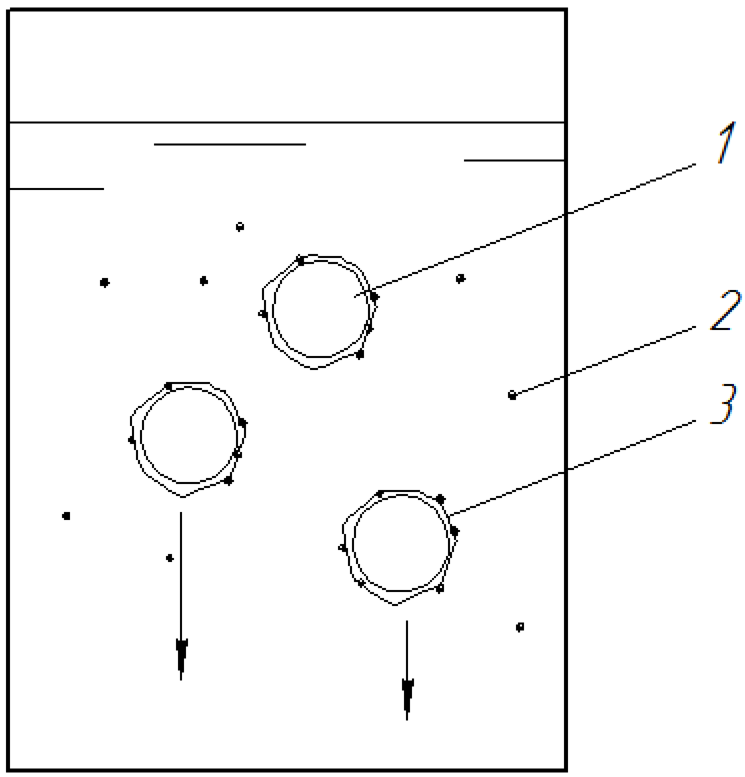
A possible diagram of the flocculation process when adding activated sludge is shown in Figure 7.2.

This process can be represented as multi-stage, which includes the formation of flocules ("activated sludge-particle of pollution") and their subsequent separation from the water under study.

In this case, an analogy can be drawn with a sequential monomolecular reaction (Fig. 7.3).

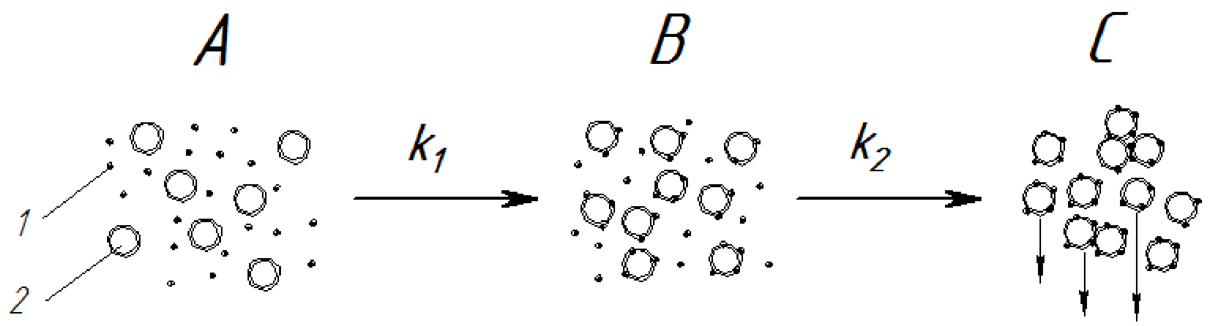
In the diagram, state A is a state where activated sludge microorganisms and pollution particles do not interact. In the process of their interaction, the particles of contaminants stick together with the polysaccharide layer of cells.

This process is determined by state B - an intermediate state (phlocules "active sludge particle of pollution"). Then the formed complexes precipitate (state C).



1 — microorganisms of activated sludge; 2 — particles of pollution; 3 – polysaccharide layer

Fig. 7.2 — Possible scheme of the flocculation process when adding activated sludge



1 — particles of pollution; 2 – microorganisms of activated sludge with a polysaccharide layer

Fig. 7.3. Scheme of multi-stage flocculation process:

Let's take the following designations:

CA, SV, CC are the concentrations of particles in states A, B and C, respectively, at time t;

k1, k2 are the velocity constants of the first and second stages of the process;

w1, w2 are the rates of the first and second stages of the reaction;

C_0 is the initial concentration of particles.

$$A \xrightarrow{k_1} B \qquad w_1 = k_1 C_A;$$

$$B \longrightarrow C \qquad w_2 = k_2 C_B;$$

The flocculation process is then described by the following system of differential equations:

$$\begin{cases} \dfrac{dC_A}{dt} = -k_1 C_A \\ \dfrac{dC_B}{dt} = k_1 C_A - k_2 C_B \\ \dfrac{dC_C}{dt} = k_2 C_B \end{cases}$$

Let's find the dependence of concentrations in states A, B, C on time t.

The rate of formation of the initial state A is expressed by the equation:

$$w^{(1)} = (-1) w_1 \text{ or } \frac{dC_A}{dt} = -k_1 C_A. \qquad (1)$$

The integration of this equation after separating the variables from 0 to t and from C_0 to C_A results in the expression:

$$C_A = C_0 e^{-k_1 t} . \qquad (2)$$

The rate of formation of B in the first and second stages is expressed by the equations:

$$w_1^{(3)} = (+1)\,w_1 \text{, where } w_1 = k_1 C_A ;$$
$$w_2^{(3)} = (-1)\,w_2 \text{, where } w_2 = k_2 C_B .$$

Hence, the total rate of formation of B in both successive stages is:

$$w^{(3)} = w_1^{(3)} + w_2^{(3)} ; \ \frac{dC_B}{dt} = k_1 C_A - k_2 C_B .$$

Substituting C_A from the expression (2), we get:

$$\frac{dC_B}{dt} + k_2 C_B = k_1 C_0 e^{-k_1 t} . \qquad (3)$$

To solve this differential equation, multiply both parts of it by $e^{k_2 t}$ and bearing in mind that

$$e^{k_2 t}\frac{dC_B}{dt} + C_B k_2 e^{k_2 t} = \frac{d}{dt}(C_B\, e^{k_2 t}) ,$$

Get

$$\frac{d}{dt}(C_B\, e^{k_2 t}) = k_1\, C_0 e^{(k_2-k_1)t}. \qquad (4)$$

The integration of equation (4) from 0 to C_C and from 0 to t results in the expression:

$$C_B e^{k_2 t} = \frac{k_1 C_0}{k_2 - k_1}(e^{(k_2-k_1)t} - 1).$$

Dividing both parts into $e^{k_2 t}$, we get the desired expression for C_B:

$$C_B = \frac{k_1 C_0}{k_2 - k_1}(e^{-k_1 t} - e^{-k_2 t}). \qquad (5)$$

Expression for concentration C_C can be found from the differential equation of the rate of formation C:

$$w^{(2)} = (+1)\, w_2 \text{ or } \frac{dC_C}{dt} = k_2 C_B. \qquad (6)$$

Also, this value can be found from the equation of material balance:

$$C_0 - C_A = C_B + C_C. \qquad (7)$$

At the same time, we believe that at the beginning of the reaction $C_{B0}=C_{C0}=0$. Hence

$$C_C = C_0 - C_A - C_B. \qquad (8)$$

Substituting in (8) equations (2) and (5), we obtain the desired expression for C_C:

$$C_C = C_0\left(1 - \frac{k_2}{k_2 - k_1} e^{-k_1 t} + \frac{k_1}{k_2 - k_1} e^{-k_2 t}\right).$$

Dependency type C_A, C_B, C_C is presented on the graph in Fig. 7.4.

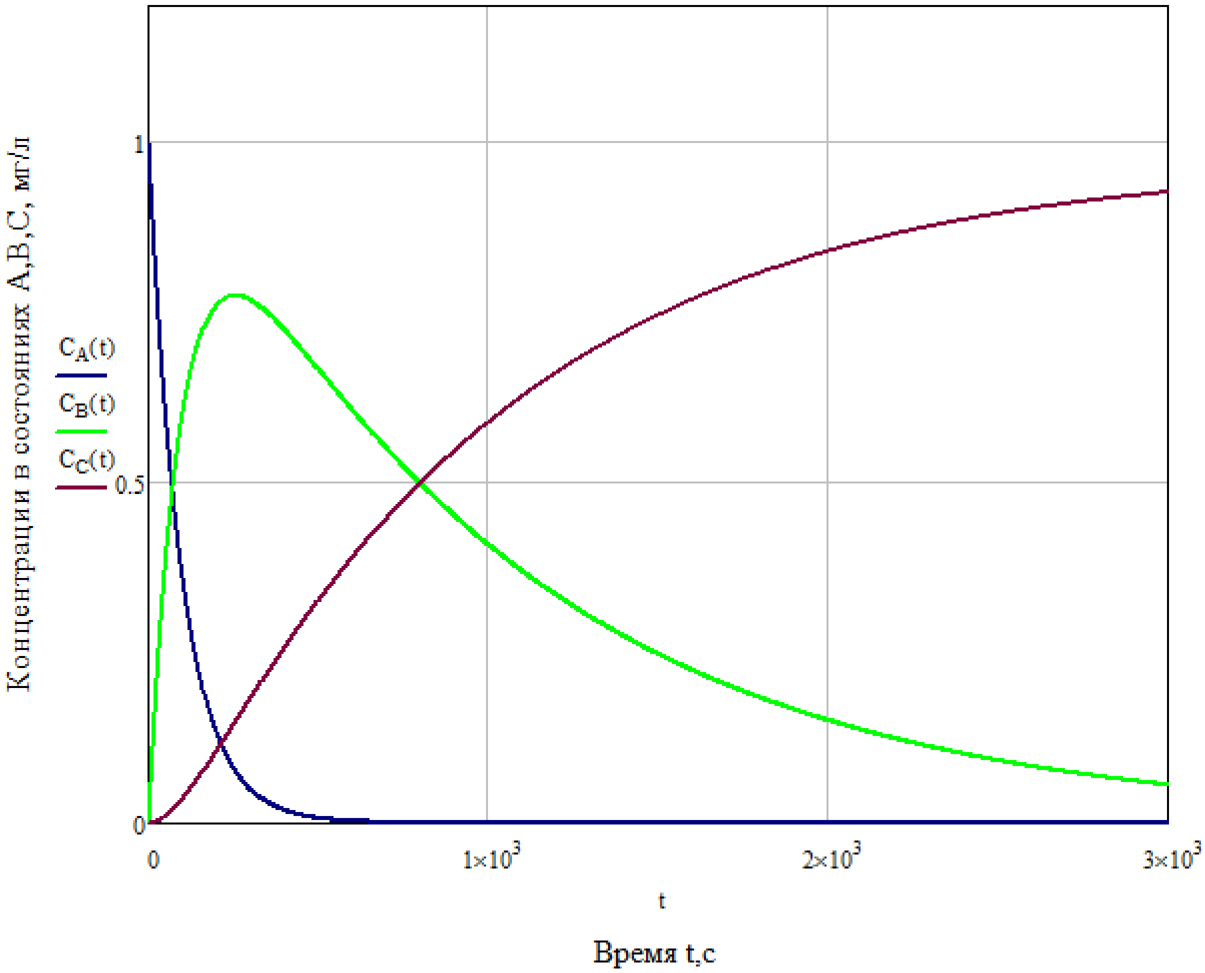


Fig. 7.4. Dependencies C_A, C_B, C_C from time to time when using activated sludge

Experimental studies confirm the proposed mechanism of flocculation using activated sludge.

It is important to find the optimal dose of activated sludge, which is determined by the method of trial coagulation. In Fig. Experimental data on the dependence of clarification (turbidity) of wastewater on the dose of activated sludge are presented in Fig. 7.5. In this case, a suspension with a concentration of activated sludge of 22 g / l was used.

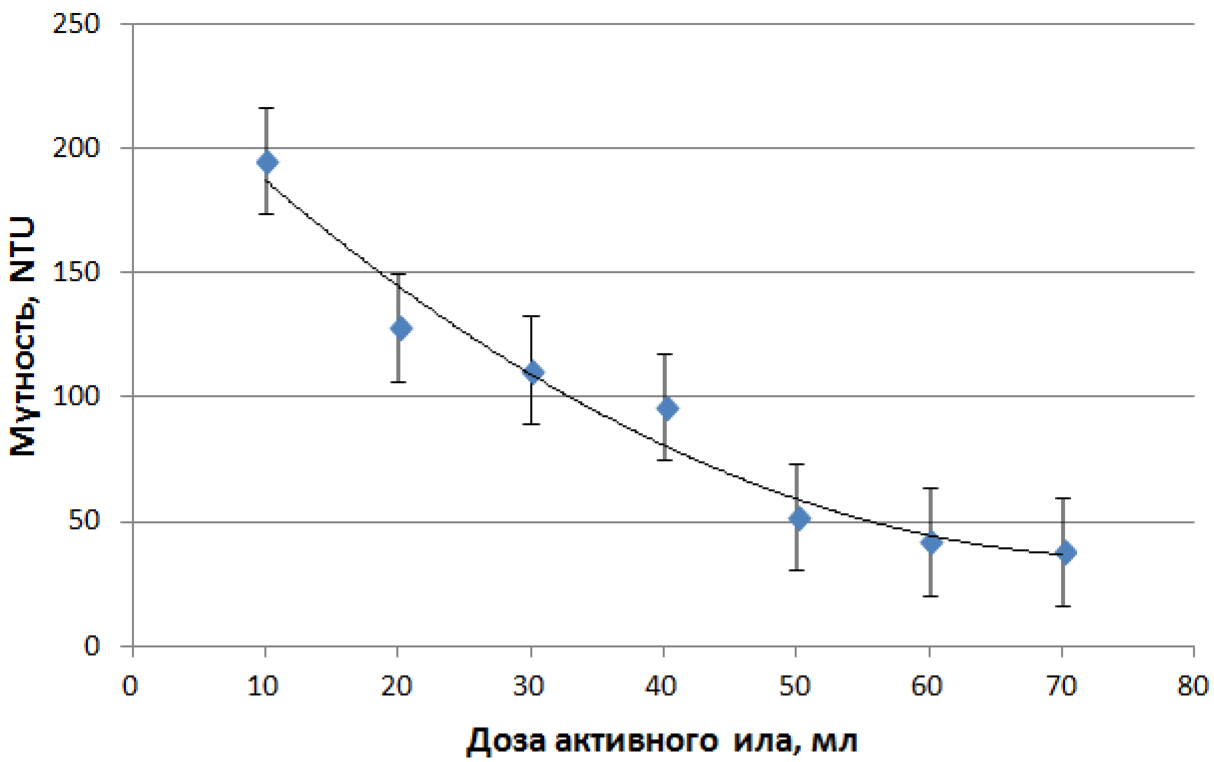


Fig. 7.5. Determination of the optimal dose of activated sludge

Of great importance is also the procedure for adding activated sludge to wastewater when using synthetic reagents.

In this regard, experiments were conducted on the joint use of activated sludge with synthetic reagents. As a result, it was found that the combined use of activated sludge and other reagents allows to achieve lower values of turbidity of the treated effluent. Below are the results of such experiments and the determination of optimal doses of other reagents (Fig. 7.6 – 7.8).

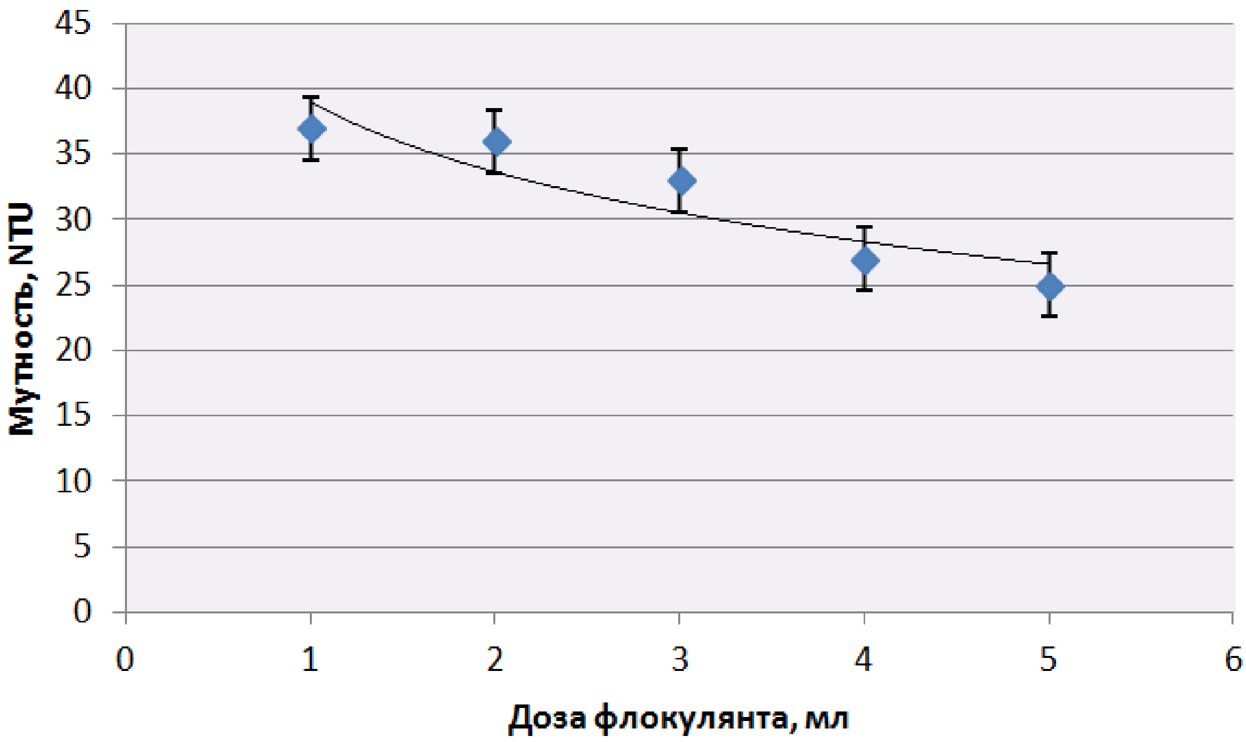


Fig. 7.6. Determination of the optimal dose of flocculant FLOPAM FO 4550 SH when used with active sludge (50 ml / l)

The best result is achieved by adding 2.5 ml of flocculant.

Experimental data on the joint use of activated sludge and Nalco 71221 are presented in Fig. 16.

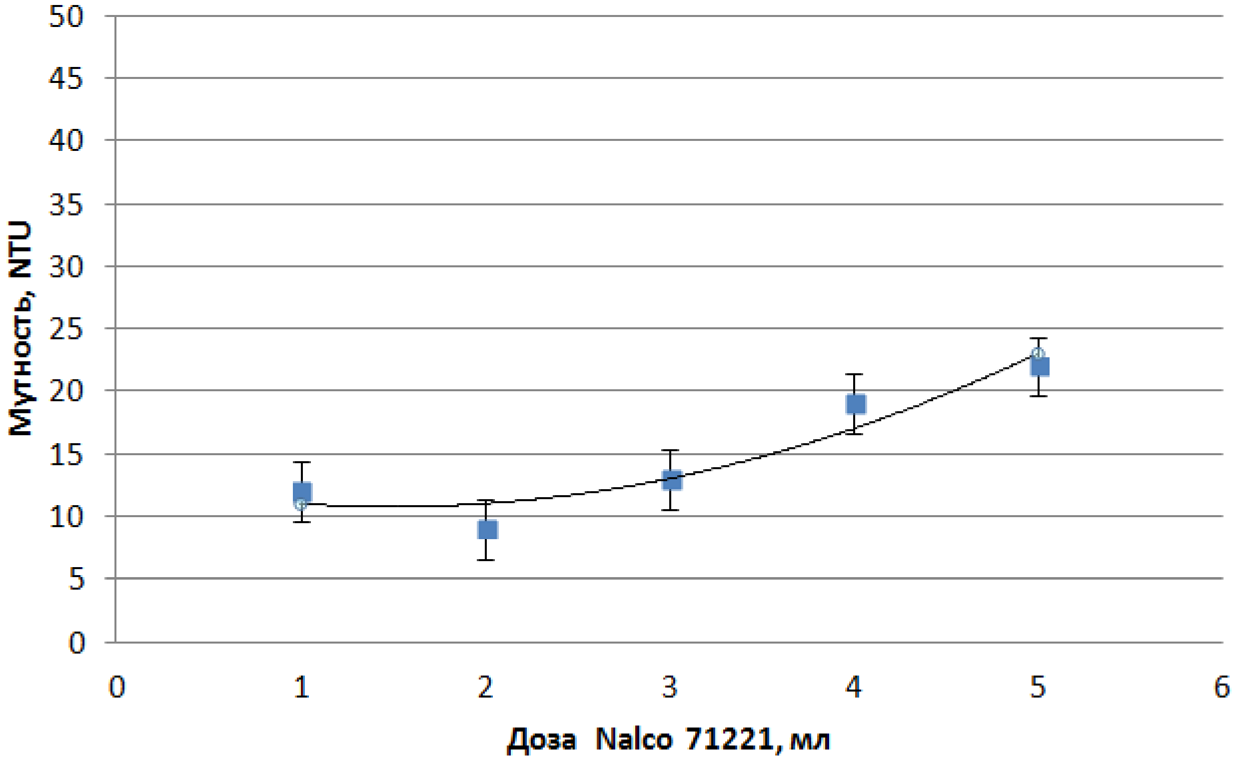


Fig. 7.7. Determination of the optimal dose of coagulant Nalco 71221 when used with activated sludge (50 ml / l)

The results of similar studies on the joint use of activated sludge and Nalco 8186 reagent are presented in Fig. 17.

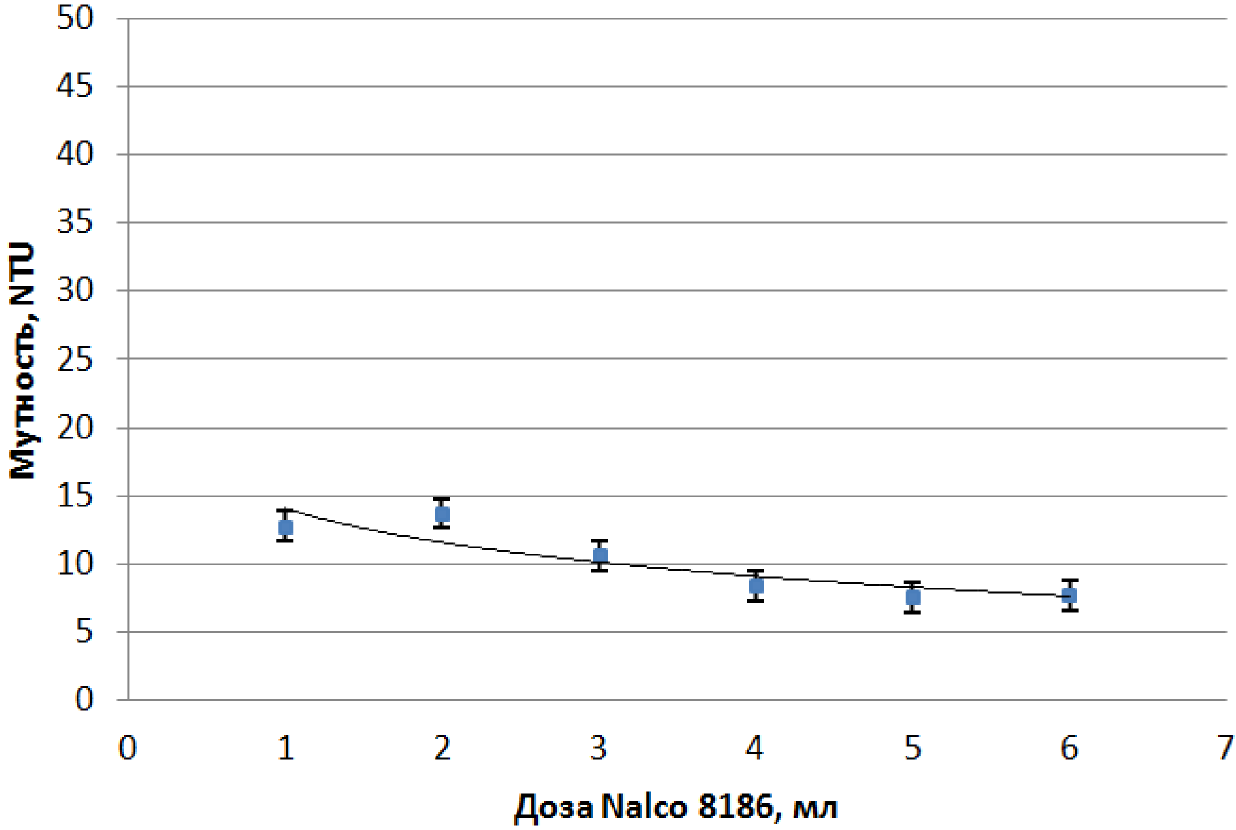


Fig.7.8. Determination of the optimal dose of coagulant Nalco 8186 when used with activated sludge

The obtained data of experimental studies allow usto draw the following conclusions.

The use of activated sludge as a flocculant in optimal doses allows to intensify the process of sediment of suspended solids in wastewater. The combined use of activated sludge in combination with various reagents makes it possible to intensify the process of clarification of wastewater compared to the use of activated sludge alone.

The comparative effectiveness of the combined use of activated sludge (AI) and synthetic reagents is presented in Fig. 7.9. From those presented in Fig. 7.9 of the data shows that the best result of the reagents used is obtained by combining activated sludge with flocculant Nalko 8186.

Therefore, the most appropriate option is the joint use of activated sludge with synthetic reagents.

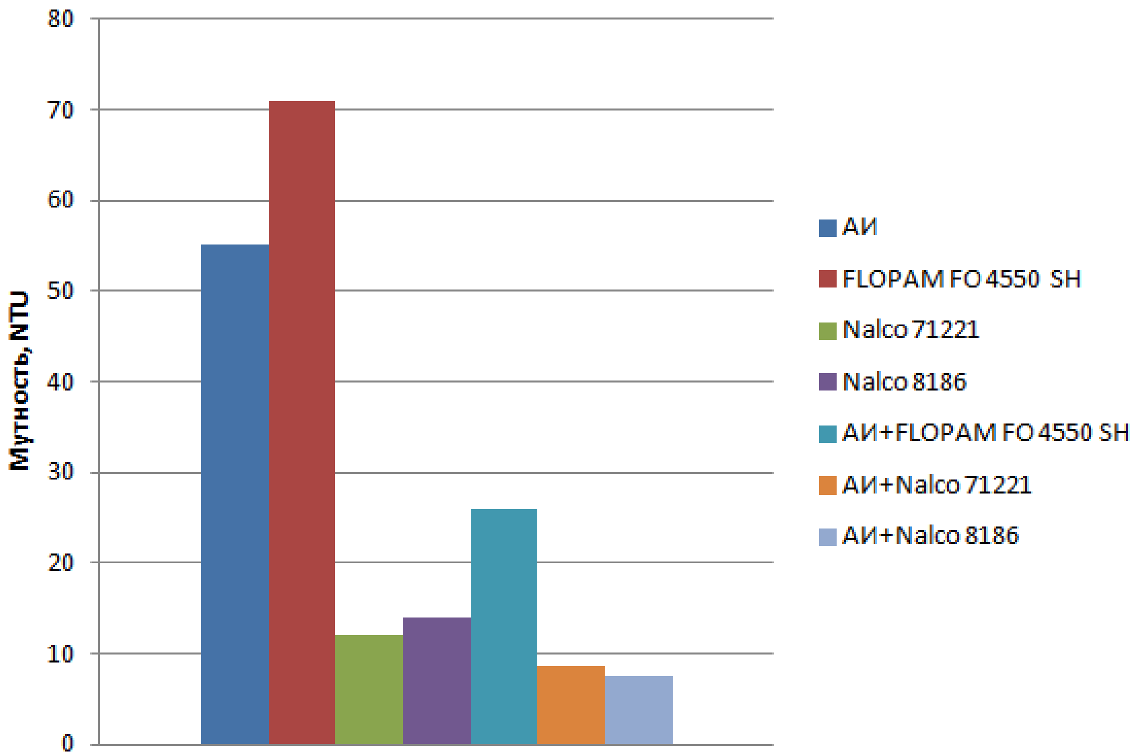


Fig. 7.9. Comparison of the effectiveness of the reagents used in combination with activated sludge

Thus, this technological technique allows not only to use and dispose of excess activated sludge, but also to reduce the consumption of synthetic reagent used for wastewater treatment.

Taking into account the above data, based on the implementation of experimental studies, the following recommendations for the use of activated sludge as a biofloculant have been developed.

1. In accordance with the theory of the formation of flakes of activated sludge, which is based on the interaction of extracellular high-molecular polyelectrolytes. Therefore, when using activated sludge, it is necessary to take into account its age and phase of development. This conclusion was confirmed during the experiments. Over time, after the collection of excess activated sludge, its flocculation properties deteriorate. Thus, in the practice of wastewater treatment, it is advisable to use excess activated sludge preferably no later than a few hours (2-3 hours) after its collection from a secondary sedimentation tank or sludge compactor (depending on the existing technological scheme).

2. In some cases, the most optimal possible way to use activated sludge is its joint use with chemical reagents (coagulants and flocculants).

3. In the absence of a biological stage in the technological scheme Wastewater treatment, excess activated sludge can be supplied from the nearest major treatment plants. However, it is necessary to take into account the additional transportation costs for the supply of activated sludge, as well as the deterioration of its flocculation properties over time during the pumping process. Thus, the proposed option for the use of activated sludge is optimally carried out at local treatment facilities without pumping to other facilities.

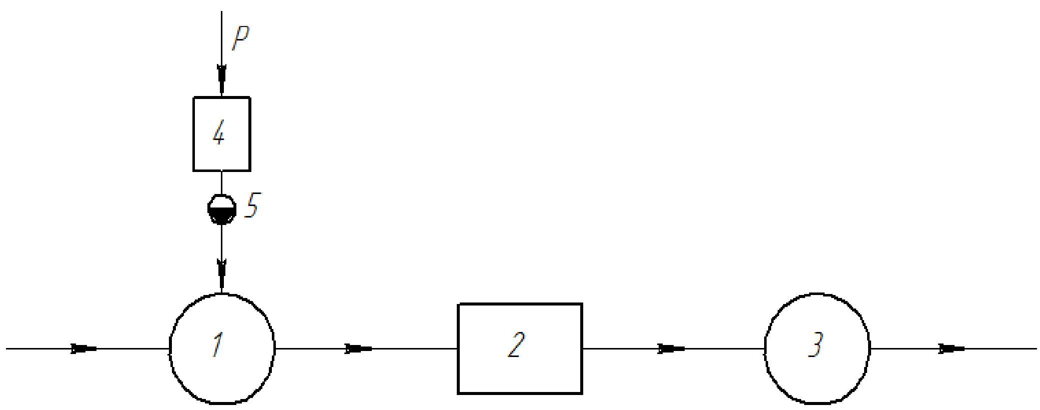
When developing wastewater treatment projects using activated sludge as a flocculant, it is necessary to make technical and economic calculations in order to choose the most profitable option.

In accordance with the recommendations described above, it is advisable to use activated sludge as a biofloculant in existing treatment facilities with stages of biological and physico-chemical treatment. In this regard, it is necessary to take into account possible capital costs (for additional equipment for excess activated sludge) and current costs for the cost of reagents.

Consider the implementation of such a technological scheme (Fig. 7.10).

Wastewater enters the primary sedimentation tank, where the process of deposition of contaminants is intensified by the use of a reagent. After biological treatment in the aeration tank, the water enters the secondary sedimentation tank and then for post-treatment.

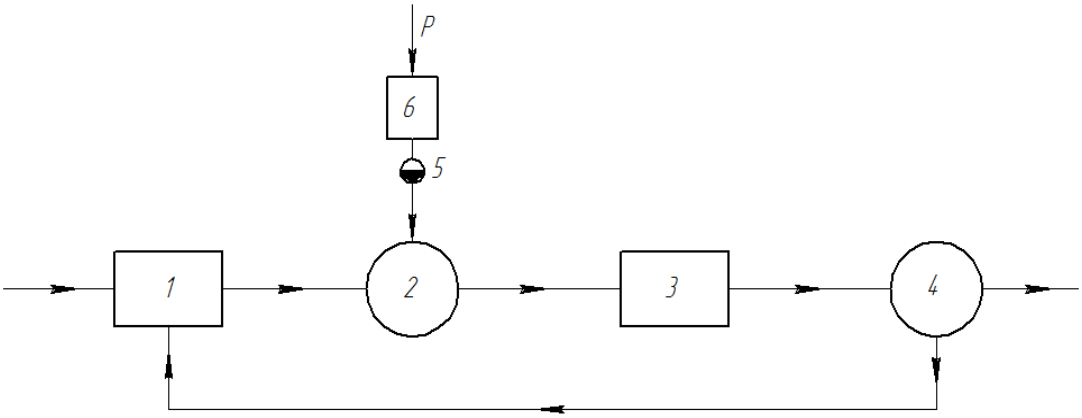
To use activated sludge as a biofloculant, it is necessary to modernize this scheme and ensure the return of excess sludge to the primary sedimentation tank.



1 — primary settling tank; 2 — aeration tank; 3 — secondary settling tank; 4 — reagent tank; 5 — pump—dispenser; P — synthetic reagent used

Fig. 7.10 – Technological scheme of wastewater treatment

The technological scheme in this case takes the following form (Fig. 7.11).



1 — preaerator; 2 — primary settling tank; 3 — aeration tank; 4 — secondary settling tank; 5 — pump—dispenser; 6 — reagent tank; P — synthetic reagent used

Fig. 7.11. Technological scheme of wastewater treatment after modernization

This scheme provides for the return of part of the excess activated sludge to the preaerator, then the sludge mixture is fed into the primary sedimentation tank to improve the purification process.

As is known, the sedimentation characteristics of activated sludge can be improved by various methods of pretreatment (physical, chemical). The properties of sludge are noticeably improved after preliminary aeration. Aeration can be carried out in specially prepared structures - preaerators.

Preliminary aeration also contributes to a better preparation of wastewater for biological treatment, since the process of release of suspended substances takes place most fully. In addition, during biofloculation, biochemical oxidation of some part of the lekgo-oxidizing solutes can occur, which helps to reduce BOD.

By reducing the consumption of the reagent, the cost of its acquisition is reduced.

For example, by calculating the reduction in the consumption of the reagent per stream of purified water with a flow rate of 100^{m3} / h, it is possible to obtain an economic estimate of the reduction in the cost of its acquisition.

Consider the cost reduction on the example of flocculant Flopam FO 4550 SH.

Specific flow rate of flocculant per 1^{m3} of purified water – 50 g. The addition of excess activated sludge will reduce flocculant consumption by 35% and the savings in flocculant consumption per year will be more than 15 tons, which gives a significant economic effect.

7.7. Use of activated sludge and peat as a flotation reagent

The use of natural materials for wastewater treatment is of great environmental importance, as it does not lead to additional water pollution. In addition, natural materials can be disposed of by natural biocenoses. As such materials, various natural clays as a sorbent, sand in the form of filter loads, active sludge and peat as an adsorbent and a natural ion exchanger that allows extracting petroleum products, fats, as well as metal ions from purified water can be used. Peat is of particular interest because of its possible diverse uses, for example as a flotation agent. The fact is that peat includes various fractions, including the bituminous fraction, which is characterized by hydrophobic properties, and, consequently, the ability to flotability.

In addition, peat particles can mechanically capture gas (air) bubbles. In this case, aeroflocules are formed, capable of flotation separation from water. Various possible options for attaching gas bubbles to peat particles, as well as to the components of aggregates including peat particles and activated sludge flakes, are presented in Fig. 7.12 – 7.13.

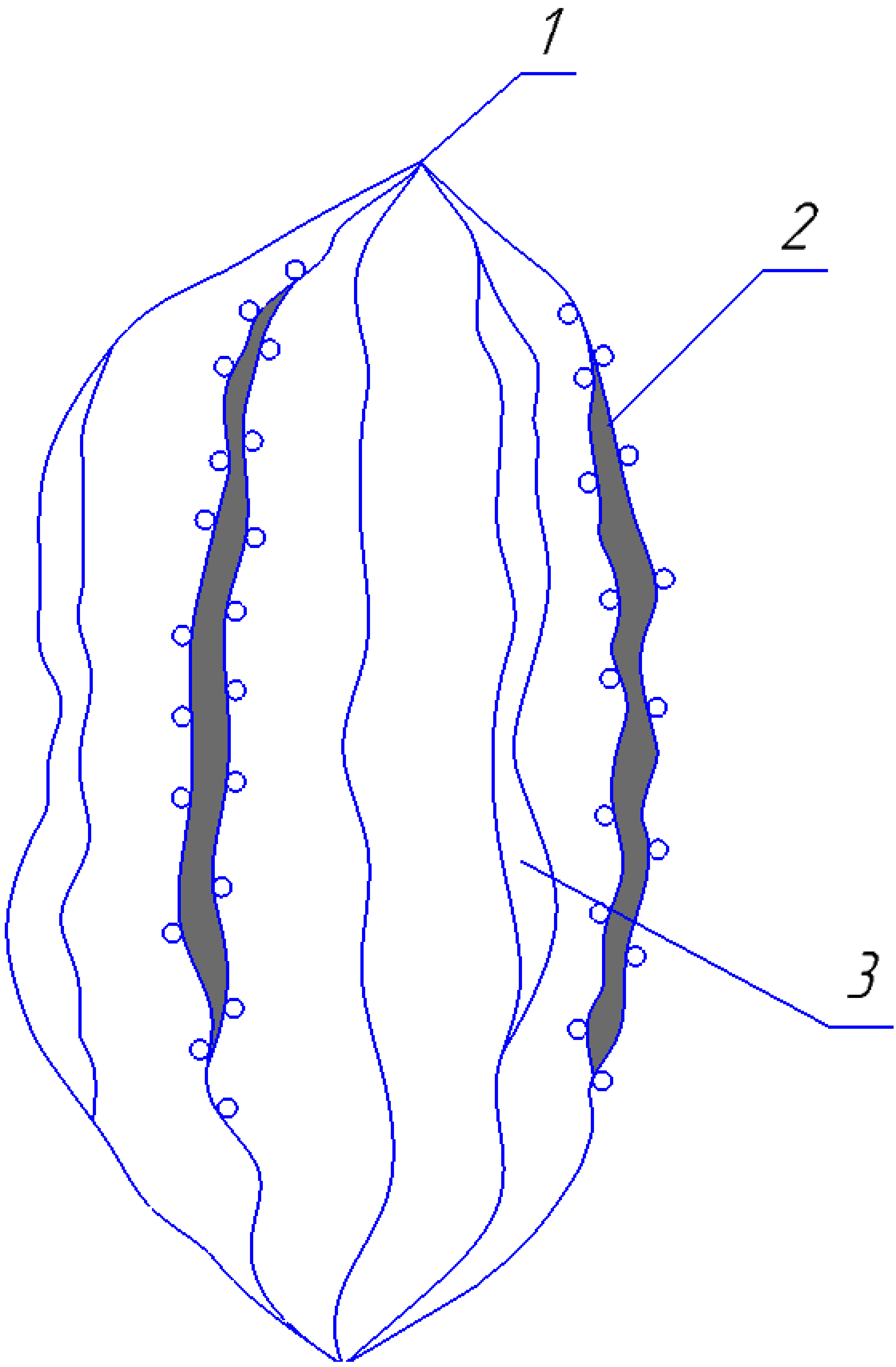


Fig. 7.12. Scheme of interaction of peat particle with gas bubbles:

1 - peat particle; 2 - bituminous part of peat particle; 3 - gas (air) bubbles

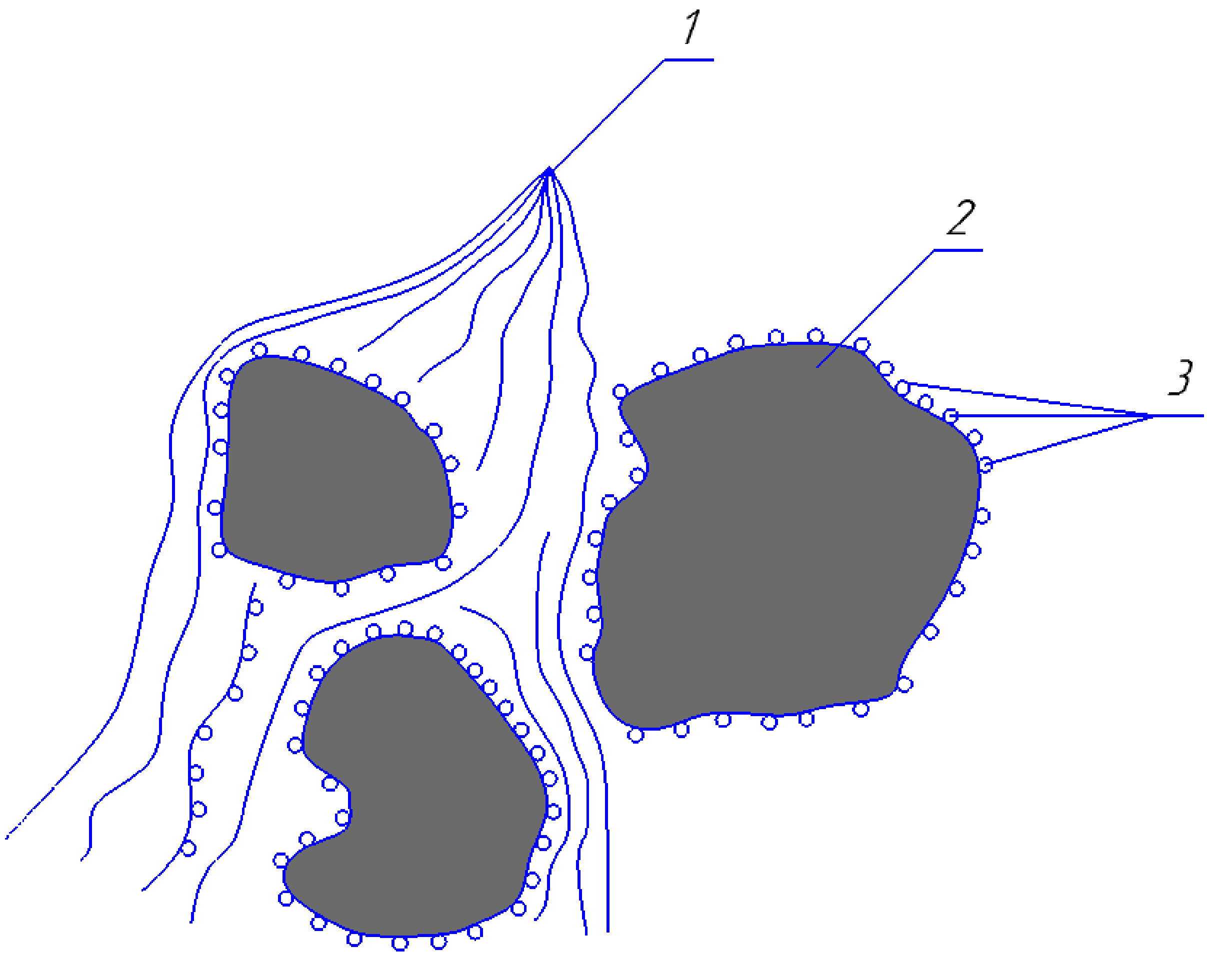


Fig. 7.13. Scheme of interaction of peat particles with gas bubbles and flakes of activated sludge:

1 – peat particle; 2 – cotton of activated sludge; 3 – gas (air) bubbles

The presented variants of the interaction of gas bubbles with peat particles and flakes of activated sludge are observed visually using a stereomicroscope. At the same time, the largest air bubbles (more than 1 mm) are sometimes not held on the surface of peat particles and break off, which indicates a weak bond. This observed phenomenon can be explained by the fact that, although some peat particles belonging to the bitumen fraction retain gas bubbles quite firmly, but at the same time most peat particles have a hydrophilic surface and therefore do not retain gas bubbles that have previously adhered to them, especially large bubbles (larger than 1 mm in diameter). Nevertheless, the partial interaction of a small part of hydrophobic particles with gas bubbles in some cases is sufficient for the flotability of aggregates represented by peat particles and flakes of activated sludge.

Taking into account the probabilistic distribution of peat particles, as well as aggregates including peat and activated sludge in the form of flakes, it is advisable to separate them from water in the mode of flotation lag. The practical implementation of the above ideas was carried out in the processes of wastewater treatment from petroleum products and fat.

It should be noted that the treatment of oil-fat-containing wastewater has continued to be relevant over the past decades and, in addition, the emerging new challenges require in some cases the development of integrated installations.

As a result of theoretical and experimental research, we have developed various combined installations for the treatment of oil and fat-containing wastewater. At the same time, the installations were developed for universal use in the processes of water purification from hydrophobic contaminants of various industries and include a pneumatic flotation machine for basic cleaning, in some cases an oil trap for preliminary cleaning from coarse droplets of oil or fat, and for post-treatment filters with both granular (for example, sand) and coal loading.

In most cases, the proposed combined plant for the treatment of oil and fat wastewater includes a horizontal thin-layer oil trap, a pneumatic flotation machine and post-treatment filters, and to increase the efficiency of cleaning, the settling tank and flotation unit are equipped with thin-layer clarification units with hydrophobic corrugated shelves made in the form of a set of semicircles or halves of ellipses, flotation machine and the post-treatment filter contain a combined filter load consisting of particles of various sizes ranging in size from 0.5 to 5.0 mm.

The combined unit consists (Figure 7.14) of a horizontal oil trap comprising a body 2 with an inlet pipe 1, thin-layer blocks 3, a bottom part for collecting sediment 4, a pipeline for pumping out sediment 5, a semi-submersible partition 6, a device for regulating the level of liquid 7, an outlet pipe 8; from a pneumatic flotation machine consisting of a body 10 with an inlet pipe 9, divided by partitions 11 into three sections, in the lower part of which porous aerators 12 are installed, and also including a thin-layer clarification unit 13, a combined filter load 14, a device for regulating the liquid level 15, a conditionally pure water chamber 16, an outlet pipe 17; from a post-treatment filter made in the form of a cylindrical housing 19 with a magnetic part of the filter load 20 and a non-magnetic part 21, with an outlet pipe 22. In this case, the thin-layer clarification units 3 and 13 are made in the form of a set of semicircles or semi-ellipses with a hydrophobic surface, and the combined loading 14 consists of particles of various sizes ranging in size from 0.5 to 5.0 mm, and the size decreases from top to bottom.

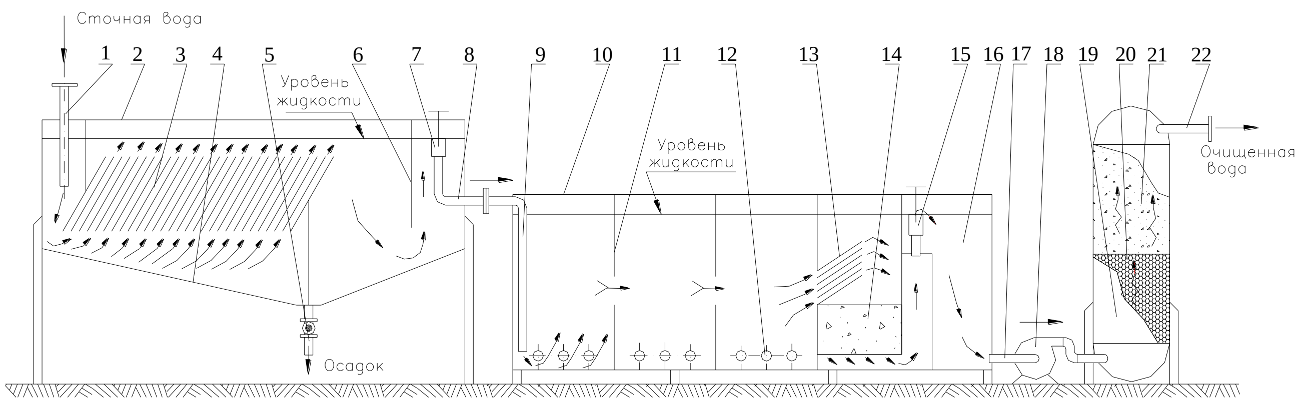


Fig. 7.14. Combined plant for treatment of oil and grease-containing wastewater

A wastewater treatment plant works as follows. Initial oil- or fat-containing wastewater with bituminous peat and activated sludge added to it in a ratio of 1: 1 and a total concentration of 0.5% by weight. are supplied through the receiving pipe 1 to the body 2 of the horizontal settling tank, where solid phase particles up to about 0.1 ... 0.01 mm, as well as the surfacing of coarsely dispersed emulsified fats or petroleum products, and in this case the surfacing occurs in the inter-shelf spaces of the blocks of the thin-layer clarifier 3. Due to the shape of the shelves of the clarifier 3, made in the form of a set of semicircles or semi-ellipses, there is an intense coalescence of pop-up droplets of oils or petroleum products, which accelerates their separation from water. To remove the settled solid phase from the bottom part 4, a pipeline 5 is provided. From the horizontal settling tank, the pre-clarified liquid by gravity, through the liquid level control device 7, the outlet pipe 8 and the inlet pipe 9 enters the pneumatic flotation machine 10. In said flotation machine, consisting of 3 sections and separated by partitions 11, fine droplets of oils and petroleum products are extracted by floating them together with air bubbles formed during the dispersion of gas by pushing it into the liquid through flooded holes in the rubber aerators 12. Drops of petroleum products together with air bubbles (flotocomplexes-Fig.1-2) float due to the action of Archimedean forces, forming a foam layer in the upper part of the chamber, which is removed by gravity through a special pipe into the foam collector (not shown in Fig. 3). The purified liquid is removed from the flotation machine by passing through the thin-layer clarification unit 13 representing a set of shelves made in the form of semicircles or semi-ellipses and a combined filter load 14 with a decreasing size from top to bottom, in which the microbubbles contained in the water interact with each other, which ultimately leads to intense coalescence of finely dispersed bubbles and the formation of larger ones. flotation complexes. Such air bubbles quickly float into the foam layer, which leads to additional clarification of the purified water from hydrophobic contaminants, such as oils or petroleum products.

By means of a centrifugal pump 18, water is supplied to the filter 19 for post-treatment through the outlet pipe 17. First, the liquid passes through the magnetic portion of the filter 20. In the magnetic loading layer, finely dispersed ferromagnetic contaminants are captured, if they are present in wastewater. The liquid then passes through the non-magnetic portion of the filter 21, which consists of solid peat-based adsorbents. When water passes through the adsorbent layer, deep post-treatment of wastewater occurs, in particular from dissolved contaminants. Further, through the outlet pipe 22, the liquid is removed from the installation.

When designing and manufacturing such installations, it should also be taken into account that the speed of coalescence processes can be significantly (several orders of magnitude) increased by filtering the emulsion through various porous media. At the same time, in the pore space, the processes of interdropella (gradient, orthokinetic) and contact coalescence occur. Obviously, for oil- and fat-containing emulsions, the surface of the coalescing material should be hydrophobic.

Specially treated glass beads, granules of polyethylene, polypropylene and polystyrene are used as a filter load. The size of the granules should correspond to the size of the droplets of the emulsion being treated. Coalescing materials with granule sizes of 2-4 mm effectively separate water-oil emulsions with droplet sizes of 20-25 μm and above. The higher the dispersion of the emulsions, the smaller the size of the granules should have a coalescing load. It is desirable that the loading surface is not only hydrophobic, but also rough - this increases the efficiency of coalescence.

For the separation of finely dispersed emulsions, the method of coalescence on fibrous materials is most effective, since the thickness of the fibers is much less (5-8 μm) than the diameter of the granular loading granules. To carry out the process, a layer of material of 10-15 mm is sufficient. These materials can be used for emulsions that do not contain mechanical impurities and viscous substances, since it is very difficult to regenerate them. It is most convenient to use these materials in the form of cartridges or cartridges. In Table. Figure 7.9 shows the average data obtained during the treatment of oil and fat-containing effluents in a combined installation including a flotator and a filter.

Table 7.9. Average data on the efficiency of treatment of oil and fat-containing effluents in a combined flotation plant (flotator block – filter with peat loading)

No p/n	Type of pollution	inlet concentration, mg/l	output concentration, mg/l	Efficiency, %
1	Petroleum products	12,6	3,4	73
	Petroleum products	10,5	2,6	76
	Fats	98,3	22,4	78
	Fats	85,7	20,7	76
	Fats	76,8	19,9	74

The data presented in Table 1 indicate the achievement of a high cleaning efficiency of 73 - 78%, which also allows them to be discharged after cleaning into the city sewerage.

Thus, the use of peat for the treatment of wastewater from petroleum products and fats allows to achieve a high effect, including regulatory indicators of water quality, allowing its discharge into the sewerage.

7.8. Use of activated sludge in biotechnological processes

All microorganisms, including active sludge, are capable of extracting metals, since metals such as iron, magnesium, zinc, copper, molybdenum and many others are part of enzymes or pigments similar to cytochromes or chlorophylls. In some cases, metals are accumulated by microorganisms in significant quantities; a bacterial cell may contain potassium ions at a concentration of 0.2 M, even if potassium is present in the medium at concentrations of 0.0001 M and below. Microorganisms have absorption systems specific to certain metals and capable of their significant concentration. As a result of metabolic reactions occurring in microorganisms, various transformations of metals can occur: metabolic products released into the environment are able to form complexes with metals or precipitate them from solutions; some metals can be converted with their help into volatile forms and removed from the solution; metals can be oxidized or reduced.

The main mechanisms of immobilization of metals from wastewater by microorganisms are the following:

Transfer to volatile form;

Extracellular deposition;

Extracellular complexation and subsequent accumulation;

Binding by the cell surface;

Intracellular accumulation.

In different strains of related bacteria, the level of surface binding varies significantly. For example, Bacillus megaterium KM (at a concentration of 1 g of dry weight per 1 L) at 20 o C binds 43 mg of cadmium per 1 g of dry weight from a solution containing cadmium at a concentration of 112 mg / l (while B. polymyxa binds only 10 mg of cadmium per 1 g of dry weight).

Radiactive metals, such as uranium, can also be immobilized, which is very important for the environment.

Active sludge is a fairly effective adsorbent, for example, in the extraction of heavy metals from solutions and wastewater. Consider as an example the technological scheme of the process of bacterial leaching of rare earth metals.

The technological scheme of the process of bacterial leaching of rare earth metals from ash and slag is presented in Fig. 7.15.

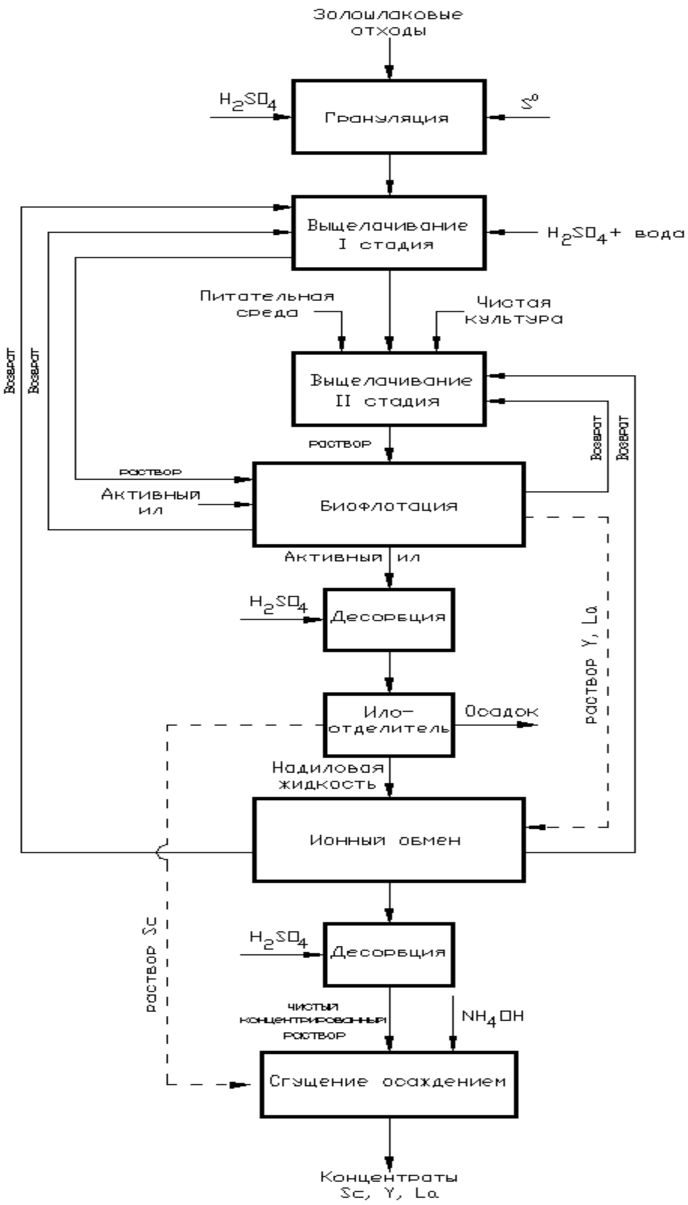


Fig. 7.15. Schematic technological scheme of the process of bacterial leaching of rare earth metals from ash and slag

The process of bacterial leaching of rare earth and noble metals from ash and slag consists of several stages. The stage of preparation of ash and slag waste consists in carrying out granulate sulfation of raw materials to obtain ash and slag granules suitable for further leaching. For this purpose, sulfuric acid H_2SO_4, elemental sulfur S_0 and water are added to the laboratory bowl granulator to the original ash and slag waste.

Next, the granules are fed to the first stage - chemical leaching, which is carried out in the leaching column. The raw material is stationary and irrigated with a specially prepared aqueous solution of sulfuric acid H_2SO_4. The solution circulates through the leaching column for 7 days, until there is practically no change in the rate of metal yield.

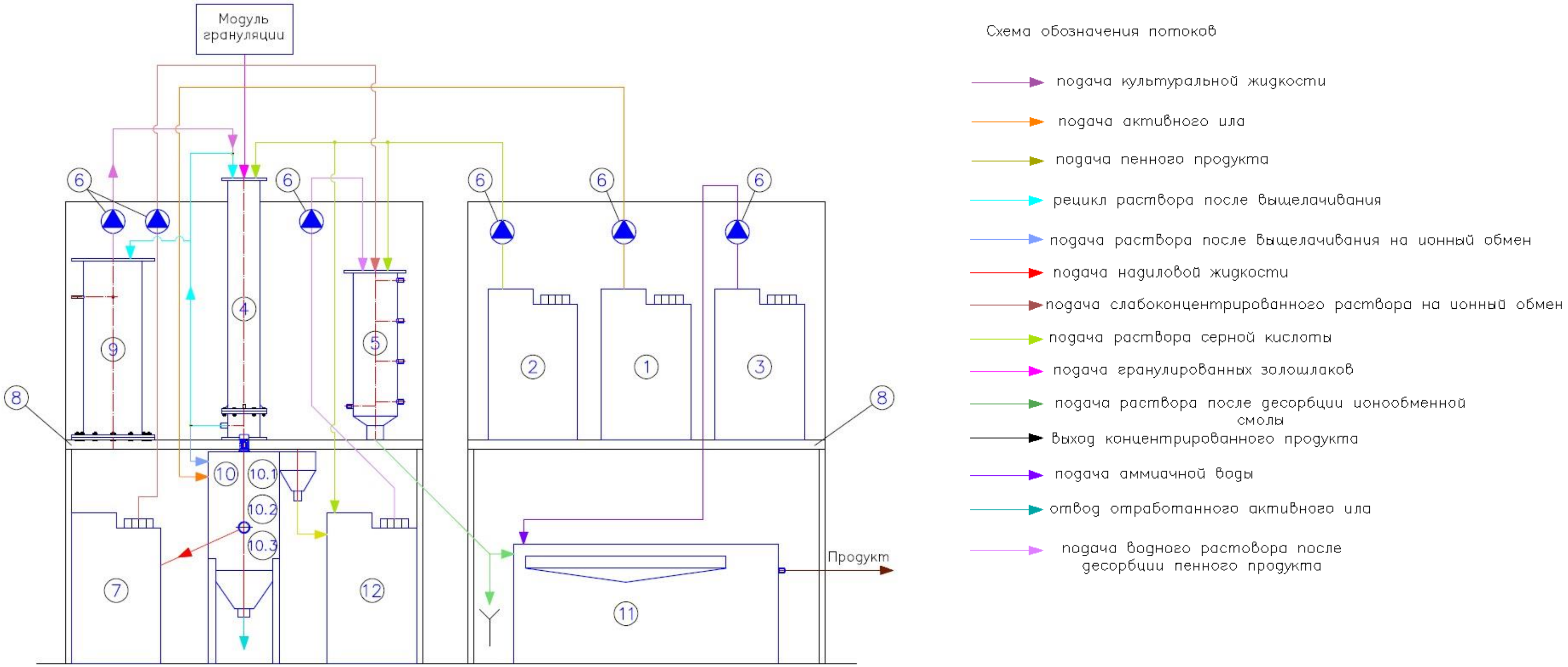
At the second stage, the process of bacterial leaching of rare earth (REM) and noble (BM) metals from ash and slag occurs. To do this, at the end of treatment with a sulfuric acid solution, the granules are irrigated with a culture liquid that contains a pure culture and a nutrient medium. The culture fluid circulates through the leaching column for 3 weeks, until there is practically no change in the rate of metal yield.

After the completion of the chemical and bacterial leaching processes, the solutions are fed to the bioflotation stage. Active sludge is used as a collector reagent. In the process of bioflotation, sorption of rare earth and BM from the solution of active sludge microorganisms by cells and thickening of activated sludge occurs. Further, the suspension is separated into a solution with a low content of rare earth and BM and condensed active sludge with a high content of rare earth and BM. The solution is sent to the stage of chemical leaching on the recycle.

Condensed active sludge is fed to the desorption stage, where a solution of sulfuric acid H_2SO_4 is also supplied. During desorption, the sorbed rare earth metals are transferred to the solution. Further, sludge separation is carried out, in which the suspension is separated into condensed active sludge and a solution with a high content of rare earth metals.

The condensed active sludge is sent for disposal, and the solution with a high content of rare earth is sent to the stage of ion exchange, which is carried out in an ion exchange column with cation exchange resin. The process of ion exchange is based on the replacement of ions of the same charge (cations) from a solution (i.e. ions of rare earth and noble metals). After ion exchange, the solution is sent to the stage of chemical leaching, and the resin to desorption, where a regenerating solution of sulfuric acid H_2SO_4 is also supplied. After desorption, we obtain a solution with a high scandium content, which is sent for thickening by sediment to the flotation settling tank. The thickening process occurs due to the reaction of the solution with ammonia water NH_4OH. At the output, we get a concentrated solution of rare earth and noble metals, in particular scandium.

To carry out the process of extraction of rare earths and BM, a pilot and laboratory sample of a plant for the extraction of rare, rare-earth and noble (scandium, yttrium, lanthanum) metals was created, the scheme of which is presented in Fig. 7.16.



1 - tank with activated sludge; 2 – tank with aqueous solution H_2SO_4; 3 – tank with NH_4OH solution; 4 – leaching column; 5 – ion exchange column; 6 – pump-dispenser; 7 – intermediate tank; 8 – support table; 9 – fermenter; 10 – flotomachine with air conditioning chamber: 10.1 – compressor; 10.2 – agitator; 10.3 – pump; 11 – flotation settling tank; 12 – extractor

Fig. 7.16. Hardware scheme of the experimental and laboratory sample of the installation for the extraction of rare, rare earth and noble metals using activated sludge

Leaching of rare earth and precious metals from ash and slag waste, the instrumental diagram of which is shown in Figure 2, is carried out in two stages.

Step I consists in the preliminary chemical leaching of ash and slag granules with a 5% aqueous solution of sulfuric acid H_2SO_4. The ash and slag waste is pre-treated in a laboratory bowl granulator, and then the resulting granules enter the leaching column 4. The sulfuric acid solution is prepared in tank 2 and fed by pump 6 to the leaching column 4. The process takes place for 7 days until then, so far, there has been virtually no change in the rate of metal yield. The resulting solution is sent to the concentration stage in a flotation machine with a conditioning chamber 10.

Step II consists in the subsequent bacterial leaching and includes a fermenter 9, where there is a constant accumulation of bacteria, for which a nutrient solution (mineral medium 9K) and an energy source (S 0) are supplied. The adjustment of the temperature optimal for bacterial growth (36 ^{0}C) occurs using a thermostat. The culture liquid from the fermenter 9 is fed using pump 6 to the leaching column 4. During the culture the liquid circulates through leaching column 4 for 3 weeks until there is virtually no change in the rate of metal yield. The resulting solution is sent to the concentration stage in a flotation machine with a conditioning chamber 10.

After the completion of the chemical and bacterial leaching processes, the solutions enter the bioflotation stage in a flotation machine with a conditioning chamber 10. Activated sludge is used as a collector reagent. Activated sludge is fed into the first chamber of the flotation machine 10 from reservoir 1. In the first (air conditioning) chamber of the flotation machine 10, intensive mixing of the activated sludge with the solution occurs using a stirrer 10.2. Ions of both rare earth and other metals are sorbed on the surface of microorganisms, and at the same time some microorganisms are separated from the water by the flotation method, and some precipitate. The precipitate is diverted for disposal. The pre-clarified leaching solution enters the flotochamber, where it is cleaned of residual activated sludge, due to the formation of flotological complexes of a particle of activated sludge - an air bubble. A compressor 10.1 and a pump 10.3 are used to prepare the working fluid. The resulting flotation complexes are particles of activated sludge - air bubbles float, creating a concentrated foam layer.

Activated sludge in the form of a foam product is sent to the desorption stage in the extractor 12, where a 5% solution of sulfuric acid H_2SO_4 is also supplied from reservoir 2 with a pH reduction to values from 2 to 3. Upon desorption, the sorbed rare earth metals are transferred to the solution. Further, sludge separation is carried out, in which the suspension is separated into condensed active sludge and a solution with a high content of rare earth metals (from 20 to 30 mg / l scandia).

The condensed activated sludge is removed from the extractor 12 manually and sent for disposal. A solution with a high content of rare earth metals (from 20 to 30 mg / l scandium) is sent to the stage of ion exchange to increase the degree of concentration of rare earth in the solution (over 2 g / l scandium). The process is carried out in an ion exchange column 5 filled with ion exchange resin RS-100.

The remaining nadil fluid in the flotation machine 10 is collected in the intermediate reservoir 7 and pumped by the pump 6 to the ion exchange column 5 for re-concentration.

After ion exchange, the depleted solution is sent to the drainage. At the same time, in the ion exchange column 5, the desorption of RYM ions is carried out. For desorption by pump 6, a solution of sulfuric acid H_2SO_4 is supplied from reservoir 2 to the ion exchange column 5. After desorption, we obtain a solution with a high scandium content, which is sent to the flotation settling tank 11 for thickening by sediment. The thickening process occurs due to the reaction with ammonia water NH_4OH. Andthe mmian water is supplied by pump 6 in the flotation settling tank 11 to pH = 4.0. Under these conditions, scandium precipitates and is further processed according to the generally accepted technological scheme.

The list of optimized modes and indicators of recovery of rare earths and BM, as well as optimal values and limit deviations, is presented in Table. 7.10.

Table 7.10. Optimized modes and parameters of the rare earth and BM extraction process

No p/n	Name of the indicator	Units. ism.	Rating	Limit deviations
1	Parameters and modes of the chemical leaching stage			
1.2	Flow rate	ml/h·cm^2	0,45	±0,15
1.3	Temperature	^{0}S	22,5	±12,5
1.4	T:F ratio	-	1:8	(1:5… 1:10)
1.5	Concentration of sulfuric acid solution	%	5,0	(0,5… 5,0)
1.6	Duration of the process	Day	5	±2,0
2	Parameters and modes of the technological process of accumulation of biomass of microorganisms			
2.1	Temperature	^{0}S	36	±14
2.2	Acidity index (pH)	-	2,0	±1,0
2.3	The main sources of energy substrate	-	Sulfur	Sulfur
2.4	Air consumption	vol./h	0,5	±0,3
2.5	Number of bacteria in the pulp	kl/ml	$110^{\cdot 7}$	($110^{\cdot 6}$… $110^{\cdot 8}$)
2.6	Redox potential (Eh)	mV	700	±50
2.7	Composition of mineral nutrient medium	g/l	$(NH_4)_2SO_4$ – 2,0 K_2HPO_4 – 1,0 $MgSO_4$ – 0,5 NaCl – 0,2 $FeSO_4$ – 5,0	$(NH_4)_2SO_4$ – 2,0 K_2HPO_4 – 1,0 $MgSO_4$ – 0,5 NaCl – 0,2 $FeSO_4$ – 5,0
3	Parameters and modes of the process of bacterial leaching of rare earth and BM			
3.1	Duration of the process	Day	25	±5
3.2	Acidity index (pH)	-	2,0	±1,0
3.3	Redox potential (Eh)	mV	700	±50
3.4	Number of bacteria in the pulp	kl/ml	$110^{\cdot 7}$	$110^{\cdot 6}$… $110^{\cdot 8}$

3.5	Elemental sulfur content	%	4,5	±1,5
3.6	Temperature	⁰S	22,5	±12,5
3.7	Flow rate	$ml/h \cdot cm^2$	1,0	±0,5
3.8	Solid-liquid phase ratio	-	(1-2) : (3-5)	(1-2) : (3-5)
4	<u>Parameters and modes of the bioflotation process</u>			
4.1	Dissolved oxygen content	mg/l	3	±1,0
4.2	Specific hydraulic load	$m^3/m^2 \cdot h$	10	±1,0
4.3	Operating environment temperature	⁰S	22,5	±12,5
4.4	Flotation machine performance with air conditioning chamber	m^3/h	0,26	±0,01
4.5	The ratio of leaching solution : reagent (activated sludge)	-	1:1	(10:1)… (1:1)
5	<u>Parameters and modes of ion exchange</u>			
5.1	Temperature	⁰S	22,5	±12,5
6	<u>Parameters and modes of the deposition process</u>			
6.1	Operating temperature	⁰S	22,5	±12,5
6.2	Acidity index (pH)	-	6,0	±1,0

Presented in Table. Figure 7.10 The data indicate a sufficiently high efficiency of the process of bacterial leaching of rare earth and BM.

Another important direction of the use of activated sludge in biotechnological processes is its use in the production of fodder yeast as an additional substrate, as well as in the implementation of various technical solutions to improve the environmental situation at enterprises of this profile.

The relevance of solving environmental protection issues at biotechnological enterprises has existed acutely for the last 3-4 decades. In the future, a number of such enterprises have introduced new technical solutions to improve environmental protection. In Fig. 7. 17 and 7.18 are the schematic diagrams for the production of fodder yeast biomass on petroleum paraffins and the production of hydrolysis fodder yeast.

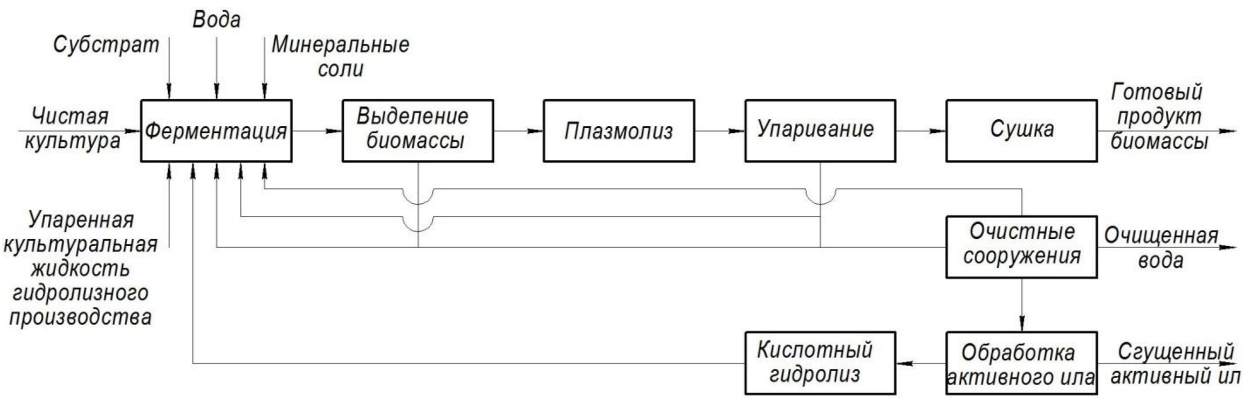


Fig. 7.17. Schematic diagram of obtaining biomass of fodder yeast on paraffin oil

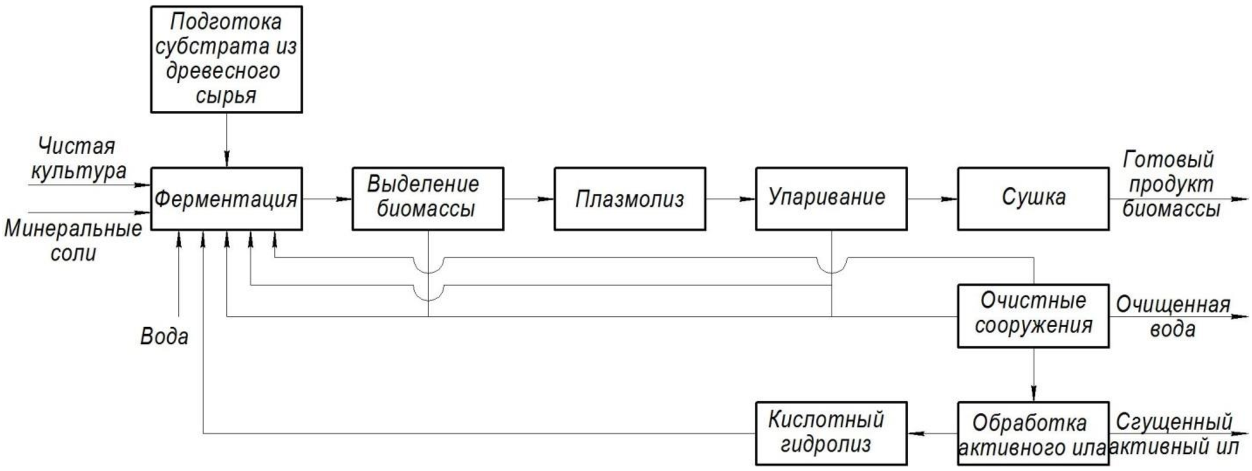


Fig. 7.18. Schematic diagram of hydrolysis fodder yeast production

At such enterprises, the main stage of production is the cultivation of microorganisms (fermentation stage). Taking into account the use of biotechnological waste, specially treated, it is possible to optimize and improve the operation of this stage of production. Let'slook at this on the example of the disposal of excess activated sludge.

The most promising methods of thickening excess activated sludge at these enterprises are flotation and centrifugation. The fact is that these methods are used in the basic technology for obtaining fodder yeast biomass and in this regard, their use for activated sludge gives universality of their use.

The use of the flotation method for these purposes is confirmed by long-term tests at BVK plants. In the process of flotation of sludge, it is possible to obtain a thickening degree of 4–6 or more. However, the entrainment of microbial biomass with clarified liquid is still significant and reaches 20-30% of the amount of biomass in the original suspension.

The use of centrifuges and separators makes it possible to automate the technological process, reduce its duration, reduce the volume of facilities for dewatering activated sludge, and reduce the cost of its processing.

A high degree of thickening of the solid phase can be achieved on disc separators. Full-scale tests of separators for thickening activated sludge have been carried out by a number of developers for a long time. The separators were tested on a pilot plant operating as follows. The activated sludge from the secondary sedimentation tanks was filtered on a drum mesh before being fed to the separator, which delayslarge mechanicalparticles. The fugate and sediment were discharged into the receiving tank, from where they were pumped into the sludge channel. The tests took place in two stages: at the first stage, the NV-600 and DSG-35 separators worked, and at the second stage, the NV-600M and SDS-631K. At each stage, the separators were tested under the same conditions. The concentration of the solid phase in the initial active sludge on the first and second et Apahs were 6.5 and 3–5 kg/m3, respectively. 7.11.

Table. 7.11. Test results of nozzle separators

Stage	Separator	Nozzle diameter, mm	Separator capacity, m3/h	Concentration in solid phase, kg/m3			Volumetric consumption of recirculant, m3/h
				in the original active sludge	in fugate	in sediment	

I	NV-600	2.6–3.0	24–28	6,5	0.3–0.5	56–65	–
	DSG-35	1.8	9.6	6,5	0.3–0.5	35–40	–
II	NV-600M	2.2	26–28	3–5	0.3–0.5	60–72	–
	SDS-631K	1.8	25–28	3–5	0.3–0.5	25–40	5–10

Comparison of the main parameters of the NV-600M and SDS-631K separators showed the same maximum productivity for the initial active sludge - 28 m3 / h. The NV-600M separator was superior to the SDS-631K in terms of thickening efficiency: the concentration of the solid phase in the sediment of the NV-600M is 60-70 kg / m3, in the SDS-631K - 40. Separator NV-600M ensured uninterrupted unloading of sludge.

During the tests of the SDS-631K separator, shift disassembly and flushing of the rotor was required to remove the residue [1]. To prevent frequent hammering of nozzles, it is recommended to isolate particles of more than 0.2–0.3 mm from the activated sludge. The HB-600M separator, unlike the SDS-631K, does not require disassembly of the rotor, since it can be washed on the go. In addition, thanks to the sludge transportation system, it allows us to process active sludge containing particles up to 0.8 mm without clogging nozzles. The possibility of using NOZZLE 501 T-2 nozzle separators was shown by us when condensing excess activated sludge at the Kirishi Biochemical Plant [2]. We also tested domestic centrifuges at the stage of thickening of the active both after secondary settling tanks and after flotators. At the same time, the degree of thickening was about 6 to 10 times. When using flocculants in the centrifugation process, the degree of thickening increased up to 12-15 times.

Thus, the thickening of excess activated sludge according to the flotation-centrifugation schemeis, in our opinion, the most promising and implemented at the enterprises of the biotechnological industry.

The most important task is also the utilization of microbial biomass of activated sludge. There are many examples of its successful use. However, until now, the use of such biomass is limited due to its composition varying greatly depending on the conditions of cultivation.

One of the ways to dispose of excess activated sludge from biotechnological enterprises is to treat it in the acid hydrolysis mode (Figure 7.19).

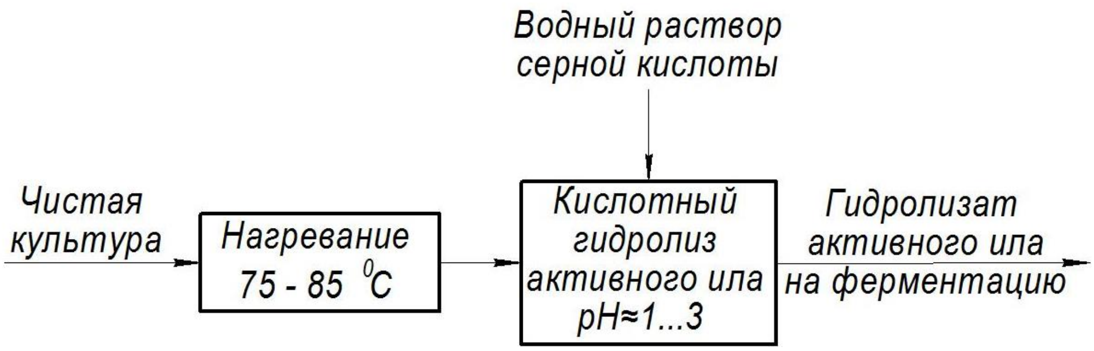
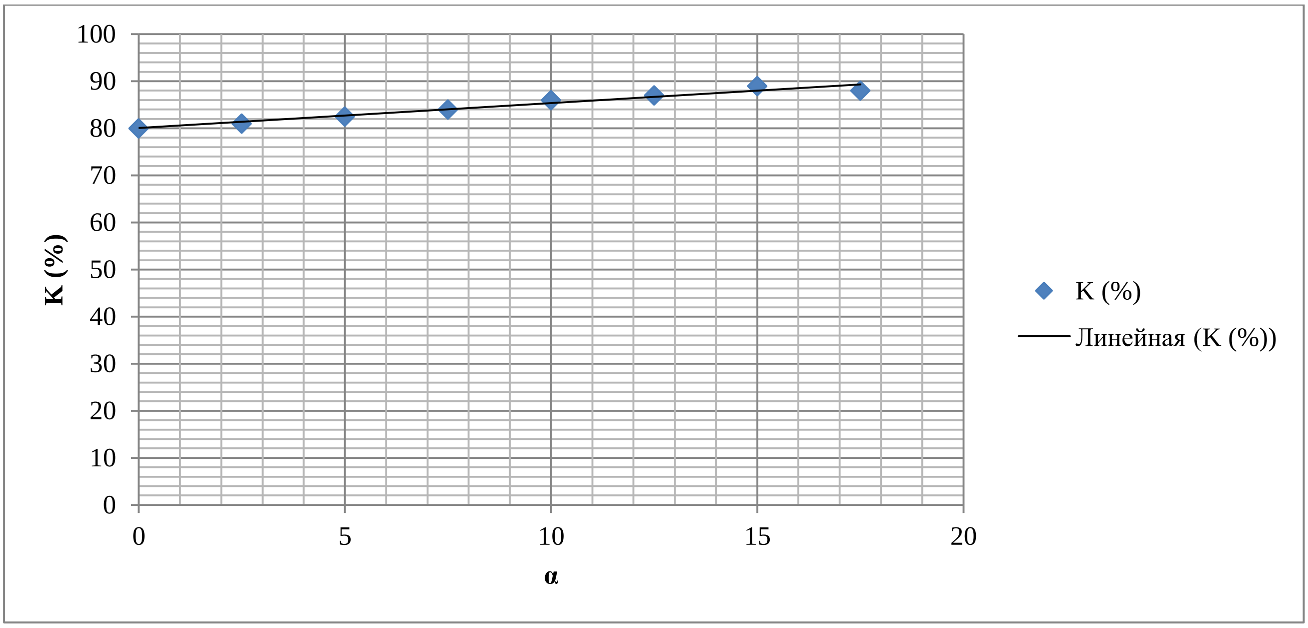


Fig. 7.19 – Scheme of acid hydrolysis of activated sludge

The active sludge treated according to this scheme is sent to the fermentation stage, where it is used as an additional substrate and source of vitamins. As a result of such a feed, one of the main indicators of the process of obtaining yeast biomass is improved - the biomass yield - the economic coefficient (Fig. 7.20).



K is the yield of yeast biomass (%), α is the relative amount of activated sludge from the size of the substrate

Fig. 7.20. Dependence of yeast biomass yield on the amount of hydrolysate submitted for fermentation

In this regard, it is necessary to develop methods for the neutralization of biomass, for example, incineration in case of unsatisfactory quality (high ash content, high content of heavy metals, etc.).

The technology of periodic and continuous pyrolysis processes is as follows. First, the excess active sludge is dried, as a result of which the CB content increases to 90-95%. It is then heated without oxygen for 30 minutes at a pressure of 1,000 Pa, turning biomass into substitutes for oil (25–30%), coal (50–60%) and non-condensable gases. At the same time, 7-10 MJ of energy can be obtained from 1 kg of sludge, which is almost 2 times higher than the energy output when burning methane formed from 1 kg of sludge.

The experimental continuous reactor system is a stainless steel container with a length of 100 cm and an internal diameter of 5 cm with mounted conveyor systems for activated sludge and solid pyrolysis product. Special inclined partitions divide the reactor into 3 zones: for volatile substances, contact of the solid fraction with the gaseous, heating of activated sludge. The capacity of the unit is 1 kg/ h of dry sludge. The retention time of solids in the reactor is controlled by changing the sludge supply rate or by special devices. Sludge is fed into the reactor by a screw conveyor. Volatile organic substances formed in the first zone are in contact in the second with a solid pyrolysis product. The resulting condensate is collected in a special trap.

One of the advantages of the method is the convenient storage of the resulting fuel. In the case of sludge burning, the energy goes to the production of steam, which must be used immediately, and the processing of sludge into methane requires additional capital costs for its storage. It is shown that the pyrolysis process is more efficient with sludge contaminated with heavy metals, 90-95% of which are concentrated in the solid phase of pyrolysis. It is likely that heavy metals play the role of catalysts.

An even more economical way to convert excess activated sludge into fuel has been developed by the Battele Pacific Nortwest laboratory (USA). By this method, the active sludge is first centrifuged, obtaining a mass with 20% ADM [5]. The sludge is then mixed with alkali and heated to 275 0C in a 45-liter continuous reactor at a pressure of 800–1000 Pa. Under these conditions, 100% of organic matter is converted into a hot liquid.

Thus, a more complete use of excess activated sludge is possible, apparently, with a comprehensive solution to the problem, which must be foreseen by the developers in advance.

Intensification of technological processes for the production of fodder yeast biomass through a more complete use of production waste is essential for the development of the microbiological industry.

The use of biostimulants, especially those derived from production waste, is of paramount importance. A particularly significant role is played by the mechanism of action of biostimulants, as well as the influence on its effectiveness of various protein substances present in the nutrient medium.

Apparently, with the deepening of knowledge about the mechanism of action of biostimulants and inhibitors on the process of obtaining fodder yeast, it will become possible to use more widely the waste of microbiological industries subjected to special pre-treatment.

At the same time, along with traditional methods of chemical and microbiological waste treatment, physical methods, in particular electromagnetic radiation of the ultraviolet range, have recently been increasingly used. At the same time, the greatest effect is achieved with the combined use of chemical oxidants and powerful radiation from an ultraviolet source.

The possibilities of using activated sludge in the technological processes of hydrolysis production are considered in detail by Sushkova V.I. and Vorobyeva G.I.

TheXthic composition of sediments of primary and secondary settling tanks and other solid wastes of hydrolysis production is presented in Table. 7.12 and 7.13.

Table 7.12. Chemical composition of hydrolysis production waste

Name of waste	Ph	Vzwe-si,g/l	A.s.v.,%	Composition of dry substances, %					
				total nitrogen	NH_4	mass-ovayadolbelka	P_2O_5	K_2O	ash
Sediment of primary sedimentation tanks	5-6	50-150	2,0.-6,0	4,5-6,0	0,4-4,0	-	2,0-4,0	0,01-0,08	5-29
Sludge of activated sludge	6,6-7,1	21-40	0,7-1,0	7,0-10,0	0,98-2,8	40-46	1,0-3,86	0,62	11,5-14,5
Condensed sediment mixture	6,0-7,0	paste	15-18	4,66-6,3	0,08-3,0	30-33	2,0-4,0	0,02-0,25	14-25
Sludge with Al spiralproduction	4,4-4,8	paste	55-59,4	0,77-1,9	-	-	0,18-0,38	0,05-0,24	51,1-52

Sludge with Al yeastproduction	5,2-5,7	paste	48-66	2,5-2,7	-	-	0,24-0,74	0,20-0,70	25,8-45
Lignin	2,5	-	34-36	0,02-0,04	-	-	0,01-0,04	0,05-0,06	1-3

It has been established that the sediments of treatment facilities in sufficient quantities contain mineral elements: nitrogen, phosphorus, potassium. In addition, active sludge contains protein (40-46%), amino acids (54.13 µg/100 cm3), B vitamins (B1 12.2; B2 12,4; B4 3380; B5 152,6; B6 3,3; B7 1,5; B8 ——————— 290 µg/g ADM).

Hydrolysis sludge mixed with sludge of neutralized activated sludge hydrolysate after filter presses of the FPAKM type has a humidity of 34-52% and an ash content of 51-52%. This sludge contains endogenous elements: total nitrogen in the amount of 0.8 1.9%, P_2O_5 - 0.18-0.38%, K_2O - 0.05-0.24%, macroelements MgO - 0.3%, CaO - 4.26% and trace elements: Mn up to 320 mg / kg–, Fe up to 0.15%, Cu up to 80 mg / kg.

The solid waste of the production of hydrolysis ethyl alcohol is also lignin, the chemical composition of which has been sufficiently studied. We have shown that lignin does not contain endogenous elements. Therefore, lignin in the composition of fertilizers will play the role of a soil structurer and increase their absorption capacity.

The amount of heavy metal ions in the waste of the Kirov Biochemical Plant was studied by the Institute of GosNIIsintezbelok. Their content in these wastes does not exceed the standards for SaNPiN 21.7.573-98. Table 7.13 presents the content of macro- and microelements in the waste of hydrolysis production.

Table 7.13. Content of macro- and microelements in hydrolysis production waste (mg/kg)

Name of waste	MgO, %	CaO,%	Mn	Fe,%	Gr	Nor	With	Zn	Pb
Sediment of primary sedimentation tanks	2,37	20,2	1400	16,8	474	280	4058	5483	229
Sludge of activated sludge	1,88	4,22	151-4680	0,49-0,76	4,1	7,2	8-143	68-780	n/a*
Condensed mixture of sediments of sewage treatment plants	-	-	74-496	0,77-11,4	15,0-51,5	14,1-33,8	25,0-96,4	286-516	4,5-12,2
Sludge with AI alcohol production	0,317	4,26	19,5-322	0,15	-13,3	-72,7	6,0-85,4	23-76,5	0,00-8,8
Sludge with YEAST	-	-	55,8	0,13	15,0	9,0	26,3	41,5	20,0

PRODUCTION AI									
Lignin	0,100	0,13	90	0,4	Sl.	Sl.	1,5	9	n/a
Standards of SaNPiN 2.1.7.573-98	-	-	n/r**	n/a	1200	400	1500	4000	1000
MPC in soil	-	-	1500	n/a	6,0	20,0	50	100	30,0

* n/o not detected** n/r is not regulated

Thus, hydrolysis production waste can be used as an organic-mineral fertilizer in the cultivation of various crops.One of the easiest and cheapest ways to dispose of excess activated sludge is to use it also in technological processes of hydrolysis as a liquid phase. At the Kirov Biochemical Plant, the possibility of using a suspension of excess activated sludge as an aqueous phase in percolation hydrolysis processes and for dilution of the substrate was tested.

A promising method of utilization of activated sludge is sulfuric acid hydrolysis and the production of amino acids. For this purpose, acid hydrolysis was carried out in the laboratory at a sulfuric acid content in a suspension of activated sludge of 0.25-0.50% and temperatures of 100-180 ^{0}C. According to the results of the research, it was found that the amount of prohydrolyzed biomass increases with increasing temperature and concentration of acid. Gidrolisates obtained at t = 180^{0}C for 2 hours have the maximum degree of splitting by biomass (82.8%).It should be noted that hydrolysates of activated sludge hydrolysis production contain biostimulants of growth of microorganisms (vitamins, amino acids, trace elements) and when added to hydrolysis substrates increase their nutritional value.

Approximately the same method of utilization of activated sludge was tested at the treatment facilities of JSC Mosvodokanal.It is known that the content of easily accessible organic matter in the wastewater entering the treatment is one of the key factors determining the quality of the biological treatment process from phosphorus. According to a number of authors, for an effective process of removal of phosfora, a BOD ratio of 5 is necessary: the total phosphorus in the incoming water is more than 20: 1, the ratio of COD: total phosphorus is more than 45 : 1. The concentration of an easily degradable organic substrate according to COD related to volatile fatty acids in the anaerobic zone should be at least 25 mg / l.

To implement biological dephosphatization on low-concentrated effluents, one of the methods of increasing the content of easily accessible organic matter is the process of acidification (prefermentation). "Prefermentation is a specially organized process of formation of soluble, biologically readily available organic matter (volatile fatty acids) by anaerobic treatment in primary tanks of suspended or precipitated organic matter contained in municipal and industrial wastewater, with the aim of using the obtained PLAs to increase the efficiency of nutrient removal."

To denote the process, the terms "acidification" and "prefermentation" are used equally, but there is a tendency to use the term "acidoficification" more frequently in the Russian-language literature, and "prefermentation" in the English-language literature. This process can be implemented both on the main wastewater treatment line in primary sedimentation tanks equipped with a sludge recycling system, and on a separate line in crude sludge prefermentation reactors with different recycling, mixing and staging schemes.

When introducing the best available technologies in the Russian water sector, acidification is considered as one of the methods of increasing the efficiency of wastewater treatment from nutrients and is taken into account when designing the construction and reconstruction of treatment facilities.

At Mosvodokanal, the University of Cape Town (UCT) process aimed at the joint removal of nitrogen and phosphorus has been implemented at the biogenic element removal unit of the Luberetsky Wastewater Treatment Plant. Urban wastewater in Moscow is characterized by a low content of easily accessible organic matter, so the urgent task is to increase the stability of biological treatment of phosphorus. In this case, one of the methods of increasing the proportion of easily accessible organic matter is the process of acidification (prefermentation) of the primary sediment. As shown earlier, the incoming wastewater and the primary sediment of the Moscow treatment facilities have an average acidification potential. This allows us to consider acidification as an appropriate method of increasing the content of available organic matter in the water entering the biological treatment.

Laboratory and pilot tests conducted at the Lyuberetsky wastewater treatment plants in Moscow showed the prospects of introducing the technology of prefermentation (acidification) of wastewater sludge (according to JSC Mosvodokanal, 2014, May 15). In a pilot experiment, a 50% increase in THE concentration of COCLFAs resulted in an additional removal of 45% of the phosphorus phosphates.

During the pilot study of the technology of acidophyaction of raw sediment, it was possible to increase the stability of the aeration tanks of the biogenic element removal unit designed for the technology of biological removal of nitrogen and phosphorus according to the UCT technological scheme, by increasing the amount of easily oxidized organic compounds by 30%. The following purified water quality indicators were achieved: N-NH4 - 0.7 mg/l; N-NO2 - 0,03 mg/l; N-NO3 - 7.7 mg / l, P-PO4 - 0.2 mg / l. When applying the acidofiction technology of crude sediment, the load on aeration tanks for ammonium nitrogen does not increase. A slight decrease in the stability of wastewater treatment from suspended substances was also found, which did not entail a change in the increase in activated sludge and the quality of water treatment. If necessary, in order to increase the stability of water purification from suspended substances when using the technology of acidification of raw sediment, it is recommended to direct the drain water for additional sedimentation.

7.9. Use of excess activated sludge for technical purposes

A greater interest, in our opinion, in the utilization of excess activated sludge biomass is observed when it is used for technical purposes. An analysis of the scientific, technical and patent literature shows that there is a clear tendency to expand the areas of use of activated sludge for technical purposes, in particular the production of biogas, components for building materials, flocculant for the clarification of finely dispersed slurries and wastewater treatment, as well as for the production of active carbons, etc.

The use of activated sludge as a flocculant for the thickening of mineral suspensions, in particular phosphorite flotaconcentrate, is a new way to dispose of activated sludge. The essence of this method, first proposed by us, is as follows. Excess activated sludge formed during biological wastewater treatment, in native form or with pre-treatment, is fed to the condensation stage of the suspension of the main production, for example, a suspension of phosphorite concentrate. Mixing of the condensed suspension with the activated sludge is preferably carried out in such a hydrodynamic mode that the phlocules of phosphorite concentrate particles formed with the help of activated sludge microorganisms are not destroyed by tangent stresses. Otherwise, there will be a process of intensive destruction of floccules. The optimal hydrodynamic mode in this case is selected by the minimum turbidity of the clarified liquid.

Favorable, from the point of view of the aggregate formation of a part of the solid phase of the condensed suspension, the hydrodynamic mode is created in the suspended layer of the sediment, which is easy to implement in an electric mixer developed and tested earlier.

The use of activated sludge allows not only to dispose of excess activated sludge, but also to reduce the loss of thickened suspension.

Currently, possible ways to dispose of excess activated sludge have not yet been fully identified. The use of activated sludge microorganisms as reagents for thickening suspensions may be one of the most promising methods for disposing of excess activated sludge.

It is known that flocculants are substances that can combine particles of pollution into large aggregates that can quickly settle into a precipitate. Biofloculants are flocculants of biological origin. In this regard, the active sludge representing the community of the microorganism can be attributed to the group of biofloculants.

The mechanism of formation of aggregates is that on the surface of microorganisms of active sludge there is a sticky substance - polysaccharides. When there are many polysaccharides on the surface of microorganisms, the effect of the formation of aggregates is higher. Preliminary aeration increases the amount of polysaccharides and therefore the effect of the formation of aggregates is higher, which leads to the rapid sediment of pollution particles into the precipitate.

Taking into account the great practical significance of the issue under consideration, studies were conducted on the influence of microorganisms on the intensification of the condensation process of phosphorite flotation concentrates.

The results of experimental studies on the influence of activated sludge microorganisms on the deposition rate of phosphorite flotaconcentrate are presented in Table. 7.14.

Table 7.14. Influence of activated sludge microorganisms on the deposition rate of flotoconcentrate

Consumption of activated sludge microorganisms, kg/t	Deposition rate of phosphorite suspension, m/h	Solid content in the drain after thickening of the suspension, mg/l
0	5,1	270
0,500	6,9	98
0,750	9,5	45
0,900	11,8	35
1,200	12,1	30
1,500	12,9	30

The results show that the deposition rate of the phosphorite flotaconcentrate suspension increases as microorganisms in the suspension increase.

Its pre-compaction is also important when using activated sludge as a flocculant. It is known that one of the simplest and most effective ways to compact activated sludge before using it as a reagent, or rather flocculant, is pressure flotation. At the same time, the flotability of activated sludge depends on a number of factors, including the conditions of its cultivation, in particular, with a significant accumulation of well-soluble gases in the flakes of activated sludge, such as carbon dioxide, ammonia, active sludge is prone to self-fluttering. The resulting foam layer is loose with a small concentration of activated sludge. The use of self-fluttering of activated sludge in combination with pressure flotation also does not allow to obtain a compact foam layer with a large concentration of activated sludge.

Our previous research has shown that one of the most effective ways to intensify the process of compacting activated sludge is to acidify it. At the same time, reducing the pH is especially useful when combined as reagents for thickening the phosphorite concentrate of active sludge and acid, for example, phosphoric.

The study of the mechanism of pressure flotation of activated sludge with its preliminary acidification showed that when the pH decreases to 1.5 - 2.0, the solubility of carbon dioxide decreases sharply and it is released from the liquid phase, including from the flakes of activated sludge. At the same time, the flakes of activated sludge after the release of carbon dioxide from them become compact and the subsequent pressure flotation leads to the formation of a dense foam layer with a concentration of activated sludge in the foam layer without prior acidification of the activated sludge subjected to compaction by flotation. In Table. Figure 7.15 provides information on both the effect of pH on the flotation seal of activated sludge and the subsequent effect of pH on the clarification efficiency of a suspension of phosphorite concentrate of class -0.074 mm with an initial concentration of solid 5% by weight.

Table 7.15. Effect of pH on flotation compaction of activated sludge and its effectiveness when further used as a flocculant for thickening phosphorite concentrate

Characteristics of the initial sludge sludge		Concentration of activated sludge in the foam layer resulting from pressure flotation (flotation time, hour) (g/L)	Dose of activated sludge used as flocculant (g/L)	Concentration of solid in clarified liquid phase after separation of phosphorite concentrate
Concentration (g/l)	pH			

				suspension by lagging within 30 min (g/l)
4,5	6,9	24,2	0,25	0,64
4,5	4,0	38,6	0,25	0,58
4,5	2,0	49,3	0,25	0,34
4,5	1,5	50,1	0,25	0,31
4,5	1,0	50,1	0,25	0,30

The data given in Table 3 show that the pre-acidification of the activated sludge to a pH of 1.5 - 2.0 not only significantly improves its flotation thickening, but also the sorption characteristics of the activated sludge, which leads to a noticeable decrease in the concentration of the solid in the liquid phase of the clarified finely dispersed suspension of phosphorite concentrate.

On the other hand, photographic studies show that when carbon dioxide is released from the flakes of activated sludge at a pH of 1.5 - 2.0, it leads to the fact that in the liquid phase of the suspension of activated sludge during pressure flotation, small air bubbles with a diameter of about 0.001 - 0.05 mm and carbon dioxide bubbles up to 0.1 - 0.5 mm can exist. which has a large lifting force, which apparently leads to an increase in the flotation rate of activated sludge and the formation of a dense foam layer with a high concentration of activated sludge. This makes it possible to obtain a more concentrated biomass of activated sludge, which can be used in a smaller volume as a flocculant. In view of the foregoing, it is advisable to use a pH value in the range of 3-4.

In general, it should be noted that when using activated sludge as a flocculant in the case of thickening of the suspension of phosphorite concentrate, there is a decrease in solid phase losses with clarified liquid by 20% or more. At the same time, in the process of drying the phosphorite concentrate, the organic part of the biomass of the activated sludge burns, and a small amount of mineral (ash) substances remains in the finished product of the phosphorite concentrate, which does not affect the quality of the finished product.

Experimental studies have shown that fresh active sludge with a low ash content, usually not exceeding 35%, has effective flocculating properties. In the case of using rotten biomass of activated sludge, its flocculation properties are noticeably weaker.

Another way to use activated sludge is to use it as a substitute for carboxymethylcellulose used to prepare drilling fluids.

Microorganisms capable of synthesizing exopolysaccharides can be found among representatives of almost all classes of groups.

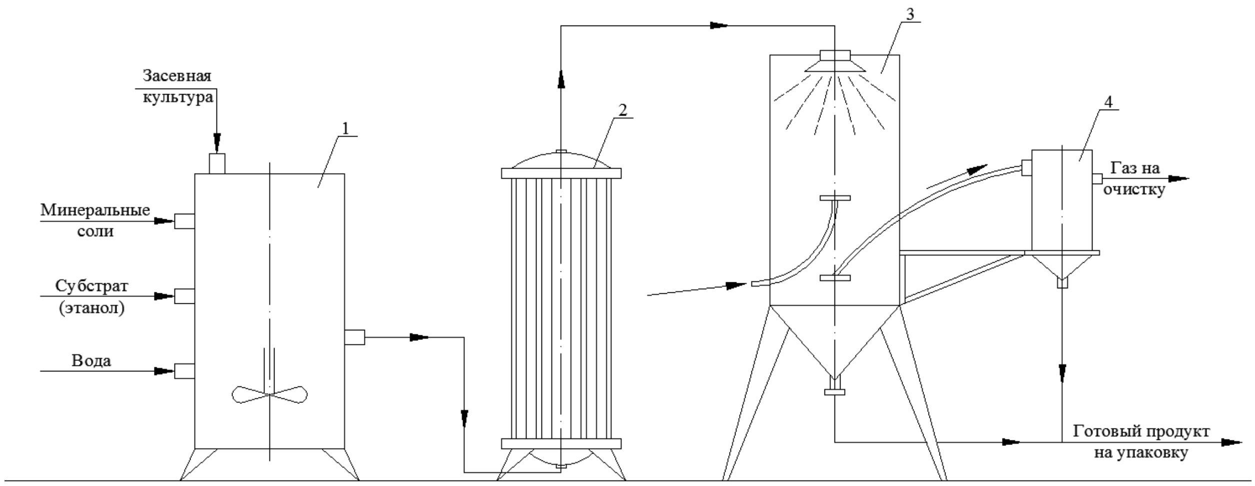
The most accessible is the biomass of activated sludge. Taking advantage of the opportunity to develop active biomass using the technology adopted for the production of fodder yeast, several tens of tons of microbial biomass were obtained. A pilot batch of such microbial biomass was sent to the Torukhansk area for biomass testing as a substitute for carboxymethylcellulose during drilling operations.

As a result of the tests, a conclusion was obtained on the fundamental possibility of such a replacement. In the future, in order to improve the necessary quality of microbial biomass used for these purposes, microbial biomass was grown in bench conditions. The criterion for the quality of biomass for these purposes was the content of polysaccharides. Bench tests have shown that under certain conditions, the content of exopolysaccharides can be increased and higher quality biomass can be obtained than in the normal mode of operation of treatment facilities.

In this case, the technological process of obtaining biomass is not fundamentally different from the traditional scheme for obtaining fodder yeast biomass and includes the known stages of cultivation, separation of bacterial biomass, drying of biomass and packaging.

However, a significant difference is the difficulty in separating biomass from the liquid due to the high viscosity of the sludge of activated sludge.

To isolate the biomass of bacteria in this case, it is advisable to use a special combined apparatus for the isolation of microbial biomass with further dehydration on a spray dryer with packaging of the finished product in kraft bags (Fig. 7.21).



1 – column-type aeration tank; 2 – combined apparatus for biomass extraction; 3 – spray dryer; 4 - cyclone

Fig. 7.21. Schematic hardware and technological scheme

The economic feasibility of obtaining microbial preparations depends on the possibilities of widespread use in the practice of preparing drilling solutions of carboxymethylcellulose (CMC), the substitute for which is the microbial biomass of activated sludge. This development is at the stage of pilot tests.

The biomass of activated sludge can also be used in various technological processes as a feedstock, for example, in construction for the preparation of concrete, cement mortars, etc.

The development of these methods of using dry sediments as raw materials for the production of lightweight concrete, building blocks, roofing material is still at the stage of testing and data accumulation.

7.10. Possibilities of using wastewater sediment as a raw material for obtaining building materials

The high content of aluminum allows us to consider the sediment as a secondary resource for obtaining building materials.

The analysis of the world experience in the secondary industrial use of water sludge conducted by the specialists of JSC "Mosvodokanal" made it possible to identify the following main areas: in construction in the production of cement and bricks, foam glass granulate, material for road surfaces; in the manufacture of paints and mastics.

Recycling in construction allows you to assimilate part of the water sludge and create on its basis materials with useful properties. However, due to the unstable composition, the use of water sludge as a building material is very limited.

Based on the analysis of the state of the problem of using this kind of waste in related fields of science and technology and the results of their own research obtained by Tsybina A.V., Dyakov M.S. and Vaisman Ya.I. methodological approaches to decision-making were developed when choosing the optimal direction of use of waste generated when using thermal methods for processing SALT, taking into account their characteristic features (multi-tonnage, presence in their composition, along with the debt resource potential of environmentally hazardous components that can migrate to environmental objects), significantly limiting the possible areas of their application.

The methodological approaches to decision-making in choosing the optimal direction of use of these wastes were based on the principle of compliance with the requirements for the best available technologies (BAT). Compliance with these requirements was assessed using a comprehensive criterion developed to assess possible directions, which included the following components:

ensuring an acceptable level of environmental and industrial safety in waste management throughout its life cycle;

economic feasibility and accessibility of the useof the resource potential established in waste in order to obtain market-demand and competitive secondary materials and products derived from them;

technical feasibility of implementing technologies for processing these wastes on an industrial scale;

economic feasibility and efficiency of the chosen direction of waste use.

The author for several years conducted research on the use of active sludge additives as an additive to concrete. However, the results obtained did not give a clearly expressed effect of improving the technological properties of concrete. Studies have also been conducted on the use of activated sludge as burnout additives, which have led to encouraging results. At the same time, the work was stopped due to lack of funding. Assessing in general the reports from various sources on the use of wastewater sediment in the technology of obtaining building materials, it can be assumed that it is possible, apparently, in some cases, such an application. This assumption, of course, must be confirmed by the results of thorough studies carried out to the required extent.

8. Experience of JSC Mosvodokanal in sediment utilization (according to JSC Mosvodokanal)

In the process of urban wastewater treatment at the Moscow treatment facilities, about 9 million cubic meters of liquid sludge is formed, requiring processing and neutralization.

Industrial methods are used to process and neutralize the sludge. Neutralization of the sediment (its stabilization) is carried out in specialized structures - methane tanks at a temperature of 50-53 °C. In order to minimize the volume of recyclable sediments (waste), the neutralized sediments were washed, compacted in gravity seals and dehydrated on chamber filter presses. In the process of such processing, the volume of sediment is reduced by more than 9 times.

The experience of operating this scheme for more than 19 years has revealed some of its shortcomings, such as:

high maintenance costs;

significant recycling of organic pollution;

a complex algorithm for controlling the technological process, requiring the participation of a large number of operating personnel.

Analysis of best practices has shown that in modern conditions the use of centrifugal devices (decanters) for the processing of wastewater sediment is the most preferable.

In order to determine the optimal type of decanters at the Luberetsky Wastewater Treatment Plant (WTP) in 2013-2014, industrial tests of centrifuges of leading manufacturers (Westphalia Separator, Flotveg, Alfa Laval) were carried out.

Analysis of operating costs showed that the use of this type of equipment allows you to get the following advantages:

high return on investment costs (about 3 years);

reduction of operating costs by more than 2 times;

release of more than 30% of production facilities;

the simplest algorithm for automating the technological process, which provides the ability to work in offline mode;

the possibility of using this type of equipment for thickening excess activated sludge, which allows to optimize the process of sediment stabilization in methane tanks;

the possibility of dewatering the non-washed sludge makes it possible to exclude from operation the compactors of the fermented sludge - the main source of release of foul-smelling substances.

JSC Mosvodokanal has started a full-scale reconstruction of mechanical dewatering shops:

in 2013, the mechanical dewatering shop at the Novolyuberetsk wastewater treatment plant was reconstructed;

In 2014, the reconstruction of the departments of the mechanical dewatering shop of the Kuryanovsk treatment facilities in the Leninsky and Ramensky districts of the Moscow region was completed, during which the morally and physically obsolete chamber filter presses were replaced with modern dehydration equipment - decanters;

in 2016 reconstruction of the mechanical dewatering shop of the Lyuberets treatment facilities was completed.

Problems of sediment disposal

The use of industrial methods of dehydration can reduce the amount of sludge by more than 9 times. Currently, the sludge is used as a reclamation agent in spent quarries and landfills of solid waste. In the current environmental situation of the Moscow region, it is becoming more and more difficult to carry out such work every year and the cost of disposal is steadily increasing.

The options for sediment disposal offered on the world market can be reduced to the following methods:

the use of sediment for the production of biosoils;

utilization of sediment on the basis of modern thermal technologies and, as a result, obtaining from waste secondary products suitable for sale in the construction industry for the production of building materials or cement.

Advantages of bio-soil production

One of the ways to solve the problem of polluted and degraded urban soils is the use of soils in the green construction of the city using dehydrated and neutralized wastewater sediment.

Municipal wastewater sludge from its treatment is a nitrogen-phosphorus organic fertilizer containing a complete set of trace elements necessary for the growth of crops. 1 mZ of dehydrated sludge contains about 9 kg of nitrogen and 18 kg of phosphorus.

The technology of soil production solves several important environmental problems at once:

disposal of waste treatment plants;

reduction of costs for the delivery of soils;

creating a sufficient number of air-conditioned soils in the city.

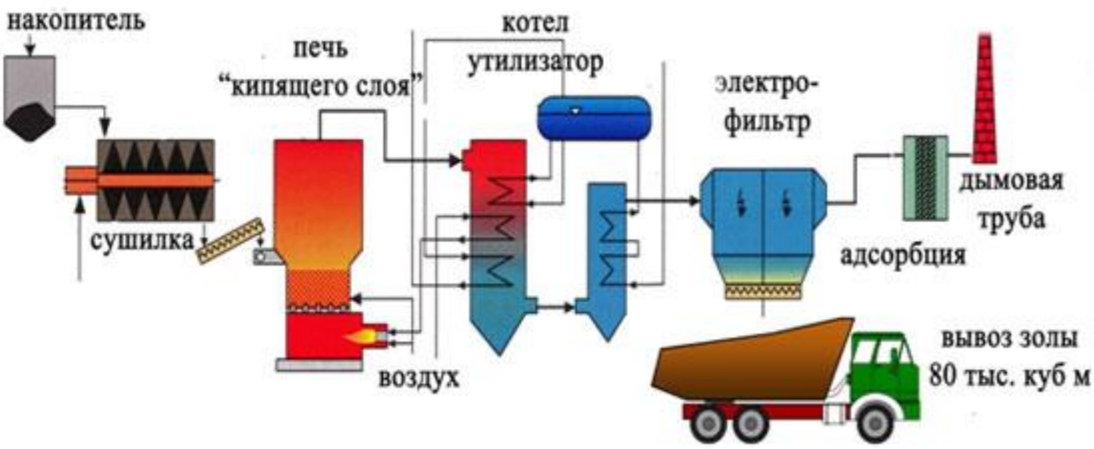


Fig. 8.1. Scheme of wastewater sludge incineration with purification of the resulting gases

The use of modern thermal technologies makes it possible to minimize emission changes resulting from the combustion of sludge, which does not lead to exceeding the normative indicators in the exhaust air (Fig. 8.1). At the same time, the thermal energy hidden in the dry matter of the sediment is used to cover the energy needs necessary for evaporation of excess moisture and heating of the combustion air.

Taking into account the difficult environmental situation in the city, it was decided to use, at the first stage, a drying scheme for dehydrated sludge. At the same time, the volume of sediment will decrease by more than 3 times, and the caloric content of the dried sediment will allow it to be used as a fuel component in the production of cement. Pilot work in this direction was carried out at the VOC. The resulting product aroused interest at the Podolsk and Voskresensky cement plants.

Of great practical interest is the technological scheme of wastewater treatment and treatment of the resulting sediments at the Kuryanovsk treatment facilities (Fig. 8.2).

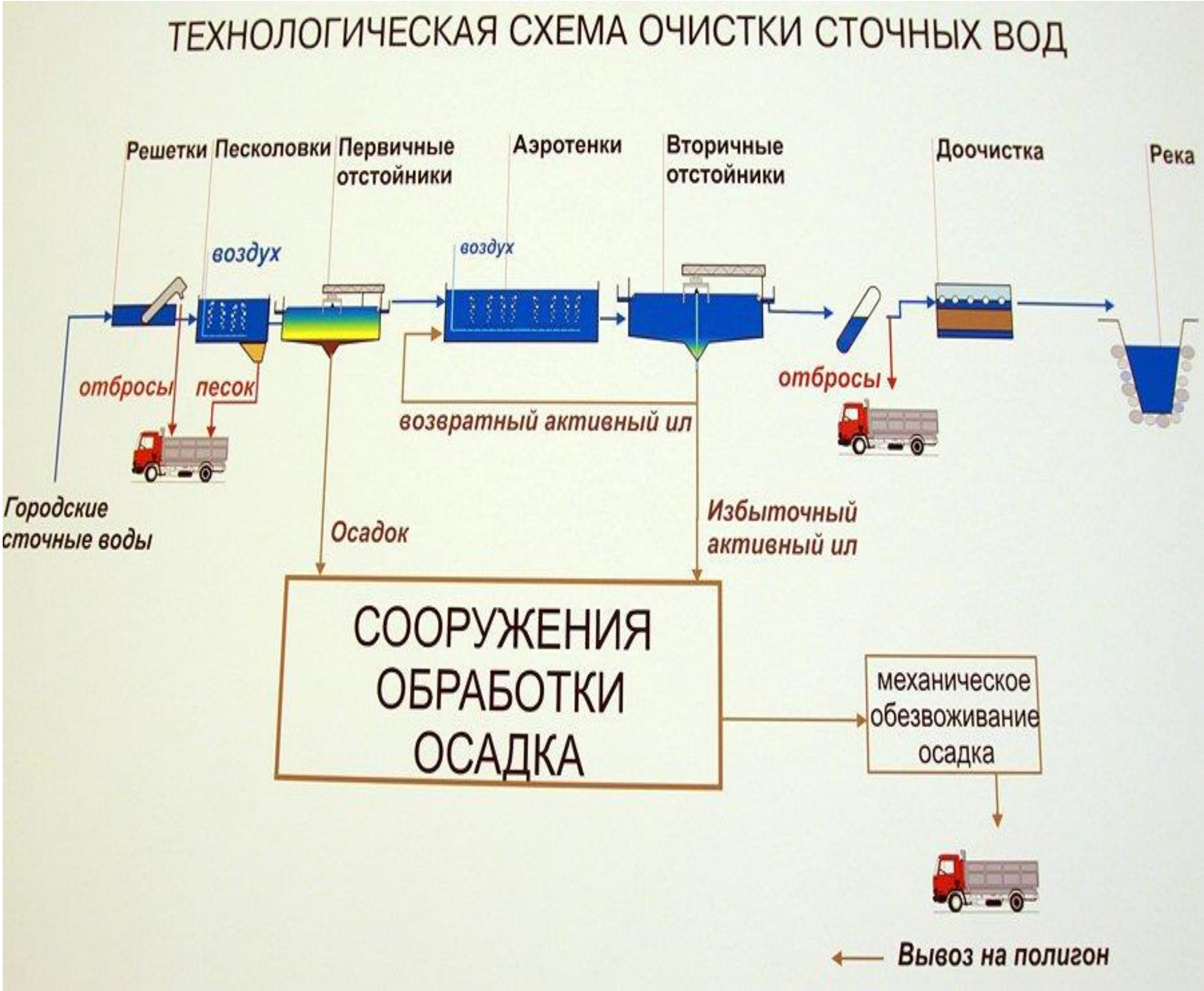


Fig. 8.2. Scheme of wastewater treatment and sludge treatment

In the process of wastewater treatment at the Kuryanovsk wastewater treatment plants, all the resulting sediment is fermented in methane tanks at a temperature of about 53 ° C, as a result of which biogas containing about 65% methane is produced.

Of particular note is the use of sediment as a raw material for the production of biogas with the subsequent production of heat and electricity. Such experience in the processing of sediment is available in JSC Mosvodokanal. In 2009, a mini-thermal power plant was launched at the Kuryanovsk Treatment Facilities (KOS) in Moscow.

It is known according to JSC Mosvodokanal earlier all biogas was sent to boiler houses to generate thermal energy. In the summer, the amount of thermal energy generated from biogas exceeded the technological needs of treatment facilities. This made it possible to move on to the next stage - the utilization of biogas at mini-TPPs with electricity generation and additional heat in gas piston engines (Fig. 43).

Mini-TPP operates in parallel with the network of JSC "MOESK" and provides approximately 50% of the station's needs for thermal energy. This allows the process of wastewater treatment to be carried out in conditions of a possible disconnection of external power supply sources.

The main technical characteristics of the mini-TPP:

- electric power of mini-TPP - 10 MW;
- thermal power of mini-TPP - 6.9 Gcal / h;
- Efficiency (general) - 84,6 %

The schematic diagram of the mini-TPP is shown in Fig. 8.3.

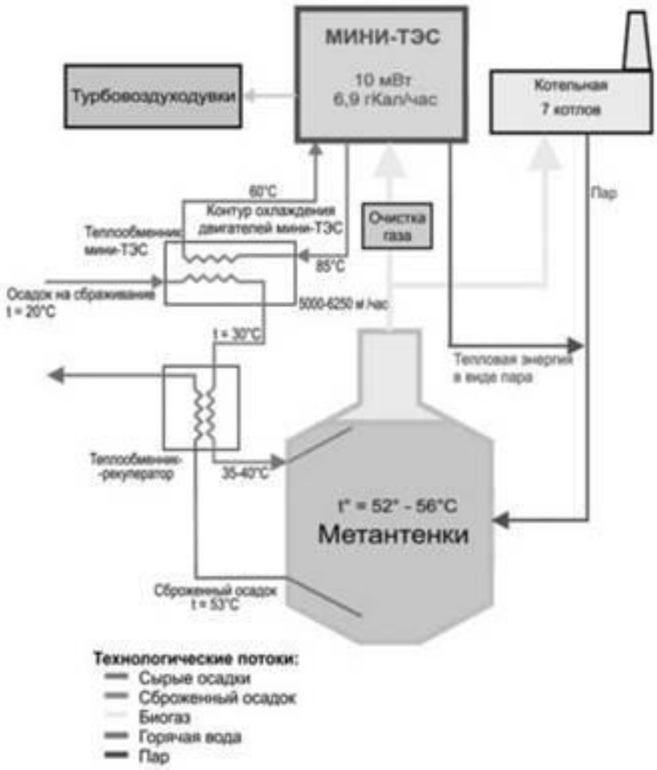


Fig. 8.3. Schematic power technology scheme of mini-TPP (according to JSC Mosvodokanal)

According to JSC Mosvodokanal, the biogas formed in the methane tanks goes through the KOS gas network to the installation of its purification. The first stage of purification involves the removal of hydrogen sulfide, which is carried out in the process of its binding to iron oxide. High-threshold iron ore is used as a filler in the purification column of the 1st stage (desulfitator). The second step involves the removal of non-hydrocarbon organic compounds, including silicon (siloxane), which is produced during adsorption in a column loaded with activated carbon.

Purified biogas goes to internal combustion engines, where it is disposed of.

The electricity produced through the medium-voltage network is sent to three transformer substations, then to consumers. Among the energy consumers connected to the mini-TPP are 5 high-voltage turbo-blowing units with a capacity of 1500 kW each (2x1500; 3x1300 kW) and electrical equipment of the boiler shop.

Flue gases having a temperature of 450-4700 ^{o}C enter the steam generators. In them, the heat of flue gases is converted into steam energy. For the production of steam, specially prepared water is supplied, which has previously passed through the deaeration and chemical preparation plants. The steam produced through the distribution comb is fed to the injectors of the methane tanks. This method of utilization of the thermal energy of the exhaust gases was chosen in order to preserve the existing system of heating methane tanks with sharp steam at the KOS.

Thus, all the heat generated as a result of the operation of mini-TPPs is recovered and directed to technological needs.

It should be especially noted that such mini-TPPs are one of the most modern solutions for the utilization of biogas and comprehensively solve the problem of eliminating the negative impact of urban wastewater sediments on the environment.

However, according to a number of experts, it is not advisable to build such mini-TPPs everywhere. In some cases, this is not entirely economical. In this regard, only a preliminary feasibility study, carried out on the basis of reliable and scientifically based data, taking into account specific features, can indicate the prospects of projects in this direction.

The search for new and more effective solutions in this direction continues. At the same time, new less expensive values of technical and economic indicators for the treatment of wastewater sediment can be achieved, which, according to some experts, account for up to 50% of the total costs of wastewater treatment.

Of particular interest is the experience of sediment treatment in Switzerland (according to RK MEDIA). At a pilot plant in St. Gallen (Switzerland), sludge from wastewater treatment plants was treated. According to the scheme of operation of the installation, the sediment is pumped from the receiving pit using a screw lift, which provides partial mixing of the sludge with sewage water with sawdust. The mixture (approximately 70% sawdust) passes from the screw lift to the storage, while it is mixed or shaken and fed by a lift-conveyor into a rotating drum. Warm air enters the rotating drum from a gas burner placed at the drum inlet.

The drum is made with internal partitions arranged in such a way that the path that the mixture takes to its exit from the drum is 3 times the length of the drum. When leaving the drum, the mixture is carried by a stream of gases into the cyclone. Hot gases escape from the top of the cyclone, while particles move down, where the transporter carries them to the vibrating screen. The material that has passed through the sieve is poured and packaged as a finished product, while the material trapped on the sieve, mainly sawdust, enters the screw lift again at the place where the sediment is supplied.

Sawdust absorbs moisture from the sediment. In the drum, under the influence of heat, the sawdust dries out, the sediment is burned. From the cyclone, small particles are removed with the outgoing gases, and inert sediment particles and most of the sawdust are returned to the cyclone. If too much sawdust passes through the sieve, then a lot of sawdust can be lost, and if too much material remains on the sieve and returns to the working cycle, then heat is lost.

A different sludge treatment system is used in Dübendorf (Switzerland). At the heart of this system is the use of a multipod furnace. Waste collected from the receiving pit by crane and belt conveyor is transferred to the primary shredder. The screw hoist mixes the waste with the untreated sludge, and the mixture is loaded into the top of the furnace. As the mixture is slowly transferred from one horizon of the tower furnace to the next, the hot gases circulating through the tower are first dried and then the material is burned. The resulting product is a fine brown powder. Temperature can be adjusted by changing the nozzle supplying the combustible mixture from the oil waste or by the nozzles on the fifth or sixth horizon of the tower furnace and the valve regulating the gas outlet at the top of the furnace. This system was used to recycle sludge in Stuttgart without adding waste, as it turned out that it is sensitive to changes in sediment moisture.

In Lausanne (Switzerland), a fluidized bed processing method was used. The crushed wastewater sediment from the receiving tanks is dehydrated on a vacuum filter. The sludge is transferred to the combustion furnace (with the supply of additional fuel). Air is blown upwards through the sand layer at the bottom of the furnace. The sediment is calcined and burned as it passes down through the hot gases and flames. This unit is equipped with an electrostatic precipitator and an economizer.

It should be noted that the considered methods and installations for the treatment of wastewater sediment will become increasingly widespread in practice.

9. Incineration and pyrolysis of wastewater sediment

9.1. Burning of wastewater sediment (experience of SUE "Vodokanal of St. Petersburg")

Prior to the commissioning of sludge combustion plants in SUE Vodokanal of St. Petersburg, dehydrated sludge was fully exported to landfills for the storage of wastewater sediment. At the moment, three wastewater sediment incineration plants have been built and are operating in the city at the largest city sewage treatment plants: the Central Aeration Station, the Northern Aeration Station and the South-Western Treatment Facilities. They burn the sludge formed in the process of wastewater treatment from all treatment facilities of the city. This made it possible to solve the main task of St. Petersburg to stop the storage of wastewater sediment and reduce the negative impact on the environment. Advantages of incineration:

- reduction of the volume of waste generated by up to 10 times;
- absence of pathogenic microflora and unpleasant odors in the ash;

• the content of harmful components in the purified gases formed during the combustion of sludge complies with the standards of the Russian Federation and the EU;

• use of heat to provide hot water supply and heating of stations;

• Electricity generation for steam utilization at SWOS and SAS;

• possibility of utilization and industrial use of ash.

The heat obtained from the combustion of sediment is used for technological needs, heating of buildings and electricity generation, which allows SUE "Vodokanal of St. Petersburg" to significantly save energy resources. Purified gases emitted into the atmosphere at all ST. Petersburg SOZs meet the requirements of Directive 2000/76 of the European Commission. The gross emission of pollutants from all combustion plants is within the limits of the maximum permissible emissions (MPE) allowed by the Rosprirodnadzor bodies. At all sludge incineration plants, online monitoring devices are used to analyze the composition of flue gases. Extended monitoring of the composition of gases is also carried out by an independent organization - the Center for Water Research and Control. In addition, a unique biomonitoring system has been introduced at the plant at the South-West Treatment Facilities: the indicators of the quality of flue gases are giant African snails that are able to respond not only to one-time emissions, but also to the accumulation of harmful substances in minimal quantities, as well as to the synergistic effect of exposure to various pollutants.

According to the data of SUE "Vodokanal of St. Petersburg", up to 1.5 million m3 / day of wastewater is treated at the CSA, while up to 200 tons of dry matter of sediment per day is formed, burned inoils using Pyrofluid technology. The sludge incineration plant is a high-tech automated and computerized production that requires a high technical level and qualification of maintenance and repair personnel. Technological and techno-economic performance of the sludge combustion plant depends not only on the above factors, but also to a large extent on the level of

technological process that has developed at the facilities, both mechanical and biological treatment. At the same time, the work of the plant, in turn, has a decisive impact on the efficiency of water purification as a whole, primarily due to the successful fulfillment of its main function - the removal of the necessary amountof dry matter from the system.
One of the main requirements for the mixture of sediments supplied for dehydration is a constant for a certain period (at least a day) and a controlled ratio of excess sludge and wet sludge (usually dry matter). Technological indicators of both dehydration and combustion depend on this ratio - the more sludge, the worse the dehydration indicators - the moisture content of the cake and the effect of retention, and therefore it is necessary to increase the dose of flocculant and reduce productivity of centrifuges. An increase in the content of excess sludge in dehydrated sludge due to its lower calorific stability than wet sludge leads to a deterioration in the combustion process and an increase in the consumption of natural gas. Indicators of dehydration and combustion processes depend on the concentration of dry substances in the incoming sludge, the lower the concentration, the worse the indicators of this process. All these factors necessary for the successful operation of the combustion plant place higher demands on the organization of the technological process of water purification and preparation of the sludge for subsequent treatment. To ensure the operation of the plant at the Central Aeration Station, the following systems were put into operation simultaneously with the construction of the plant.

1. To ensure a stable quality of sludge supplied for dewatering, software control was introduced for pumping out a given amount of sludge from primary sedimentation tanks and compacted sludge from sludge compactors, which made it possible to ensure the same level of sediment occurrence in these structures and, accordingly, its constant humidity and the absence of sludge decay.2. To minimize the content of

fibrous inclusions in the hydro flushing department, cascade grates with gaps of 2 mm are installed to filter the wet sludge and a mixture of excess sludge and wet sludge in the dewatering department of the plant. This ensured the stable operation of the centripresses and pumping equipment. 3 To reduce the sand content in the sediment during periods of uncalculated rains or snowmelt, two hydrocyclones are operated in the hydro flushing department to ensure the extraction of sand from the sediment of primary sumps.

Prior to the launch of the plant, professional training was carried out for the operating personnel, who already had experience in servicing sludge dewatering equipment on first- and second-generation centrifuges of khD Humboldt (Germany). For the operation of new equipment (Fig. 44), including furnaces, waste heat boilers, electrostatic precipitators, scrubbers, training was conducted with maintenance personnel. Thus, it was the high qualification of the company's employees that made it possible to operate the sludge combustion plant without accidents and failures, which made it possible in subsequent years to increase the productivity of the ZSO, improve the technology, and replace worn-out equipment with similar equipment of domestic production.

The system of preventive maintenance and maintenance that has existed at the plant since 1999 ensured the uninterrupted operation of the main technological equipment, as well as auxiliary.In 1999, the downtime of technological lines due to equipment failure amounted to 17.5% of the total operating time. In 2005-2007, this figure fell to 4%, which indicates the competent operation of technological equipment. In addition, the timely and full supply of materials, reagents, spare parts, contributed to the reliable operation of the sludge combustion plant. During the period of operation, individual components of the technological process were improved, which were not taken into account in the design and construction of the plant for the combustion of sediments: 1. The project did not provide for the recovery of heat generated during the combustion of sediments. In 2001, a steam utilization system (SUP) was put into operation, which made it possible to use the generated heat for the needs of hot water supply, heating of Bely Island and the residential village of Kanonersky Island. At the same time, the operating costs for the needs of the heating boiler house of the CSA decreased as follows: before the introduction of the SUP for heating and hot water supply of Bely Island in 2000, 1914.89 thousand m3 of gas were consumed per year, 13454 Gcal / year were generated. 2. The system of supply and dehydrated sludge in the combustion furnace and transportation to the backup bunker has been modernized. Screw pumps for pumping an undirected sludge mixture from the primary sedimentation tanks of compacted activated sludge were replaced with centrifugal pumps developed by Vodokanal specialists. 4. To ensure the stable operation of the alkaline column heat exchangers, industrial water filters have been developed and put into operation. 5. Work was carried out to prevent ash emissions from the storage hopper by modifying the bag filter.6. The ash humidification system was modernized, the design of the humidification system was changed, a flowmeter was installed on the water supply line for humidification. 7. Softened water installation has been modernized.

8. The acid effluent neutralization system was modernized, which made it possible to decommission two neutralization tanks, 7 alkali pumps, 4 acid effluent pumps and 2 agitators.9. An algorithm has been developed that, when changing the characteristics of the burned sludge, regulates other material flows in such a way as to compensate for the amount of heat introduced into the furnace. Work on this algorithm made it possible to maintain a constant temperature in the furnace, thereby reducing the consumption of natural gas. Products of sediment combustion (flue gases) undergo a 3-stage "wet" cleaning. In the process of wet cleaning, flue gases are passed through special devices - absorbers, where the processes of removing polluting gaseous substances are intensified with special absorbent solutions. In the processes of wet gas

cleaning to ensure high efficiency of wet gas cleaning processes, such pH values of the circulating (absorbent) solution, the temperature of flue gases at the outlet of the absorption apparatus are controlled, the concentrations of dissolved salts in the circulating solution are monitored. At the same time, automatic dosing of the reagent (absorbent) is carried out, fresh water is recharged from the circulating irrigation circuit and the saturated absorbent solution is drained to the neutralization or wastewater treatment unit.In accordance with the schedule for monitoring atmospheric air in the sanitary protection zone of the CSA, an independent accredited laboratory conducts atmospheric air. The results of atmospheric air measurements are presented in Table 9.1.

Table 9.1. Results of atmospheric air measurements

No p/n	Index	Unit	Maximum permissible concentration	Measured value
1	Nitrogen dioxide	mg/cu.m	0,2	0,01-0,047
2	Ammonia	mg/cu.m	0,2	0,025-0,158
3	Dihydrosulfide	mg/cu.m	0.008	<0,005
4	A mixture of	mg/cu.m	50,0	<1,0

	carbohydrates adjacent to C1-C5			
5	Natural Mercaptan Blend	mg/cu.m	0.00005	<0,00005
6	Dixins and furans (in terms of 2.3,7,8-TCDD)	pg/cu.m	0,5	0,0407-0,145

The sludge incineration plant at the CSA is a vivid example of the successful solution of complex environmental problems of deep sludge utilization based on modern technology, equipment, automation processes and computerization of water treatment and sludge treatment processes (Fig. 9.1).

Now in St. Petersburg there are three plants for the combustion of sludge, the largest and the very first of which - the plant at the Central Aeration Station (CSA) - was opened in 1997. The plant at CSA reached full capacity in 1999, becoming the largest of such complexes introduced in Europe over the past 30 years. Despite the fact that the plant copes with its tasks, its equipment is significantly worn out, as it has been in operation for almost 20 years. The productivity of the furnaces is gradually decreasing, which can lead to a decrease in production volumes and, as a result, an increase in the amount of incinerated sludge that will have to be taken to landfills. In this regard, Vodokanal decided to reconstruct the plant. The reconstruction project recently successfully passed public hearings. It contains a number of innovative solutions both in the field of ecology and in the field of energy saving. Thus, the implementation of the project will partially provide the sludge treatment complex with its own electricity and the entire aeration station with its own thermal energy. Due to the introduction of drying, the volume of burned sludge is reduced, which means that the furnaces will be more compact and the volume of gas cleaning will decrease. In addition, the new furnaces will significantly reduce heat discharge into the environment (up to 80%) and almost halve the consumption of natural gas.

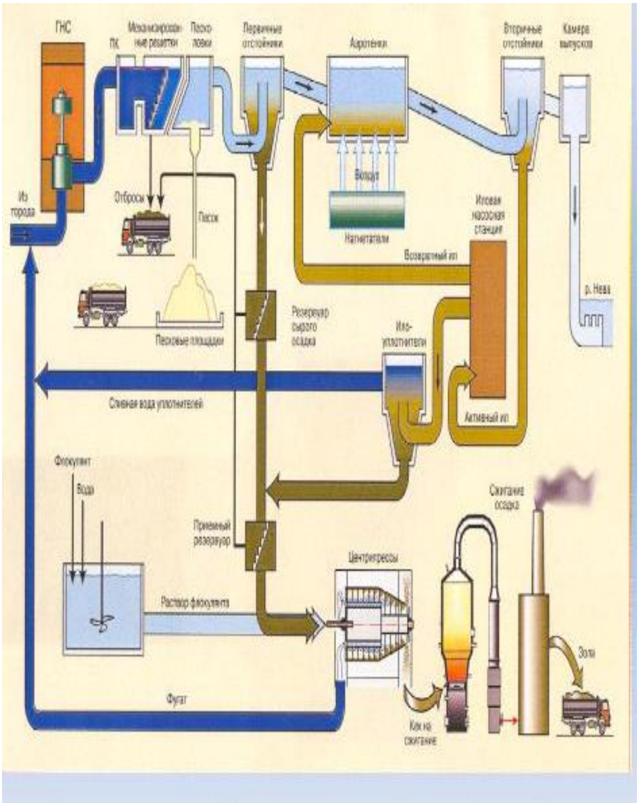


Fig. 9.1. Scheme of treatment facilities with sediment combustion (St. Petersburg)

SUE "Vodokanal of St. Petersburg" is also actively searching for solutions for the possible useful use of the ash formed during combustion. Currently, the company is considering the possibility of using ash for the production of fertilizers or technical soil (for example, in the construction and reconstruction of roads). SUE "Vodokanal of St. Petersburg" today is one of the few enterprises in Russia that managed to solve the problem of wastewater sludge disposal. The fact is that as a result of wastewater treatment, not only purified water is formed, but also a sludge containing all the pollution extracted from the effluents. Every day in St. Petersburg, in the process of wastewater treatment, about 15 thousand cubic meters of sediment are formed. Wastewater sludge is a waste of hazard class 4 and is a source of negative impact on the environment. The existing scheme for the disposal of sludge at the treatment facilities of Vodokanal involves its dewatering and burning in furnaces. The company has 3 sludge incineration plants, which allow to dispose of all the generated wastewater sediment in the city.

The introduction of wastewater sediment combustion technology in St. Petersburg has significantly reduced the environmental burden on the environment, since the volume of ash after burning wastewater sediment is 10 times less than the volume of the sludge itself. Despite the fact that during combustion the volume of sediment is reduced by 10 times, the annual volumes of ash formed at the same time are also quite large and amount to about 40 thousand tons. Ash, as well as sediment, is a waste of hazard class IV. Therefore, the problem of finding ways to usefully use ash is important and relevant for the St. Petersburg Vodokanal. Systematic work in this matter has been carried out by the enterprise for several years. As a result of the work done, Vodokanal developed and obtained technical specifications (TS) 571800-002-03323809-2008 "Ash for burning wastewater sediment for building mixtures". Over the past five years, SUE "Vodokanal of St. Petersburg" together with Russian research and production companies has been developing methods for obtaining techno-soil, which uses about 25-30% of ash. Other components of the technogrunt: dehydrated sediment, sand, clay, lime and other additives. This kind of material could be used as a techno-primer in the improvement of roadside roads, for the formation of disturbed lands, quarries, solid waste landfills, soil reclamation. Another area of application of ash, which has been considered by the company in recent years, is road construction. According to studies, ash can be a good basis for the composition from which roadbeds are made. This is caused by the excellent astringent characteristics of the ash. One of the areas of application of ash, which Vodokanal has been considering since 2015, is the preparation of organic and mineral fertilizers. Ash consists of fine mineral dust, silicon dioxide, aluminum, iron, and phosphorus anhydride.

Phosphorus anhydride (and its ash is 10-12%) is an important source of nutrition for plants. And the presence of potassium and magnesium phosphates can enrich with useful fertilizer elements and increase the absorption of phosphorus by plants. However, the salt content of heavy metals makes it mandatory to pre-treat the ash by one method or another before using it for the manufacture of fertilizers. At the moment, the search for possible ways to usefully use the ash continues. The choice of the most effective and economically justified technology for processing the resulting ash from the combustion of sludge will help make the disposal of wastewater sludge wastewater waste-free and will favorably affect the ecology of the city.

During the construction of similar sludge incineration plants at the SSA and SWOS, all the problems identified during the operation of the plant at the Central Aeration Station were taken into account as much as possible. Technologically, the sediment incineration plants of the USOS and the SAS have the following distinctive features: these plants are technologically more advanced than the first sludge incinerator at the CSA; have more efficient flue gas cleaning technologies; the generated heat is used to generate electricity and heat the sites of treatment facilities. For this purpose, turbogenerators and appropriate equipment are provided in the plants. The capacity of the SSO at SZO is 68 tSV/day for two furnaces without a reserve.To reduce the concentration of sulfur oxides in the flue gases at the SSO ZSO, the addition of limestone to the furnaces is provided.The plant provides wet cleaning of flue gases in the leaching scrubbers.

The gas purification system is similar to the gas purification system at the CSA SOA, but improved and more efficient. The first stage is the capture of ash in electrostatic precipitators. After electrostatic dust collection, the equipment of the second and third stages of wet washing of gases with a system for automatic dosing of reagents into the circulating absorbent solution is located. Flue gases successively go through two stages of wet cleaning - washing gases in acid and alkaline scrubbers. In an acid scrubber, the circulating irrigating solution is saturated with an acid condensed from flue gases, and, thereby, an acidic medium with a pH of 1-3 units is created, which allows the bonding of heavy metals into salts removed from flue gases with the drain water of scrubbers. Further, in the alkaline scrubber there is an active binding of the remaining acid-forming gases due to the dosing of the alkali into the circulating circuit of the irrigation liquid. The improvement of wet gas purification at the USOS SO is that in the second stage of gas washing for effective purification of mercury, a special reagent TMT15 (three sodium salt of trimercapto-S-triazine C3N3S3Na3 (3H2O) is introduced in the nozzle absorber. This reagent is designed for chemical binding of mercury in the circulating liquid of the scrubber, which provides a higher efficiency of removal of mercury, as well as cadmium and some other heavy metals. Wastewater from wet water Gas treatment at the USOS SOR meets the requirements of EU Directive 2000/76 with respect to the concentrations of hazardous substances in the wastewater of gas cleaning systems of waste incineration plants.The capacity of the SSA sludge incineration plant is 112.4 tons of dry matter sludge / day for two furnaces, and taking into account the reserve capacity of the third furnace will be 183.6 tons of CB / day. The technological difference between the sludge combustion plant at the FSA and the sludge combustion plant at the CSA is as follows. The SSA uses a flue gas cleaning system of a more modern type - a dry system that replaces the wet gas cleaning system. In the dry method, mainly highly active, non-regeneratible adsorbents are used, as well as substances that neutralize acid-forming gases. In such systems, wastewater is not generated from gas treatment processes, which are usually returned to the head of treatment plants.

In the CSA dry gas treatment system, two dry reagents are introduced into the flue gas stream - sodium bicarbonate (NaHCO3) and activated carbon (C). The flue gas mixture reacts with the injected reagents and then enters the bag filter, where the exhaust reagent with the captured pollutants is retained and collected in the waste bin. For filtration, high-tech filter materials made on the basis of fluoroplastic (Teflon) are used, which causes chemical resistance to aggressive components of flue gases, high reliability and efficiency of cleaning the filter system. In order to increase the efficiency of using the reagent, part of it is recycled from the waste hopper back into the flue gas stream, where the fresh reagent also enters. The spent reagent from the waste bin is continuously diverted to a storage tank for temporary storage before unloading into vehicles. Further, this waste is sent to a special landfill for burial. The FSA provides a closed steam circuit with a vapor pressure of 32 bar, which is used to drive the turbogenerator and generate electricity. Purified gases at all SSOs in St. Petersburg, on emission into the atmosphere, meet all the requirements of the European Commission Directive No. 2000/76, which regulates the conditions of combustion and the requirements for emissions of pollutants into the atmosphere from waste incineration plants. Along with this, the more stringent requirements of the Russian sanitary and environmental legislation are being met, regulating the achievement in the surface layer of atmospheric air at the border and outside the sanitary protection zones of treatment facilities, the concentration of pollutants at a level less than the MPC. All three plants provide for the incineration of other waste generated at the treatment facilities: floating substances, waste from grates. Each plant is equipped with a receiving bunker for receiving dehydrated sludge from medium-capacity treatment facilities (for example, the KOS of Pushkin, Kronstadt, Sestroretsk, etc.).

Ash from the burning of wastewater sediment mainly consists of fine mineral dust, silicon dioxide, oxides of phosphorus, aluminum, Fe (iron), and other metals. Ash is a waste of the IV class of danger, and its annual volumes for three plants are about 120 thousand tons per year. Work on the search for ways to dispose of ash began simultaneously with the commissioning of the plant for the combustion of wastewater sediment in 1997 Based on the results of the biochemical, toxicological, chemical and radiological directions, temporary technical conditions for ash were developed and a hygienic certificate was obtained for the use of ash in building materials. The first direction in which the work was carried out was the use of ash in the production of ceramic bricks at NPO Keramika, where a batch of bricks was produced with the addition of ash from burning CSA sediments. However, for a number of reasons, this direction has not received further development. Another direction for the disposal of ash in building materials was the use of ash in the production of light cellular and foam concrete. Research on the use of ash for these purposes was conducted by the Department of Engineering Chemistry and AIA of the St. Petersburg University of Railway Engineering together with SUE "Vodokanal SPb". Technical specifications for "Construction products from ash ketons" were developed and certificates for them were obtained and tested. The department organized the development of an experimental and industrial batch of ash concrete. But the use of ash in the production of all brands of concrete (light, medium, heavy) is impractical due to the insignificant amount of ash added - up to 5%. More promising is its use in the production of foam ash concrete, where its content can be up to 30%. A completely different direction in the processing of ash was its melting in electric furnaces, carried out in JSC "Institute Gipronickel". At high temperature, the ash passes into a glassy state. At the same time, the volume of ash residue is significantly reduced. Most of the compounds of heavy metals go into a bound state, which significantly reduces their activity in contact with the environment.The resulting glassy material is cooled with water and a glass crumb is obtained, which, after sieving, can be used in the production of tiles for flooring, abrasives, slate roofing, asphalt, sealed aggregates.

The density of the resulting material is 2.74 m3, a decrease in volume compared to the original ash by more than 4 times. However, the cost of electricity is about 800 kW / h per 1 ton of ash, the cost of building one furnace will be about 500 thousand dollars. The most realistic and promising direction of ash is its use in the production of foam concrete, since the ash content in this material can be 20-25% . 1. Low-rise and multi-storey construction as insulation of the external walls of the building instead of aerated concrete blocks. 2. Production of blocks from non-autoclaved concrete. 3. Road construction. 4. Insulation of air steam pipelines with a temperature of 3000 ^{o}C and above using removable and non-removable formwork, insulation of underground heating mains and repair of old ones. 5. Building mixtures, where ash can replace part of the cement and sand. Research is underway to obtain and ash of phosphorus fertilizers.

9.2. Foreign experience in the incineration and disposal of wastewater sediment

According to foreign developers, the combustion of sludge can be carried out both jointly with other energy sources (for example, solid domestic waste or fossil fuels), and separately when adding another type of fuel only as an auxiliary. Design solutions for the combustion of sludge in boilers depend on the mixture and calorific value of different fuels. Fermented, dehydrated and dried sediment can be burned. The sludge can be burned without drying and without fermentation, but in this case auxiliary fuel is often required.

Sludge burning of domestic or industrial wastewater is more common in Germany and Finland compared to other countries in the Baltic Sea region. In case of joint combustion, combustion technologies are used in boilers with grate, as well as combustion in a fluidized (fluidized) bed.

Co-incineration of sludge and municipal solid waste in grate boilers is a well-known and proven method in Central Europe, but it is not very widely used in the Baltic Sea region, with the exception of Germany, where the incineration of sludge together with coal is practiced, for example in Bielefeld, Farg (Bremen), Duisburg and Weltheim.

Monoburning of sludge, as a rule, is intended only for the thermal destruction of sediment without energy recovery, since the net calorific value of the sludge does not allow the production of excess energy. The calorific value of the fermented sediment is even lower. Typically, the calorific value of the sludge is about 3 MJ/kg of dry matter. Therefore, the installation for monoburning of sludge consists only of systems for loading, mixing and supplying fuel, a furnace with burners of auxiliary and starting fuel (oil, natural gas, coal or biogas obtained during fermentation). In practice, the fluidized bed combustion method is the only one suitable for individual combustion.

The incineration of sludge and municipal solid waste in a fluidized bed is a well-known and proven method in industrial plants in the Baltic Sea Region. It is used at several large sludge treatment plants: in Copenhagen (Denmark), St. Petersburg (Russia) and, for example, in Krakow, Gdansk, Lodz, as well as at the Pomozhany treatment plant in Szczecin (Poland). Outside the Baltic Sea region, this technology is used, for example, in the UK, the Netherlands, Switzerland, Austria, France and Italy.

Generalized information on combustion in boilers with grate and in the fluidized bed are presented in Table. 9.2.

Table 9.2. Main characteristics of wastewater sludge combustion processes in grate boilers and fluidized bed

Метод	Основные характеристики	Применимость	Примечания
Сжигание в котле с колосниковой решеткой	Сжигание при температуре 850–1000°C в печи, состоящей из колосниковой решетки и футерованной топки.	Не подходит для моносжигания осадков сточных вод. Применяется для совместного сжигания осадка при доле осадка <20%.	Инвестиционные затраты – 60–100 млн €. Установленная мощность 300–500 кВт. Для организации процесса требуются 4–5 операторов и специальные знания. Эксплуатация установки обычно не осуществляется работниками очистных сооружений.
Сжигание в кипящем слое	Сжигание в печи при температуре 850–950°C. Установка состоит из воздухораспределительной решетки с соплами, футерованной топки и слоя песка.	Подходит как для моносжигания, так и для совместного сжигания осадка. В регионе Балтийского моря применяется на некоторых крупных очистных сооружениях в Германии, России и Польше.	Инвестиционные затраты – 20–40 млн €. Установленная мощность – 300–500 кВт. Для организации процесса требуются 4–5 операторов и специальные знания. При моносжигании эксплуатация установки может осуществляться работниками очистных сооружений.

Analysis of the presented in Table.... The data indicates the advantage of fluidized bed combustion.

9.2.1. Disposal of wastewater sediment and ash from its incineration

In Europe and in the countries of the Baltic Sea region, there are different strategies for the disposal of sludge (Figure 9.2). In countries such as the Netherlands, Belgium and Switzerland, the agricultural use of wastewater sediment is prohibited or restricted, so the sludge is burned. In other countries (e.g. Finland, Estonia and Norway), composted sludge is used for the improvement of green areas. In some countries, for example, in Iceland, Malta and Greece, all the sediment is exported to landfills.

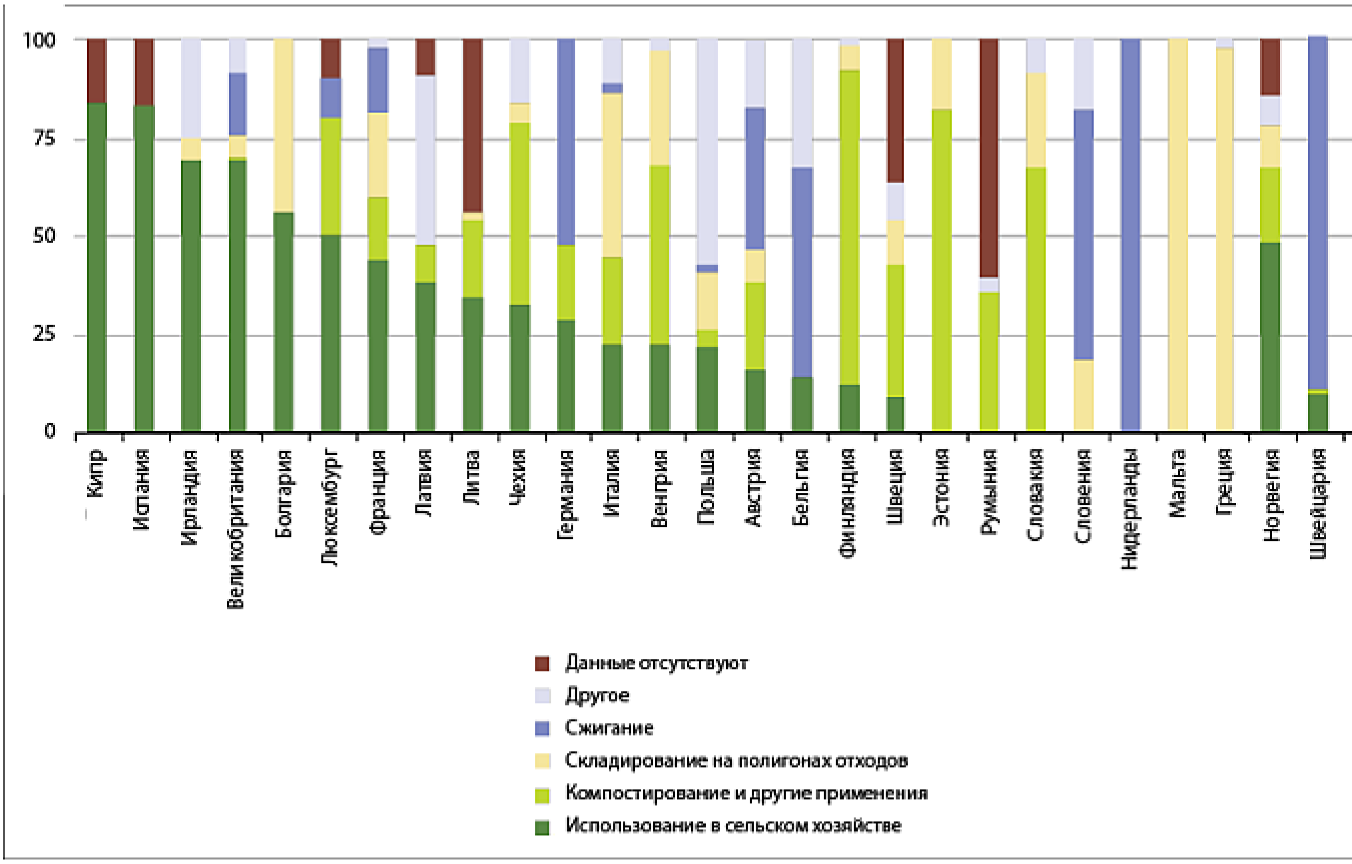


Fig. 9.2. Methods of utilization of municipal wastewater sediment by type of its treatment, 2009* (% of total mass). Source: Eurostat.

Belgium, Germany, Luxembourg, the Netherlands and Austria, 2008; Czech Republic, Ireland, Latvia and Slovakia, 2007; Greece and Switzerland, 2006; Italy, Cyprus and the United Kingdom, 2005; France and Hungary, 2004; Iceland, 2003; Sweden, 2002; Finland, 2000; Denmark and Portugal – no data available.

9.2.2. Use of wastewater sediment in agriculture

Municipal wastewater sediment in agriculture has been used in the Baltic Sea region for more than 40 years. Different countries in Europe and the Baltic Sea region show varying degrees of interest in the agricultural application of sediment. Even approaches within the same country, such as Germany, can be very different: in the northern part of Germany, the share of agricultural use of draught is more than 60%, while in the south of the country it is less than 20%. Representatives of the agricultural sector, politicians and the public express serious doubts about the permissibility of the use of sediment in agriculture, given the presence of pollutants and the likelihood of microbiological contamination. It is expected that in the near future, new technologies will make it possible to restore nutrients from sediment for use in agriculture.

Transportation of wastewater sediment to solid waste landfills

In the European Union, the practice of exporting sludge to landfills of solid waste, which cannot be used in agriculture and landscaping, is widely used. When using sludge for the reclamation of solid waste landfills, there are no special requirements for its quality, except that it cannot be in liquid form, which corresponds to the general limitation of the discharge of any other liquid waste into landfills. Recent restrictions and bans in EU countries on the export of biodegradable materials to landfills will ultimately also limit the export of sediment to landfills and the use of composted sediment for landfill reclamation. This restriction does not apply to countries outside the EU.

Utilization of ash obtained during monoburning of sediment

Foreign experience shows that only ash obtained during monoburning of sediment, or ash in a mixture with other ashes with a high content of phosphorus and other biogenic elements, is suitable for further processing and reuse. The ash produced by co-incineration has a very low concentration of phosphorus and sometimes too high a level of pollution, for example, if the sludge is incinerated together with municipal solid waste, so it is discharged into landfills. There are no problems with the disposal of sludge incinerated in cement plants due to the fact that the ash is used to produce the product.

Conclusion on foreign experience of wastewater sludge disposal

There are several ways to dispose of sludge; draught management strategies in the Baltic Sea Region are not uniform.

Agricultural use of sludge or its incineration with ash utilization allowsthe potential of the sludge to be used as a material or energy resource. These methods of disposal are quite common in the region.

Composted or disinfected by other methods, sediment in some countries of the region is used to create green areas (for example, in the landscaping of parks).

The bioavailability of nutrients in the sludge depends on the wastewater treatment process.

The pollutants present in the sediment limit its use for agricultural purposes: although the concentrations of heavy metals in the sediment are decreasing in many countries, a number of new problems have emerged.

In agriculture, ash from monoburning sludge with a high phosphorus content and in the absence of other pollutants can be used.

The concentration of biogenic elements in ash is low and their extraction requires additional processing, the methods of which are still under development.

Silocopiers are still used in some parts of the region, hampering the sustainable management of sediment because it cannot be used as a material, a source of nutrients and an energy resource, and leaks from sludge reservoirs pose a potential danger to the aquatic environment.

9.3. Possibilities of using pyrolysis for sediment treatment

One of the possible methods of processing dehydrated sediments is pyrolysis with the production on their basis of organomineral adsorbents suitable for wastewater treatment. It should be noted that sorption methods of industrial wastewater treatment, due to their universality in relation to various classes of pollution, are widely used in world practice. With regard to pulp and paper enterprises (PPE) with a developed biological treatment system, sorption methods should be considered as processes for removing organic substances that are not assimilated by active sludge formed at the stage of wood delignification and bleaching of cellulosic semi-finished products. Some of these substances, such as organochlorine and sulfur compounds, lignins, resin acids, terpenes, furfural, methanol and others are very undesirable for the inhabitants of water bodies. They have both toxic and mutagenic properties, can accumulate in organisms and are transmitted through the food chain. Thus, some of them implicitly pose a danger to humans.

The widespread use of sorption methods is constrained primarily by the lack of cheap adsorbents on the world market suitable for use in the existing technology of wastewater treatment using biological methods. Active coals of various brands that can be used for these purposes are produced in limited quantities, according to outdated technology and are very scarce even for traditional consumers. Therefore, it is hardly advisable to focus on the use of trademarks of this type of adsorbents for wastewater treatment at the moment.

Recently, comprehensive studies have been conducted to assess the possibility of wastewater treatment with all kinds of mineral sorbents such as bentonite clays, zeolites and others of both natural origin and synthetic. This direction has a prospect, but its wide development is possible only under the condition of a sharp increase in the specific sorption of pollutants by the inner surface of sorbents.

There are numerous examples of sorption treatment of wastewater in the petrochemical, chemical industries, in coke chemistry and others. All of them differ in the use of specific adsorbents (activated cokes, anthracites, coals), obtained for this purpose directly at enterprises. The production processes of adsorbents are usually combined with the processes of their regeneration with the inclusion of a separate stage in the existing wastewater treatment system.

Chemical wood processing enterprises annually generate a significant amount of organic, mineral and organo-mineral waste, among which wastewater sediment is the most difficult to dispose of and is of potential interest for processing by pyrolysis methods to obtain adsorbents suitable for wastewater treatment. Pyrolysis of sediments is indispensable in cases where they contain harmful, toxic substances and cannot be used directly as fertilizers, composts, feed and other products.

It should be noted that interest in the pyrolysis of pulp and paper pulp and paper sediment has existed for at least the last 20-25 years. So, for the conditions of the Segezha pulp and paper mill in the mid-80s of the last century, VNIIneftekhim and Mosgiprobum performed a technical and economic analysis of a pyrolysis plant focused on the processing of wastewater sediment. Unfortunately, the development of this project did not take into account the latest achievements and existing world experience in the construction of such plants, which did not contribute to its practical implementation. In addition, pulp and paper and other enterprises of chemical processing of wood in Russia are very specific and the technology of isolation and pre-treatment of sediments on them is significantly different from those generally accepted in world practice. Mineral reagents introduced into the sediments at the conditioning stage significantly affect the process of their thermal decomposition during pyrolysis, the yield and properties of the products obtained.

It should be noted that pulp and paper wastewater sludge is rarely processed by pyrolysis methods. The main direction of their utilization is thermal combustion with subsequent storage of ash components. At the same time, the methods and processes of pyrolysis do not depend on the departmental affiliation of the sediments, but are determined by the goal pursued, since their species composition in the orientation to thermal processing is not decisive.

Kuznetsova L.N. (Dissertation Pyrolysis of wastewater sludge pulp and paper with the production of organo-mineral adsorbents for the treatment of industrial effluents: dissertation ... Candidate of Technical Sciences: 05.21.03. - Arkhangelsk, 2000. - 190 p.) it is shown that pyrolyzed wastewater sediment (PWS) of the pulp and paper mill, conditioned with ferric chloride and lime and dehydrated by technology using vacuum filters, are organo-mineral adsorbents suitable for wastewater treatment from organic contaminants. The conditionally optimal area of sediment pyrolysis has been determined: the processing temperature is 900 - 920 °C with a duration of 50-60 minutes. The humidity of the initial sludge up to 20% does not have a significant effect on the adsorption properties of the PWS. Increasing the heating rate during pyrolysis has a positive effect on the formation of the PWS structure as a sorbent for wastewater treatment.

At the same time, it was revealed that the determining effect on the adsorption properties of PWS is exerted by reagents introduced into the sediments during conditioning. Dosages of reagents, optimal from the point of view of the formation of sorption properties of POSV in relation to wastewater pollution, are: EEC1z -10 -11% and Ca (OH)2 - 38 - 40%. The indicated dosages of reagents are close to optimal and with conditioning (FeC13 - 10%; Ca (OH) 2 - 35%). Iron hydroxides introduced into the sediments during conditioning by the reaction of hydrolysis with Ca(OH)2 determine the formation of the porous structure of the PWS. Lime that has not reacted does not affect the formation of PWS as a sorbent, but participates in the process of water purification due to coagulation of ligno-like compounds and sediment of the formed gels on the outer surface and in the macropores of PWS.

It should be noted that steam-gas activation by both water vapor and oxygen of the air not only does not improve the adsorption efficiency of PWS, but also leads to a significant combustion of the carbon component and the isolation of samples, which reduces the yield and worsens the performance of organic-mineral sorbents from sediment. For the option of oxidative pyrolysis of sediment, the amount of supplied air should not exceed the stoichiometric necessary for the complete combustion of steam gases.

According to the data of pilot tests at the Arkhangelsk Pulp and Paper Mill of a cyclone reactor designed for thermal processing of wastewater sludge in the mode of oxidative pyrolysis, it was revealed that the carburized residue introduced from the hydro-ash removal system (HRS) exhibits adsorption properties at the level of industrially produced clarified coal OU-A. It is shown that it is impractical to separate the sorbent from the liquid phase before supplying wastewater treatment. From the analysis of adsorption isotherms, it follows that the Adsorbents of the GZU obtained by oxidative pyrolysis of sediments in a cyclone reactor have a sufficiently developed porous structure available for molecules of various sizes. Calculated data obtained from experimental isotherms of iodine adsorption show that the specific surface area of industrially obtained Adsorbents of the HRS reaches 690m2 / t.

It is proved that the introduction of crushed adsorbents based on sediments into existing aeration systems and the organization of the process in the biosorption mode favorably affect both the results of wastewater treatment and the sedimentation and filtration properties of activated sludge. Adsorbents introducedinto aeration tanks in the amount of 0.6-0.7 g of sorbent per 1 g of BOD stabilize the biological treatment process and make it less susceptible to external influences.

It is shown that the use of chlorinated sulphate instead of iron (III) chloride in the conditioning of sediments makes it possible to synthesize adsorbents that significantly exceed the adsorption properties of industrially produced active carbons (on the example of OU-A), both in relation to generally recognized sorbates and in wastewater treatment in terms of COD and BOD. Dosages of reagents, optimal from the point of view of the synthesis of adsorbents, allow to ensure reliable conditioning of wastewater sediment.

It has been experimentally proven that adsorbents synthesized in the presence of iron hydroxides from sediments have ferromagnetic properties, which means that they can be used to purify wastewater in powdered form with subsequent separation from the treated water by magnetic separation methods. The conditions for the treatment of sediment during their deposition with ferrous sulfate from the ammonia suspension have been determined; dosage Of Pe2(804)w - 30% per Fe203; pH of processing - 8,0 - 8,5. The pyrolysis temperature, at which ferromagnetic properties are formed, is in the region of the conditional optimum during the formation of adsorption properties (840 - 860 °C).

A schematic technological scheme of sediment processing using the method of oxidative pyrolysis in a cyclone reactor has been developed. At the same time, technical and economic calculations confirm the feasibility of obtaining adsorbents from sediment with a focus on their use in systems for ensuring the environmental safety of pulp and paper enterprises.

In general, conclusions should be drawn regarding the formation of the adsorption properties of pyrolyzed wastewater sediment treated before mechanical dewatering, that is, at the stage of conditioning, with chlorinated iron sulphate and lime. First, the use of chlorinated sulphate instead of iron (III) chloride makes it possible to synthesize adsorbents that significantly exceed the adsorption properties of industrially produced active carbons, in particular on the example of OC-A.

Secondly, at the stage of conditioning the sediments with the named reagents, substances (presumably iron III hydroxide) are formed, which have an activating effect on the organic substances of sediment.

Thirdly, calcium hydroxide introduced into the precipitate has an independent positive effect on the processes of wastewater treatment both from hard-to-oxidize IUDs and colloids (lignosulfonates), presumably due to coagulating effects, and from biologically oxidized dissolved organic substances. In the latter case, most likely, there is a chemical interaction of calcium ions with contaminants with their transfer to a state that is not oxidized by microorganisms.

Fourthly, the dosages of reagents that are optimal from the point of view of the synthesis of adsorbents make it possible to ensure reliable conditioning of wastewater sediment.

Experimental studies characterizing the effect of chlorinated iron sulphate introduced into the sediments at the conditioning stage made it possible to synthesize adsorbents that significantly exceed in their adsorption properties similar materials obtained when using iron chloride as a reagent for conditioning. The increased chemical activity of the reagents formed during chlorination of vitriol did not find its experimental confirmation in the previous sections of the dissertation, It was only suggested that the chemical activator that determines the formation of the adsorption properties of PWS samples during pyrolysis are the products of hydrolysis of iron salts remaining in the cake during mechanical dehydration of sediments by filtration. The most likely products of this purpose may be iron hydroxides, quantitatively passing into the solid phase and having a certain catalytic activity in redox interactions. It is these interactions that mostly determine the course of the processes of chemical activation of organic materials in the technology of obtaining carbon adsorbents. Given that the reactions of thermal decomposition of iron hydroxides in the presence of a carbon reducing agent will certainly be accompanied by the formation of oxides and other reduced forms of iron, it was to be expected that pyrolyzed precipitates would be carriers of not only adsorption, but also ferromagnetic properties.

On the other hand, as a result of the treatment of iron sulfate with molecular chlorine, along with iron chloride, its sulfate is formed, and in an amount 2 times higher than the formation of chloride. The behavior of ferrous sulfate in the treatment of its aqueous solutions with alkaline reagents is significantly different from the behavior of iron chloride. Along with hydrolysis reactions in an alkaline environment, ferrous sulfates are prone to complexation with the formation of compounds such as alum, especially in the presence of monovalent alkaline cations. A higher catalytic activity of the latter in the processes of activation is not excluded, especially at elevated temperatures, when iron hydroxides will be purposefully reduced to its elementary forms.

In view of the foregoing, the synthesis of adsorbents from sediments using ferrous (III) sulfate as a reagent for conditioning was carried out purposefully with alkalinization of the suspension not with calcium hydroxide, as in previous series, but with ammonia water. It was assumed that in the presence of ammonium hydroxide, the hydrolysis of ferrous sulfate at certain stages would pass through the formation of iron-ammonium alum, which could modify the nature of the subsequent thermochemical activation, and hence the adsorption properties of the samples obtained.

As in the previous sections, the pilot study on the development of POSV was carried out using experimental design methods. Taking into account the high interpolation properties of statistical models obtained earlier on the basis of the implementation of the second-order plan, namely the central compositional rotatable uniform plan, it was decided not to change the research strategies and to implement this plan. It was taken into account that for stochastic processes with well-regulated input parameters, in which the variance of response functions does not depend on the levels of independent variables, such plans are optimal if it is necessary to minimize labor costs in the construction of response functions.

Due to a significant change in the scheme of preparation of sediments for pyrolysis, the variants of representation of independent variables varied in the treatment of sediments before dehydration have also been slightly modified. In addition, it was found that in order to give the sludge-containing sediments satisfactory water-giving properties in the conditioning process, it was necessary to introduce ferrous sulfate several times more than chloride, especially in the absence of subsequent introduction of lime.

Thus, the following were chosen as independent variables presumably affecting the properties of the synthesized PWS samples in this case: the dosage of ferrous sulfate, the pH of treatment determined by the amount of ammonia injected, and the pyrolysis temperature of the filtered and dried mixture of sediment with the hydrolysis products of the iron-containing reagent introduced into its structure.

10. Deposition of wastewater sediment

In the process of transportation of wastewater through sewage networks and their subsequent treatment, various wastes are generated at sewage treatment plants. Basically, this is a sediment from cleaning sewage networks and wells, garbage from grates, sand from sand traps, ash from burning a cake.

Currently, two large landfills with a total area of 118.7 hectares are operated in St. Petersburg - "Severny" and "Volkhonka-2". Over the years of operation, 4.9 million m3 of sediment has been stored at the landfills, and the facilities have been filled to critical levels.

Due to the fact that landfills are a source of odor and a potential source of pollution of the atmosphere and groundwater, the search for a solution to this problem is one of the priority areas of work of SUE "Vodokanal of St. Petersburg".

The sediment stored in landfills is a heterogeneous mass containing large inclusions. The concentration of dry matter in the sediment is approximately 23-25%, the mineral part - about 33-35%. Obviously, such a precipitate cannot be used in its original state, so it must be pre-treated. Methods of sludge treatment were proposed by various companies - "Umveltechnik GmbH", "Naus GMbH EkoKG", "Khansareba", "Ashland Eurasia" and LLC "Litos". After conducting a feasibility comparison of the proposed technologies, the method of static dewatering of stored sludge in geotubes was chosen (Fig. 10.1).

Fig. 10.1. Geotubes filled with recycled wastewater sediment

The main advantages of this technology:

no need for mechanical dehydration;

the properties of the fabric material allow you to quickly pass water and retain solid particles;

during operation, no costs for spare parts and filter fabrics are required;

ease of installation and commissioning;

the cost of dewatering in containers - geotubes is 20-30% lower than with hardware processes;

overdose or lack of an air-conditioning reagent (flocculant), failures in the supply of pulp do not have a significant impact on the final indicators of dehydration due to the sufficient residence time of the sediment in the container;

prompt installation and dismantling of production infrastructure of any capacity;

the production site is any planned site without the need for the construction of capital structures;

simplicity and aesthetics of the technological process, the absence of complex elements;

the possibility of dewatering raw materials or waste at the disposal site, temporary storage or permanent burial. Containers can be stacked in a multi-layered way, which can significantly save space;

non-stop mode of the dewatering process - until the free water completely disappears against the background of biostabilization and geoconsolidation of the solid phase;

protection of dehydrated waste from wind and water erosion;

low power consumption for the technological process.

The essence of the method is static dehydration, i.e. filtration of the liquid phase of the sediment through the walls of geotubes - containers made of polymer filtering fabric, which are located on a specially prepared drainage site (Fig. 10.2). Before feeding into the geotubes, the sediment is treated with special additives: polymer flocculant - to increase the efficiency of filtration; stabilizer - to suppress the process of decay of the organic part; disinfectant - to suppress the smell and microflora of the sediment; a special reagent - for binding salts of heavy metals.

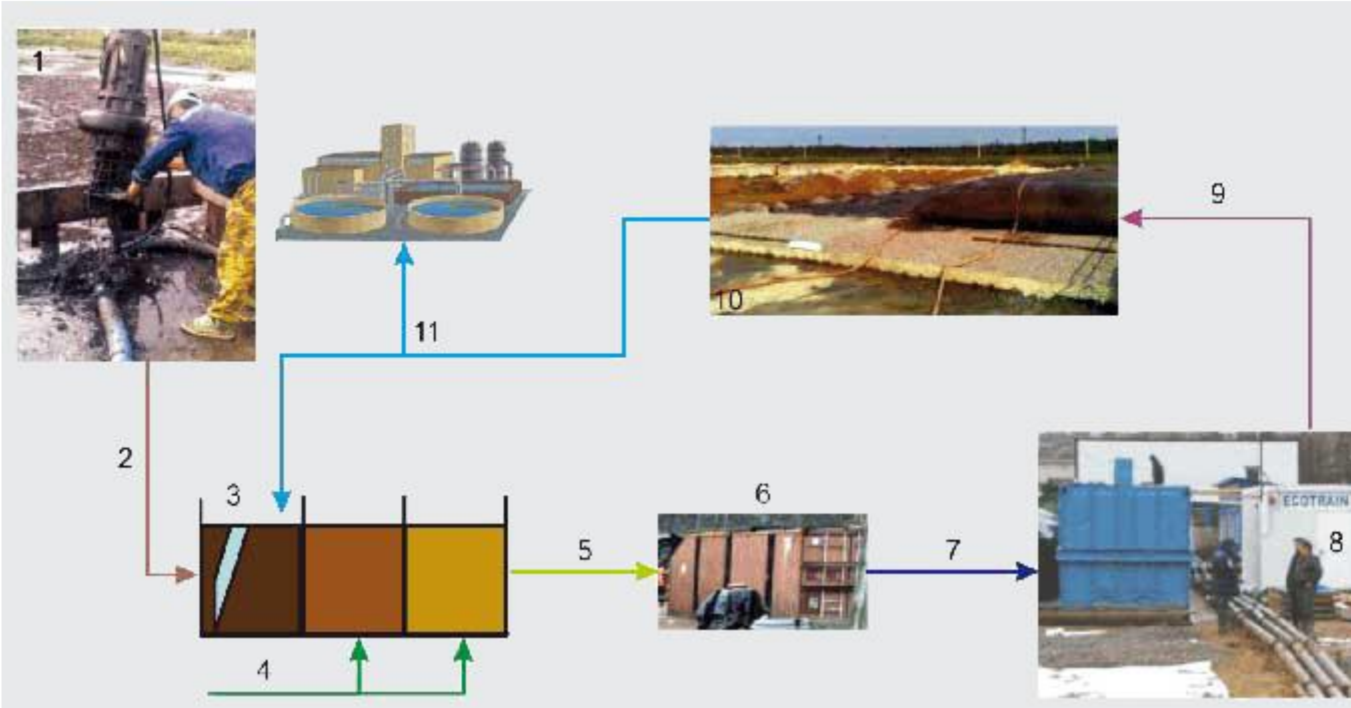


Fig. 10.2. The main stages of sediment treatment using geotubation technology

1 – excavation of sediment from the sludge storage facility using a submersible pump; 2 – transportation of sediment to receiving tanks;3 – filtration of sediment through grates and dilution of sediment with leachate to a humidity of 95% in tank No. 1;4 – supply of reagent solutions (heavy metal precipitator, disinfectant, deodorant) to tanks No. 2 and 3 and subsequent treatment of sediment with reagents; 5 – pumping of sediment into the bunker; 6 – treatment of sediment in the bunker with a stabilizing reagent;7 – transportation of sediment to the Ecotrain unit; 8 – treatment of sediment with flocculant; 9 – injection of the treated sediment into geotubes; 10 – static dewatering of sediment in geotubes;11 – leachate drainage to the averager or to the head of treatment plants

Currently, the Technological Regulations for the processing of wastewater sediment stored at the «Severny» landfill have been developed. Work on this regulation began in the summer of 2009.

Implementation of the complex of works in full will allow:

eliminate the threat of emergency situations at the landfill with the possibility of soil and water pollution;

eliminate harmful effects on the environment;

eliminate unpleasant odors from the stored sediment;

create a backup sludge treatment system in case of equipment failure at the sludge treatment complex of sewage treatment facilities;

redistribute the sediment stored at the landfill, minimizing the territory of its storage. This technology will make it possible to place the sediment after its treatment on an area of about 10-15% of the site currently occupied;

use disinfected, stabilized and dehydrated soil after geotubes for the preparation of techno-primer.

Findings

Currently, 7.9% of the sediment stored at the «Severny» landfill of SUE Vodokanal of St. Petersburg has been processed using geotubation technology. By 2016, all the sediment of the city's sewage treatment plants stored at the landfill will be treated in this way and will not pose a danger to the environment. At the same time, the territory previously occupied by the landfill will be freed up to create a green zone, reserve sites will appear for the storage of sediment for the period of preventive work at the sludge combustion plant (Fig. 10.3). The use of geotubes at the Severny test site is a pilot project for the further implementation of this method at the largest polygon of the city, Volkhonka-2. Processing of the sludge stored there is scheduled to begin in April 2012.

Fig. 10.3. The planned results of the application of the technology of geotubation of sediment - the territory for the storage of ash and technological waste (a reserve for 25 years is provided); - the released territory for the creation of a protective forest belt; - Geotube storage area

11. Prospects for the use of flotation equipment for the treatment and dewatering of wastewater sediment

11.1. Cleaning of sand sediments

The problems of neutralization of the resulting sediments are quite relevant both from the point of view of their possible disposal and their storage in case of impossibility of use. There are various ways to neutralize sediment. However, consider those methods that are used only to neutralize sand sediments, for example, formed in sand traps or in primary sedimentation tanks. Such sediments after neutralization in most cases can be used for various purposes, including the planning of production sites.

The experimental data obtained in the laboratory made it possible to develop a scheme for a pilot plant, on which it is possible to obtain specific technical and economic data for the implementation of the developed method in the practice of wastewater sediment treatment from oil pollution.

The developed installation for the treatment of sediments includes a device for collecting sediments from the dump, a transport device and a device for cleaning the sediment. At the same time, a flotation machine with a fluidized layer and a reagent dosing unit is used as a device for soil cleaning, and the reagents are injected through an ejector with simultaneous air supply, and the mechanical flotation machine includes from 4 to 12 chambers with a chamber width to height ratio of 1: 1.5 to 1: 2.5, with aerators made in the form of propeller agitators with 2 ... 6 blades. Water drainage from the flotation machine is carried out by transporting the purified suspension through a self-cleaning filter, made in the form of a rotating cylinder of porous and metal. A distinctive feature of the flotation machine used is that the intensity of aeration in it decreases in the course of the movement of the cleaned suspension through the chambers of the mechanical flotation machine, and the water discharged from the self-cleaning filter is clarified from contaminants in the pneumatic type flotation machine, consisting of 2 ... 6 chambers, half of which are equipped with thin-layer clarification units with a distance between the shelves from 1 to 8 cm and at the same time the reagent preparation unit is made in the form of a chamber with a pneumatic aeration system.

This installation (see Figure 11.1) consists of a sediment intake device 1, under the end of which a grate 2 is placed, below which a conveyor 3 is installed, the upper end of which is located above the first chamber of the flotation mechanical machine. Above the first chamber of the flotation machine, a preparation unit 4 and the supply of reagents in the form of an ejector 5 are also installed.

The flotation mechanical machine used 6 consists of 4... 12 chambers, with 7 aerators installed in them, made in the form of propeller agitators with 2... 6 blades and a suspension level control device 9.

On the outside of the flotation machine, a foam chute 8 is made, from the lower part of which a pipe emerges, the lower end of which is connected to the foam product collection 15.

Attached to the last chamber of the flotation machine is another large chamber in which a rotating self-cleaning filter 10 is installed. The filter is made in the form of a vertical closed cylinder of porous metal. A pipe is attached to the bottom of the filter to drain the filtered water. The bottom of the filtration chamber is made in the form of a cone, which passes into a branch pipe with a screw mechanism 11. Under the outlet of the screw mechanism is a conveyor 12.

The installation also includes an intermediate tank 13 with a pump 14, a foam collector 15, a pneumatic flotation machine type 16 consisting of 2 ... 6 chambers, half of which at the exit of the flotation machine are equipped with thin-layer clarification units 18. Aerators 17 are installed in the chambers at the entrance. On the side, on the outside of the flotilla, there is also a foam chute. Part of the purified water is returned to the first chamber of the mechanical type flotation machine, and part passes through the after-treatment filter 19 and is discharged into the tank.

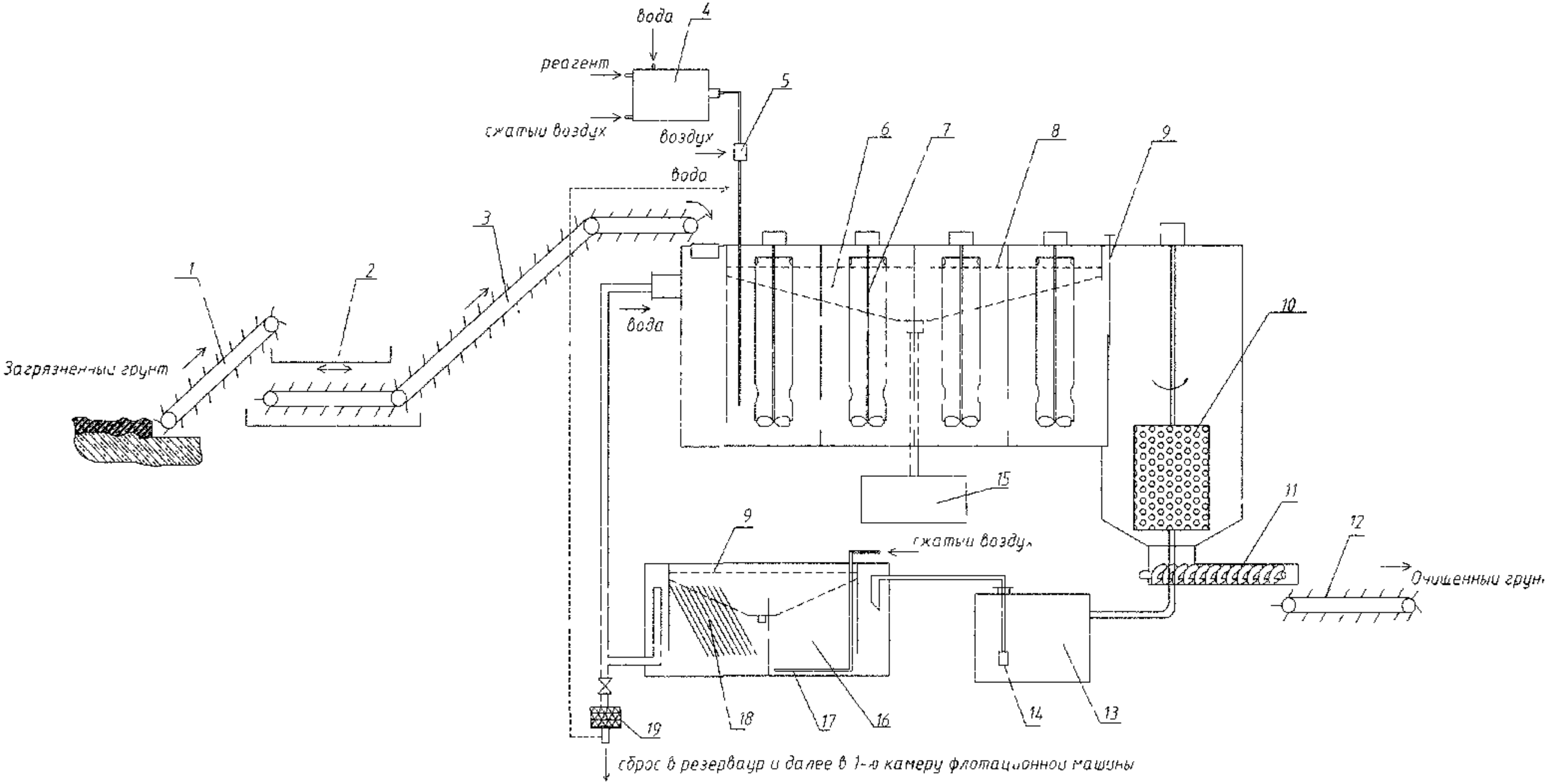

вода
4
реагент
сжатый воздух
5
воздух
вода
6
7
8
9
3
2
1
Загрязненный грунт
вода
10
15
9
сжатый воздух
11
12
Очищенный грунт
19
18
17
16
14
13
сброс в резервуар и далее в 1-ю камеру флотационной машины

Fig. 11.1. Scheme of the installation for washing sand sediment

The principle of operation of the proposed installation is as follows. The contaminated sediment is taken from the dump using the intake device 1 and then enters the grate 2, through which small particles of the soil are sifted, and large inclusions, for example, stones, various metal objects remain on the grate 2 and, as they accumulate, are removed by a special device (in Fig. not shown). A significant portion of the sludge sifted through the grate enters the transport device 3 and further into the first chamber of the flotation mechanical machine 6, where water and an air-aerated solution of reactants prepared in the reservoir 4 and supplied through the ejector 5 simultaneously enter. Preparation of the solution of reagents takes place in a tank 4 with a pneumatic aeration system that allows mixing the solution of reagents using compressed air. Further, the prepared solution of reagents is fed with the help of an ejector 5 to the first chamber of the flotation mechanical machine 6, in the chambers of which, in the fluidized bed mode, the sediment particles are cleaned of contaminants. This is facilitated by the presence of reagents that have pronounced properties of surfactants that contribute to the separation of contaminants, for example, in the form of petroleum products, oils, fats, etc. Pollution detached from the particles of the sediment sticks together with air bubbles, forming flotation complexes that float into the upper layer and are removed by gravity into the foam gutter. A similar process is repeated in the following chambers in the course of the suspension.

Further, the purified suspension enters the self-cleaning filter 10, by which the suspension is separated into a solid phase, then removed by means of transport devices 11 and 12, and the separated liquid phase first enters the intermediate reservoir 13, from where the pump 14 is supplied to the pneumatic type flotation machine 16, from which it enters the tank and then with the help of a pump (in Figure 54 ... not shown), in the first chamber of the mechanical flotation machine.

To work out the mode of purification of sediment from petroleum products by flotation, experimental studies were conducted in the laboratory.

Experiments on cleaning the sediment from oil pollution were carried out on a laboratory flotation machine with a chamber volume of 1 liter and a prototype of a four-chamber flotation machine with a chamber volume of 15 liters of mechanical type without forced air supply. Flotation time ranged from 15 to 45 minutes, and in some cases up to 60 minutes.

As an object of research, samples of sediment taken from the production site of a gas station (GS) and samples of sediment specially contaminated with spent oils containing petroleum products were used, respectively, 3... 6% and 25... 28%.

After loading the contaminated sediment into flotation chamber, water was added in a sediment ratio: water equal to 1: (1-5) and the resulting mixture in the form of a suspension was flotated in the mode of self-suction of air.

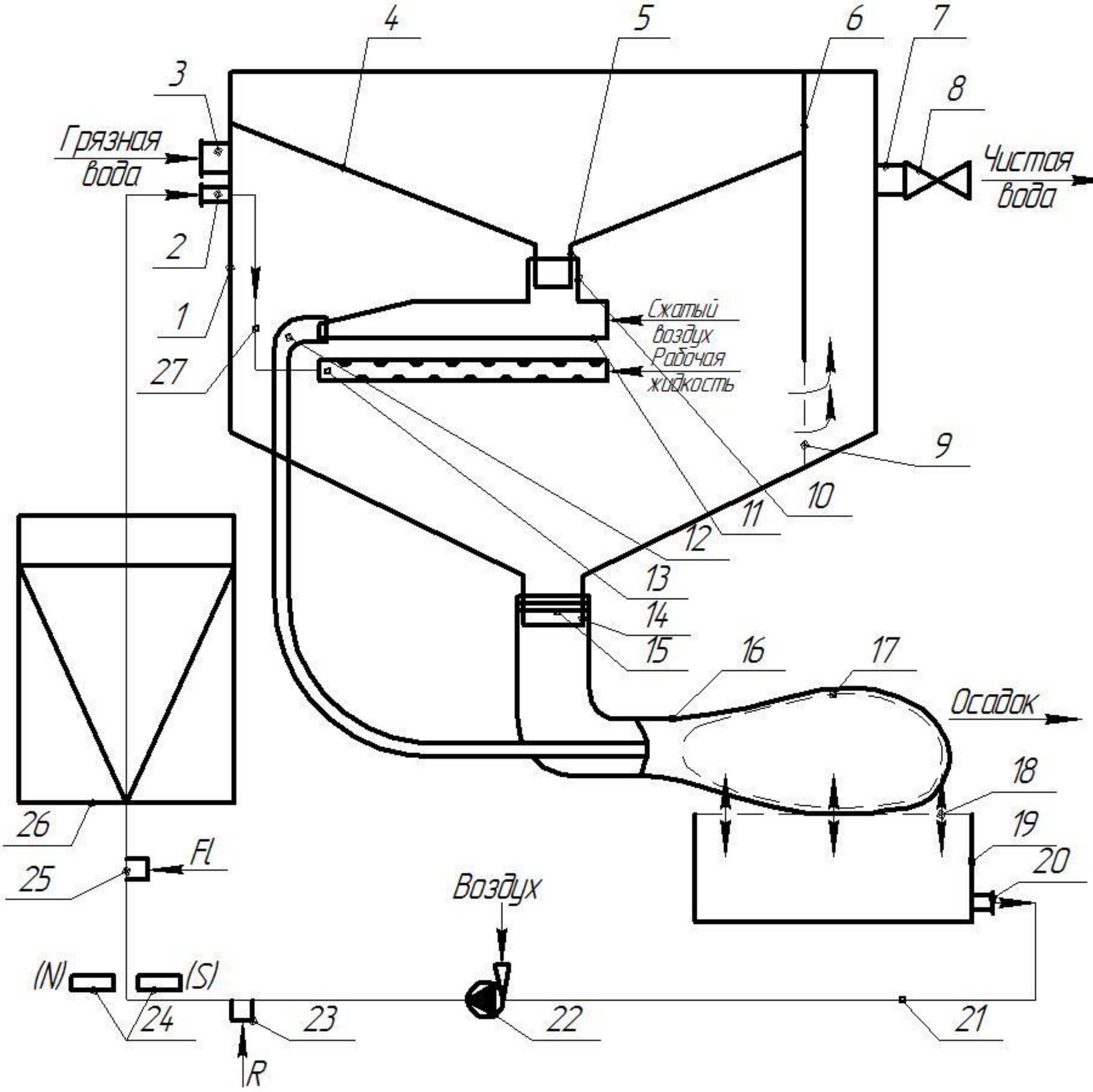
Studies have shown that during flotation treatment there is a significant change in the composition and structure of the sludge, which is confirmed by both visual observation and instrumental control of the quality of the sediment.

Experimental data obtained during research in laboratory conditions indicate that the effectiveness of sludge treatment from contaminants depends on the flotation time, the volume ratio of sediment to water, the initial contamination, and the temperature of the washing water. It is established that the increase in flotation time from 15 to 45... 50 minutes leads to a significant increase in the efficiency of sludge treatment from petroleum products. The efficiency of purification also increases markedly with an increase in the volume ratio of water - sediment from 1: 1 to 2: 1 and the addition of foaming agent OP-10 at a dose of 10 ... 15 mg / l. Experimental data obtained in the laboratory made it possible to develop a scheme for a pilot plant, on which it is possible to obtain specific technical and economic data for the implementation of the developed method in the practice of cleaning sediment from oil pollution.

11.2. Dewatering of sediments using flotation combines

The development of flotation technology, carried out by us along the path of creating combined machines and devices, led to the development of flotation combines for wastewater treatment and simultaneous dewatering of the resulting sediments. A distinctive feature of flotation combines from various types of combined flotation equipment is that all the processes of wastewater treatment and simultaneous dewatering of the resulting sludge have coordinated hydrodynamic regimes.

Further development of wastewater treatment technology in flotation combines has led to the expediency of using more complex processes than when using conventional flotation equipment. This applies to almost all processes, including mixing of reagents with purified water, formation and thickening of the foam product and sediment. Consider the main stages of the processes occurring in the workspace of the flotation combine, in the treatment of wastewater. The scheme of the flotation combine developed by us is presented in Fig. 11.2.



1 – Flotation combine body; 2 – branch pipe for supplying recirculating liquid; 3 – dirty water supply pipe; 4 – foam gutter; 5 – branch pipe for the output of the foam product; 6 – semi-submersible partition; 7 – clean water outlet pipe; 8 – adjustment valve; 9 – filter mesh; 10 – connecting element; 11 – ejector; 12 – connecting hose; 13 –

perforated element; 14 – sediment drainage pipe; 15 – cover; 16 – bag; 17 – pores; 18 – vibration platform; 19 – leachate collection; 20 – filtrate outlet branch pipe; 21 – pipe pipeline; 22 – pump; 23 – coagulant supply pipe; 24 – a pair of magnets; 25 – flocculant supply pipe; 26 – air conditioning chamber; 27 – recirculating fluid supply pipeline

Fig. 11.2. Scheme of the flotation combine (author's development, application No. 2017112476/20(021948))

The flotation combine for wastewater treatment and sediment dewatering includes a housing 1 (Fig. 11.2), on the outside of which there are branch pipes 2 and 3, respectively, for the supply of recycling liquid and initial (dirty) water, as well as a foam chute 4 with a branch pipe for the output of the foam product 5, a pipe for the output of pure water 7 with an adjustment valve 8, a branch pipe for the output of the sludge 14, which is worn by the cover 15 of the bag 16, having pores 17. In this case, the branch pipe 5 is connected by a connecting element 10 to an ejector 11, which is connected by a hose 12 to a bag 16, oscillating in an upright position by means of a vibration platform 18, under which is placed a leachate collector 19 with an outlet pipe 20 connected by a conduit 21 to the pump 22. After the pump 22, pipes for entering the coagulant 23, a pair of magnets 24, a flocculant supply pipe 25 and a flake chamber 26 are placed on the pipeline 21.

Inside the housing 1, a semi-submersible partition 6 with a lower window with a mesh 9 and a perforated element 13 connected by a piping 27 to a branch pipe 2 are installed.

The principle of operation of the flotation combine is as follows. The dirty water entering through the branch pipe 3 is mixed with the recirculating and working fluids, which leads to the formation of flotation complexes and aggregates of pollution particles without bubbles, which within about 15-30 minutes are separated respectively into a foam layer and sediment. The foam layer is removed into the foam chute 4 and then enters through the nozzle 5 by sucking into the ejector 11 and further through the hose 12 into the bag 16. Aggregates of contaminant particles without air bubbles precipitate, which through the branch pipe 14 and further through the cover enters the bag 16. The mixture of precipitate and foam product entering the bag 16 is dehydrated by gravity removal of moisture and the simultaneous intensifying action of the vibrating platform 18. The resulting filtrate is discharged through the branch pipe 19 and is further used as a recirculating liquid supplied to the workspace through the branch pipe 2. The dehydrated precipitate is removed along with the sac 16.

Pure water is discharged from the working space of the housing 1 sequentially through a lower window with a mesh 9 of the semi-submersible partition 6 and then through a branch pipe 7 with the possibility of regulating the discharge flow.

A temporary assessment of the processes taking place in the flotation combine will be carried out in stages. Starting from the introduction and mixing of reagents, in particular coagulant.

The mixing time τ is determined from the solution of the kinetic equation. In the case of considering a one-dimensional problem, we have:

$$\frac{\partial f(x,t)}{\partial t} = div\left[\mu f(x,t)\nabla\varphi + D\nabla f(x,t)\right]$$

here μ - the mobility of current carriers, D - the diffusion coefficient, ϕ - the potential of the electric field; f(x, t) is the distribution function. Assuming that the mixing effect of the electromagnetic field is observed mainly in regions commensurate with the scale of turbulent pulsations, we obtain a solution to the problem only for local space. The solution of the above kinetic equation in the case of neglect of the last term is:

$$f(x,t)=f_0 e^{-\frac{t}{\tau}}, \quad \tau=\frac{q\lambda^2}{12kT\mu}$$

where: λ is the size of the region commensurate with the scale of turbulent pulsations,

T is the temperature of the liquid.

k is the Boltzmann constant.

q is the charge of current carriers (ions).

μ is the mobility of ions in an electric field.

The value λ is estimated from the well-known expression

$$\lambda=\nu^{3/4}\varepsilon^{-1/4}$$

where ν is the kinematic viscosity, ε is the rate of dissipation of energy.

Taking:

q=1,6·10-19 k,

λ= 10-4 м,

μ is the mobility of ions in an electric field

K=1,38·10-23 J/deg

T=300°К,

μ=10-7 m2/s * V

Get

$$\tau=\frac{1{,}6\cdot10^{-19}\cdot10^{-8}}{12\cdot1{,}3\cdot10^{-23}\cdot3\cdot10^{2}\cdot10^{8}}=0{,}34 \text{ c}$$

In the case of μ=10-8 m2/s * V, we have τ=3.4 s.

The order of values shows that in areas of 10-4 m in size, the time of "resorption" of ions in a liquid is 0.1-10 s. This allows mixing of the electrically conductive and non-electrically conductive components in mixers of a relatively small volume.

Further, at the stage of conditioning, the formation of flotation complexes of particle- bubble occurs. At the same time, as a rule, not all particles of pollutants stick together with air bubbles and remaining in a single state or in the form of aggregates precipitate.

Particles stuck together with small bubbles form microflotocomplexes that slowly float and in this connection they are carried away by the flow of the purified liquid moving in a horizontal direction. Such microflotocomplexes, reaching the reticulate septum, come into contact with each other with the formation, as a rule, of larger vesicles, which quickly surface, forming a flotilla. Purified water, passing through the mesh partition, is removed using a special device and then removed from the flotation combine through the outlet pipe. The effect of water purification in this case significantly exceeds the results achieved on analog installations. Consider the schemes of processes in the flotation combain of the above type.

Let's denote the concentration of contaminants in water in the form of C, where part of the contaminants that have hydrophobic properties is C1, and the other part in the form of C2 is hydrophilic pollution.

Herewith

$$C = C1 + C2$$

Let the flotation extraction process proceed according to the following scheme:

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C \xrightarrow{k_3} X$$

For initial conditions: t = 0, C1A = a0, C1B = C1C = C1X = 0.

Kinetic equations are:

$$\frac{dC_A^1}{dt} = -k_1 C_A^1$$

$$\frac{dC_B^1}{dt} = k_1 C_A^1 - k_2 C_B^1$$

$$\frac{dC_C^1}{dt} = k_2 C_B^1 - k_3 C_C^1$$

$$\frac{dC_X^1}{dt} = -k_3 C_C^1$$

Constants k1... k3 is characterized by the rates of transition of extracted hydrophobic particles from state A to B, C and X to obtain condensed flotation sludge.

Decision:

$$C_A^1 = a_0 e^{(-k_1 t)}$$

$$C_B = \frac{a_0 k_1}{k_2 - k_1}\left[e^{(-k_1 t)} - e^{(-k_2 t)}\right]$$

$$C_C^1 = k_1 k_2 a_0 \left(\frac{e^{(-k_1 t)}}{k_3 - k_1} + \frac{e^{(-k_2 t)}}{(k_2 - k_1)(k_2 - k_3)} + \frac{e^{(-k_3 t)}}{(k_3 - k_1)(k_3 - k_2)}\right)$$

$$C_X^1 = a_0 \left(1 - \frac{k_2 k_3 e^{(-k_1 t)}}{(k_2 - k_1)(k_3 - k_1)} - \frac{k_1 k_3 e^{(-k_2 t)}}{(k_2 - k_1)(k_2 - k_3)} - \frac{k_1 k_2 e^{(-k_3 t)}}{(k_3 - k_1)(k_3 - k_2)}\right)$$

For the accompanying settling process we have:

$$A \xrightarrow{k_4} D \xrightarrow{k_5} Y$$

with initial conditions: t = 0, C2A = b0, C2D = C2Y = 0.

the following kinetic equations can be written:

$$\frac{dC_{\mathrm{A}}^2}{dt} = -k_4 C_A^2$$

$$\frac{dC_D^2}{dt} = k_4 C_A^2 - k_5 C_D^2$$

Here are the constants k4... k5 is characterized by the rates of transition of extracted hydrophilic particles from state A to D and Y to obtain a condensed precipitate.

Decision:

$$C_A^2 = b_0 e^{(-k_4 t)}$$

$$C_D^2 = \frac{k_4 C_A^2}{k_5 - k_4}\left[e^{(-k_4 t)} - e^{(-k_5 t)}\right]$$

At

$$t = t_m = \frac{1}{k_5 - k_4} ln \frac{k_5}{k_4}$$

the concentration of the intermediate product reaches a maximum:

$$C_{Bmax}^2 = b_0 \left(\frac{k_5}{k_4}\right)^{\frac{k_5}{k_4 - k_5}}$$

Concentration of the final product:

$$C_Y^2 = b_0 \left(1 - \frac{k_5}{k_5 - k_4} e^{(-k_4 t)} + \frac{k_4}{k_5 - k_4} e^{(-k_5 t)}\right)$$

Verification of the main indicators in the clarification of wastewater and sediments in the flotation combine

Comparison of theoretical and experimental data indicates the possibility of using the proposed mathematical models in practical calculations. It should be noted that the theoretical data exceed the experimental results. This indicates that some assumptions are simplified and do not take into account individual phenomena, although, apparently, they do not have a significant impact on the efficiency of processes in the flotation combine. The order of such a discrepancy does not significantly affect the calculations of the main overall dimensions of the flotation combine.

12. Examples of choosing methods for processing sediments

12.1. Example of choosing a method for treating copper-containing wastewater sediment

Consider an example of choosing a method for processing wastewater sediment on the example of extracting metal ions from wastewater on the example of their purification from copper ions using ion flotation.

Ionic flotation is a separation method that uses specific properties characteristic of the liquid-gas phase interface to concentrate ions or other charged particles from aqueous solutions. The use of ion flotation to extract metals from dilute solutions is widely known. In the case of flotation of ions and molecules, the concentrations of the extracted component in order of magnitude usually do not exceed 10-4 - 10-3 M, and in the case of flotation of sediment - 10-3 - 10-2 M. At the same time, low concentrations, as well as the colloidal size of the extracted particles, make it impossible to effectively isolate the components by most existing methods. To carry out the process, surface-active ions (collector ions) are introduced into the solution, the charge of which is opposite in sign to the charges of concentrated ions - colligendum ions (from the Latin colligere - to collect). Then a gas 7 is fed into the solution from below through the porous partition 3, forming air bubbles 4 (Fig. 12.1). At the same time, there is a sharp increase in the phase separation surface. The bubbles adsorb the surfactant along with the oppositely charged ions of the extracted substance of the component and then form a foam 5 on the surface of the solution. Here, the bubbles are destroyed, resulting in the formation of foam 6 (a slightly soluble, hydrophobic solid product floating on the surface of the liquid), containing these ions in a concentrated form - sublate (from the Latin sublatum - raised).

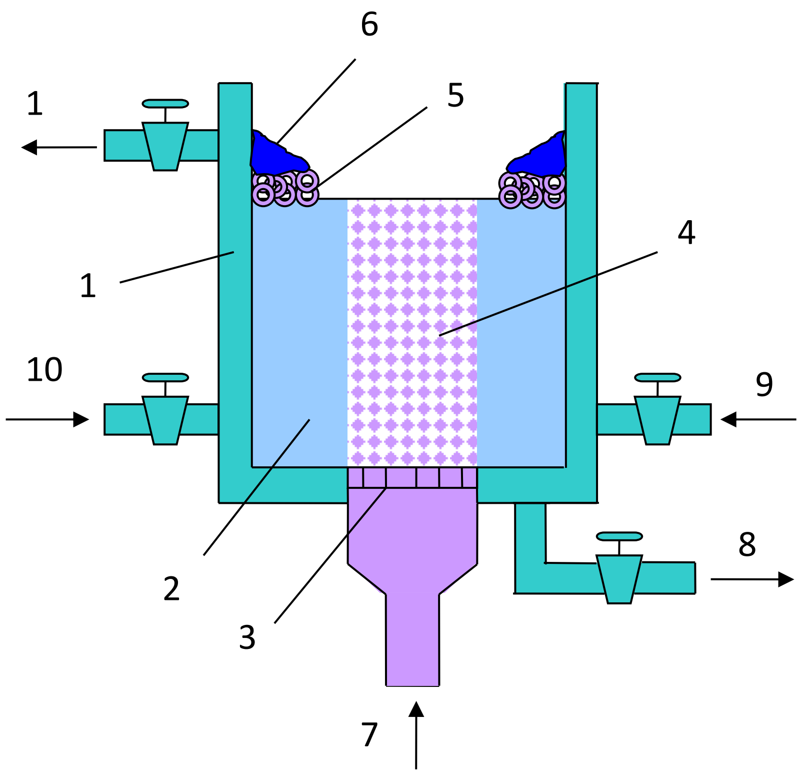


Fig. 12.1 - Scheme of the ion flotation chamber

1 – tank; 2 – initial solution; 3 – porous septum;

4 – gas bubbles; 5 – foam; 6 – sublate; 7 – input of compressed gas;

8 – removal of the purified solution through the discharge valve;

9 – collector's lead; 10 – supply of the initial solution;

11 - removal of the captured sublate.

This physicochemical process is based on the interaction of the extracted ion (colligend), the surfactant (collector) and the gas bubble in the liquid solution. The most important role in this is played by the collector.

Collectors create or increase the ability of particles to concentrate on the surface of the bubbles. In most cases, these are highly surface-active organic compounds of polar-apolar (diphilic) structure (Fig. 12.2).

With its polar group, the collector electrostatically attracts the colligendum to the surface of the bubbles or forms a coordination or any other surface-active compound with it. The nonpolar group is a hydrophobic agent and usually includes one or more hydrocarbon radicals.

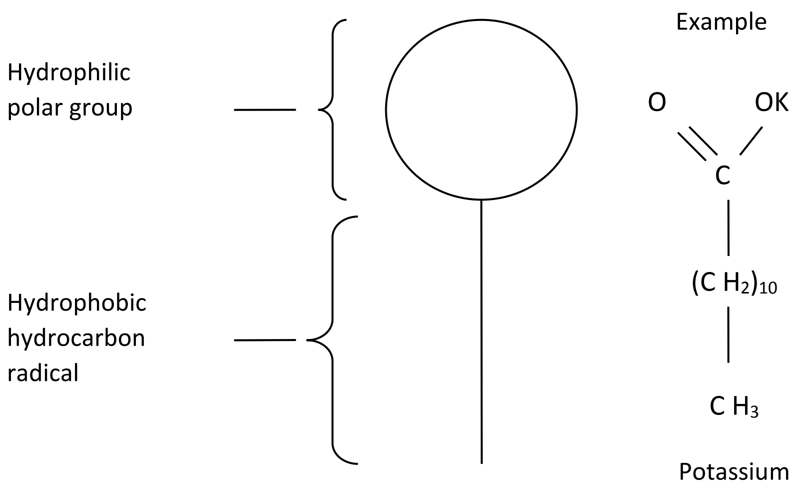


Fig. 12.2 - Diphilic structure of the collector molecule

Various schemes of wastewater treatment systems from heavy metals are proposed in the literature. At the same time, the possibility of processing the foam product according to the scheme in Fig. 12.3.

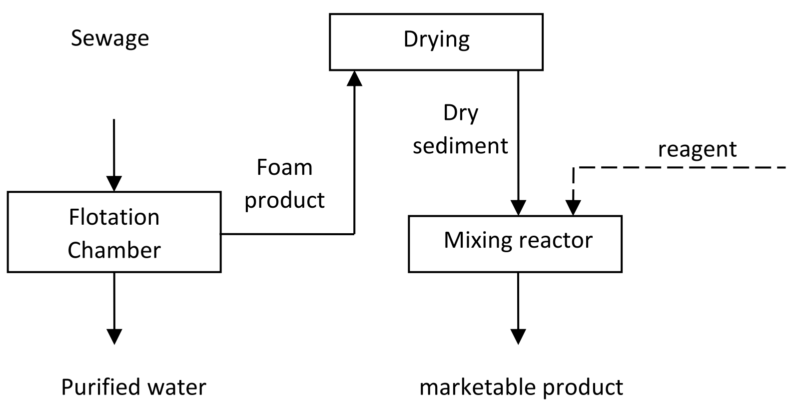


Fig. 12.3. Scheme of processing of foam product of ion flotation

Processing of sediments with the production of marketable products allows you to reduce costs and even make the scheme self-sustaining.

Justification of the choice of wastewater treatment method and description of the technological scheme

In general, the analysis of a particular technology is a multi-criteria task. Let's list the main criteria:

1. Cleaning efficiency
2. duration of the cleaning process
3. Energy consumption
4. resource intensity (including reagents)
5. cost
6. simplicity of construction (in production and operation)
7. quantity and hazard class of waste
8. possibility of recycling and reuse of waste
9. work safety

Having qualitatively considered some of these criteria, it can be concluded that the technology of ion flotation is preferable.

The amount of reagents required for ion flotation is determined by the amount of contaminants extracted, which means that in our case it will not be large. At the same time, the cost of collectors is approximately comparable to the cost of ion exchange resins, but somewhat lower than the cost of membranes for ultrafiltration.

An important advantage of ion flotation in comparison with the methods of ion exchange and ultrafiltration is the absence of the need for preliminary purification from oils, surfactants and other organic substances, as well as fine purification from suspended substances. Moreover, ion flotation is a universal way to remove both heavy metal ions and the substances listed above.

All these methods to some extent allow the regeneration of working components, but with ion flotation it is possible to obtain a regenerated collector that is superior in flotation properties to the original reagent.

From the point of view of the costs of disposal and disposal of waste, the chosen method seems to be more cost-effective. The fact is that ultrafiltration and ion exchange give hazardous waste, while ion flotation produces foam products that are almost completely processed into marketable products. In this case, in some cases, the scheme can become self-supporting.

Finally, comparing the costs of electricity, we can say that ion flotation does not require more electricity than ion exchange and even more so ultrafiltration.

Thus, for the wastewater treatment case specified in the initial data, we choose ion flotation as the best available technology. The proposed scheme of wastewater treatment of the Mednogorsk Copper-Sulfur Plant is shown in Fig. 54.

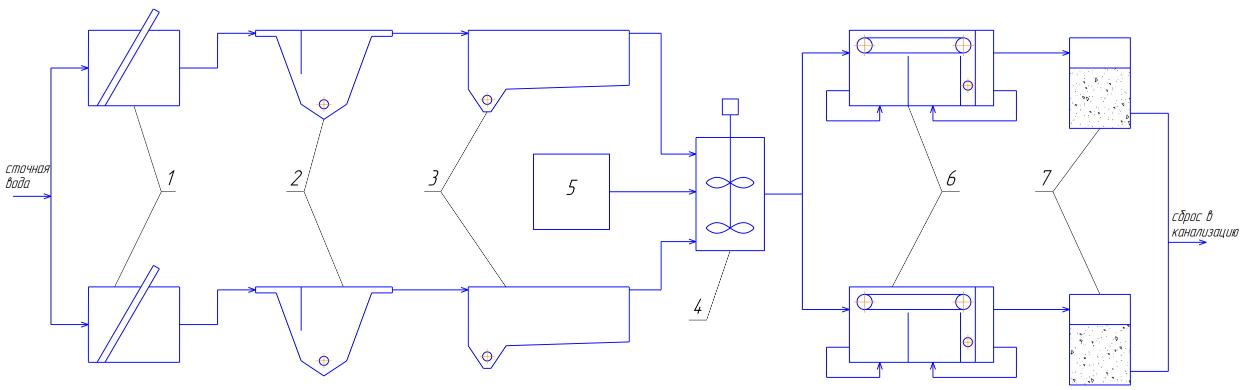


Fig. 12.4. Schematic diagram of treatment facilities

1 – grilles; 2 – sand traps; 3 – settling tanks; 4 – mixing reactor;

5 – tank with reagent; 6 – flotators; 7 – filters (clinoptilolite.)

According to the diagram presented in Fig. 12.4, the wastewater is first subjected to mechanical purification on standar equipment: grates, sand traps and settling tanks. Then the water enters the mixing reactor, where in turn a reagent is added (EMKO collector). The resulting suspension enters the flotators, where deep cleaning of heavy metals takes place. At the final stage, the effluents on the filter are refilled with a load of clinoptilolite to remove the residues of suspended substances and heavy metals in order to achieve water quality requirements for its discharge into the city sewer.

When wastewater is treated by ion flotation, so-called foam products are formed. At the same time, the composition of these substances can be quite diverse depending on the reagents used and the pollutants extracted.

For the subsequent use of extracted substances (for example, non-ferrous metals), it is necessary to process foam products. Since ion flotation has the property of selectivity, the most valuable individual substances can be obtained from foam products with appropriate processing.

In some cases, the processing of foam products allows you to regenerate the reagents used. The fact is that some reagents (mainly surfactants) are quite expensive, so to reduce costs it seems advisable to regenerate them for reuse.

In addition, as a result of the processing of foam products, it is possible to obtain commercial products. This allows you to reduce the cost of wastewater treatment, and sometimes even make the treatment system self-sustaining.

Finally, the processing of foam products helps to reduce the amount of waste generated, and therefore leads to a reduction in the cost of their transportation and burial.

Thus, the processing of foam products is a very important aspect in the treatment of wastewater by ion flotation.

Two groups of methods of processing foam products are fundamentally possible. The first is based on the destruction of surfactants, the second ensures their regeneration.

The simplest method of surfactant destruction is oxidative roasting of the foam product. During the firing of metal-containing sublates, surfactants are destroyed to water vapor, carbon oxides, nitrogen, etc., and the metal passes into the burn, usually in the form of oxide.

Methods of processing foam products that allow the regeneration of surfactants are based, as a rule, on the use of aqueous solutions of alkalis, acids or salts

, or on the use of organic solvents. The separation of colligendum and surfactant is carried out by transferring them to different phases: the formation of hardly soluble or gaseous compounds, the use of ion exchange or liquid extraction.

Finally, quite promising from an economic point of view is the direction of processing foam products with the production of marketable products. It can be produced both separately and entered into the processing system by the methods listed above. The literature proposes several different schemes for wastewater treatment with the production of marketable products in the processing of foam products. For example, in the hydrometallurgical processing of foam products of mine water purification from copper and zinc, it is proposed to obtain commercial copper and zinc sulfates. At the same time, the regeneration of the collector occurs.

The EMCO carboxyl collector is used as a flotation reagent. It is known that metal soaps of carboxylic acids have numerous applications - as paint components, lubricants and so on. As a result of flotation cleaning, we obtain:

1. foam product of the simplified formula nMe(OH)2·Me(OH)(RCOO), (where n=4-16, and RCOO- is an anion of carboxylic acids contained in the EMCO flotation agent).

The scheme involves the conversion of these compounds into medium soaps (RCOO)2Me, which are highly soluble in a toluene-nefras mixture (1:1).

The process of obtaining soap proceeds in accordance with the following equation:

$$n \cdot Me(OH)_2 \cdot Me(OH)(RCOO) + 3n \cdot RCOOH \xleftrightarrow{t} 2n \cdot Me(RCOO)_2 + 3n \cdot H_2O$$

The foam product must be pre-dried. If wet sediment is used, then the water cannot be separated from the organic layer (a stable water-oil emulsion is formed). The resulting organic 10-15% solution of medium heavy metal soaps can be used as a commercial product, for example, as siccatives or in compositions for coatings on wood and metals, and the presence of Compounds Cu(II), Zn gives the coatings antiseptic properties.

According to the scheme, water enters the mixing chamber, where the collector is added - a 2% aqueous solution of EMKO in the ratio [ΣMe]:[RCOONa] = 16:1. The optimal temperature of the solution is 20 - 23 ° C. After 2-3 minutes of stay in the chamber, the solution is sent to the flotator to separate the foam of the general formula nMe (OH) 2 ·Me (OH) (RCOO) for 15 minutes due to the released tiny bubbles of dissolved air.

The foam is collected in a collection and then goes to drying. The estimated amount of dried nMe(OH)2·Me(OH)(RCOO) precipitates is fed through a loading funnel to the displacement reactor with a 15% solution of cubic residue of synthetic fatty acid production in a toluene-nephras mixture (1:1). The suspension is heated to 60 ◦ C, the solid phase is dissolved, stirring for 30-40 minutes, and the 10-15% solution of metal soaps is packed.

At the same time, wastewater was treated to the requirements of the MPC and COD for discharge into the city collector, the residual content of Fe (III), Cu, Zn, Ni, Cr (III) was from 0.34 to 0.02 mg / l. The feasibility of obtaining metal soaps and their use for protective coatings was confirmed.

Thus, the processing of foam products of ion flotation is an important problem in the treatment of wastewater by this method. A qualified application of a foam product can reduce the cost of cleaning costs and even make the scheme cost-effective. In the process of water purification according to the developed scheme, a so-called foam product is formed in the flotator, which must be buried. As an alternative, it is proposed to completely process this waste into marketable products (Fig.

12.5). To justify the implementation of this technological solution, it is necessary to assess its economic efficiency.

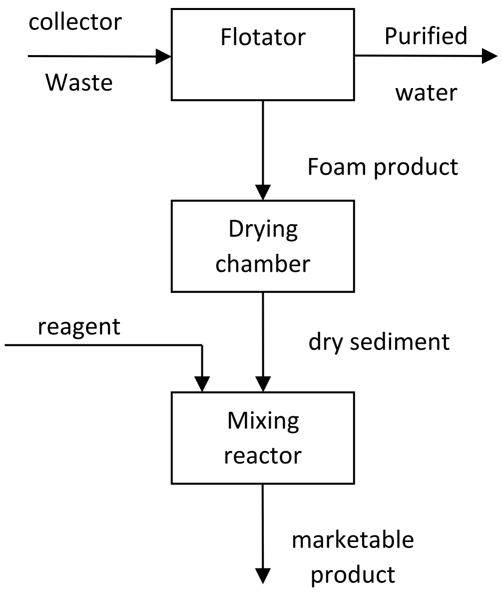


Fig. 12.5. Scheme of processing of foam product

To assess the cost-effectiveness of the proposed measures, it is necessary to determine the following values:

1. Capital (K) and operating (C) costs for the water treatment and waste treatment system.
2. Revenue from the sale of a marketable product and the cost of burying a foam product (prevented expenses) – income (D).

There are typical types of operating costs:

1. costs of materials and components used in the operation of the facility;
2. salaries of service personnel, including repairmen;
3. the cost of fuel and energy consumed;
4. depreciation deductions.

According to the assessment of the distribution of costs in similar industries, we will adopt the following ratios between the existing items of operating expenses:

1. reagents – 50 %
2. salary – 5 %
3. electricity – 30 %
4. depreciation deductions – 15 %

Since the greatest contribution to operating costs is made by reagents, we will determine the number and price of reagents used.

To implement the process of ion flotation, an EMCO collector TU 84-07509103.454-96 is added to wastewater. The price of this substance on the Russian market varies from 100 to 150 rubles / kg.

The reagent added to the mixing reactor is a 15% cube residue (CW) solution produced by synthetic fatty acids (FFAs) in a nephras-toluene mixture (1:1).

KO (TU 38-1071231-89) is a multi-tonnage petrochemical waste. As a result of research on the proposals of this substance on the market, several manufacturers were found: OJSC LUKOIL-VOLGOGRADNEFTEPERERABOTKA, JSC BASHNEFTEKHIMZAVODY, NP OJSC SINTEZPAV, JSC SIBNEFT-OMSK OIL REFINERY, LLC POLYMERELAST, etc. The price of KO according to various sources ranges from 15 to 25 rubles / kg.

Coal toluene shale according to GOST 9880-76 is produced by various enterprises. Prices for it vary from 32 to 50 rubles / kg [Electronic resource. (http://www.pulscen.ru).

Petroleum solvent (nephras) C4-155/200 (TU 35.1011026-85) is better known as white spirit is produced by various manufacturers and is sold at a price of 36 to 55 rubles / kg [Electronic resource. (http://www.pulscen.ru) .

Exact prices depend on the volume of the order, the type of packaging, the availability of demand in the market and other factors. Let's calculate the arithmetic means of prices for the reagents used. According to the specified concentration of pollutants and the adopted technology of wastewater treatment, we will estimate the amount of the required reagent per 1 m3 of treated effluents. The results of the calculation will be summarized in Table. 12.1.

Table 12.1. Costs of reagents*.

Reagents	Price, rub./kg	Flow rate per 1 m3 of wastewater	
		kg/m3	rub./m3
1) EMCO Collector TU 84-07509103.454-96 (in terms of dry residue)	125	0,002	0,25
2) 15% SOLUTION of KO in a mixture of nephras-toluene (1:1)	-	0,415	16,49
TEL: +381 11 38 107 1231-89	20,0	0,063	1,26
coal toluene shale GOST 9880-76	41,0	0,176	7,22
nefras S4-15 5/200 TU 35.1011026-85	45,5	0,176	8,01

TOTAL	16,74

*Prices are given to illustrate approximate calculations.

Thus, for the purification of 1 m3 of wastewater and the processing of the resulting sediments, we spend 0.415 kg of reagent and 0.002 kg of the collector, which costs 16.74 rubles.

Given that the cost of reagents is equal to half of all costs, we calculate the operating costs for processing a foam product from 1 m3 of wastewater, which will be: St = 16.74/0.5 = 33.5 rubles / m3.

The capacity of flotators is 24 m3/h = 576 m3/day. Let's calculate the amount of operating costs per year:

N = 576*365*33.5 = RUB 7.04 million/year

Capital costs in this case consist of the costs of designing treatment facilities, construction and installation works, including engineering support for treatment facilities, in particular the supply of additional electricity, water supply, household sewerage, ventilation, etc., as well as the purchase, installation and installation of equipment, namely: a drying chamber and a mixing reactor.

A review of the market of the required equipment with the necessary technical characteristics was carried out. As a result, it turned out that the prices for drying chambers vary from 300 thousand to 400 thousand rubles Prices for mixing reactors range from 300 thousand to 360 thousand rubles. [Electronic resource. (http://www.pulscen.ru) Let's take the arithmetic mean of the prices found and sum them up. To take into account the costs of delivery and installation of equipment in capital costs, we will introduce a coefficient of 1.2. Then the cost of equipment will be:

So = 1,2 (350 + 330) = 816 000 RUB

According to the approximate estimates, the cost of designing treatment facilities can be approximately Sproject = 10 million rubles.

The remaining components of capital expenditures were estimated based on the experience of building similar production facilities and can be roughly taken as equal to Cost = 10 million rubles.

Then the total capital costs for wastewater treatment in the flotator and waste processing are:

K = 0.816 + 10 +10 = 20.8 million rubles

As a result of the implementation of the process of processing the foam product, an organic 10-15% solution of medium soaps of non-ferrous metals is obtained. A review of the literature suggests that this substance is used, for example, in the paint and varnish industry: in compositions for coatings on wood and metals, as well as as siccatives. At the same time, the resulting substance has a number of important advantages, for example, the presence of copper and zinc in it gives the coatings antiseptic properties, coatings based on it are suitable for protecting metals from corrosion. These and other advantages make the product competitive in the market.

Analysis of prices on the market of siccatives, similar to the one obtained, showed that prices vary from 85 to 100 rubles / kg [Electronic resource. (http://www.pulscen.ru) To ensure competitive advantages for our product, we will accept a price equal to 80 rubles / kg, which is lower than the minimum prices for similar products. This, together with the high quality of the goods, should help ensure stable demand for this product.

To determine the revenue received, it is necessary to estimate the volume of production of goods, i.e. in our case, the yield of the final product of processing of 10-15% of the solution of metal soaps. According to the given concentration of metals in wastewater and taking into account the technology of purification and processing, the amount of the resulting substance is 0.422 kg per 1 m3 of wastewater. The capacity of the cleaning station is 24 m3 / h = 576 m3 / day, so the production volumes will be:

$$M = 576*0.422 = 243 \text{ kg/day}$$

Let's calculate the proceeds from the sale of goods at the price agreed above. The results of the calculation will be summarized in Table 2.

Table 12.2. Proceeds from the sale of goods*.

Time period (or volume of effluents)	Revenue, RUB
per 1 m3	33,8
in time	810
per day	19.4K
per year	7,10 mln.

*The data obtained are illustrative in nature

Modern sediment treatment technology includes the stages of compaction, stabilization, air conditioning, dewatering and disposal. The main directions of sediment disposal are: burial in special landfills, incineration, use as a fertilizer. However, in Russia, neither the burning nor the use of salt wastewater sludge in agriculture has found wide application. More than 90% of the resulting sediment is removed and stored in specially designated areas - dumps.

There are very few data on the cost of sediment disposal in the literature. According to some authors, for an average single enterprise, the cost of exporting and storing sediment is 15 - 90 thousand rubles / day. In general, the cost of treatment and removal of sediments reaches up to 50% of the cost of wastewater treatment. At the same time, the specific value depends on the amount of sediment formed, as well as on the prices of the enterprise engaged in the removal of sediment, to which the corresponding agreement was signed.

Since the foam product is only a part of all the sediments formed at the treatment plant, the cost of its burial is less than the cost of burying all the sediments. In this regard, for the calculations, we will take the minimum value from the above range, i.e. Soth = 15 thousand rubles / day. Since the enterprise in question works around the clock and seven days a week, the cost of exporting and burying the foam product per year will amount to 5.48 million rubles / year.

Calculation of the economic efficiency of the proposed event

First, let's determine the income from the proposed event. To do this, you need to add the calculated above (Table. 12.2) revenue from the sale of finished products with prevented costs for the removal and disposal of sediments Soth: A = 7.1 + 5.48 = 12.6 million rubles / year

Let's calculate the desired economic efficiency of the processing process in comparison with the traditional export and burial of the foam product:

A1 = 12.6 – 7.04/20.8 = 0.267 1/year

Let's determine the payback period for the costsof the proposed event according to the formula:

$$Q = 1/0.267 = 3.74 \text{ years}$$

Thus, the costs of the foam product processing system will pay off quite quickly, which means that this measure is economically feasible.

12.2. Example of treatment of sludge of grease-containing wastewater

The task is to design a wastewater treatment system and the treatment of the resulting sediments of meat processingplants with a capacity of 2 m3 / h.

The existing treatment system does not ensure the achievement of permissible concentrations for the discharge of industrial wastewater into the sewerage system of Moscow in accordance with the Resolution of 29.07.2013 No. 644 ''On Approval of the Rules of Cold Water Supply and Sanitation and on Amendments to Certain Acts of the Government of the Russian Federation'' (electronic resource http://www.consultant.ru).

Table 12.3. Characteristics of wastewater of a meat processing enterprise

Substance	Concentration in source water, mg/l	Concentration in purified water, mg/l	MPC, mg/l
Suspended solids	2000	1000	300
Fats	1000	50	50

Purification of grease-containing wastewater occurs in a flotation combine, and the extracted fats are removed in the form of a foam product, and suspended substances in the form of a sludge.

Consider the problem of disposal of sludge formed after wastewater treatment.

We will determine by calculation the volume of draught per hour - 0.03 m3 / h.

Then the volume of sediment formed per day is 0.72 m3:

Unloading of sediment from the flotilla combine is carried out once a day.

To dewater the sludge in the cleaning system, a bag vacuum filter UVO-0.8 is installed, which is presented in Fig. 12.6.

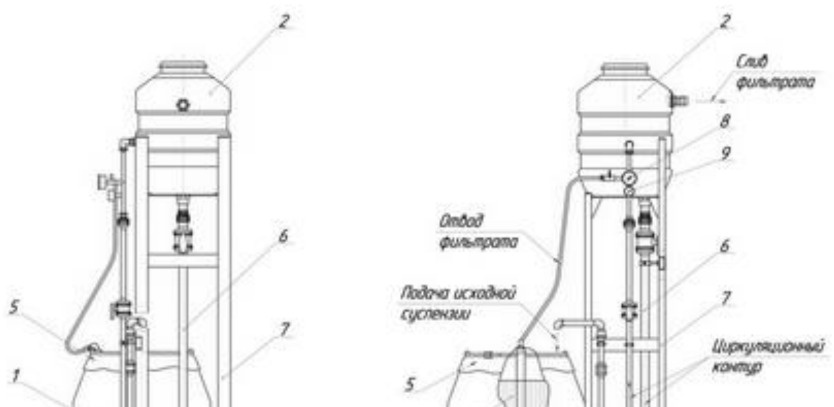


Fig. 12.6. Bag vacuum filter

1 – receiving capacity; 2 – circulation tank; 3 – pump; 4 – filter element; 5 – recycling bag; 6 – pipeline and shut-off valves; 7 –frame; 8,9 – KIP.

During the three-hour operating cycle, the installation allows to obtain a precipitate with a dry matter content of 20-40% (humidity of about 80%).

The advantages of the bag vacuum filter include:

- ease of operation and versatility of use;
- a large specific surface area of filtration due to the folded fabric of the filter element;
- relatively low wear of the fabric filter element, the possibility of its repeated regeneration and problem-free replacement;
- the possibility of excluding the sediment tank between the pump and the filter from the system (as is customary in installations with a nutch filter), since the removed liquid enters directly into the circulation circuit of the vacuum station;
- relatively low price compared to devices performing similar functions

The characteristics of the selected bag vacuum filter UVO-0.8 are presented in Table. 12.4.

Table 12.4. Characteristics of the bag vacuum filter UVO-0,8

Параметр / Тип установки	**Ед-ца**	**УВО-0,1**	**УВО-0,2**	**УВО-0,4**	**УВО-0,**
Объём загрузки исходной суспензии на рабочий цикл, не более	л	90	190	380	760
Продолжительность рабочего цикла, средняя	ч	2,5	3	3	3
Кол-во осадка вл.75% за рабочий цикл (исх. суспензия гидроокись металлов вл.99%)	кг	≈3,5	≈7,5	≈15	≈30
Площадь фильтрации	$м^2$	0,6	0,6	1,2	2,4
Рабочая температура, не более	°C	35	35	35	35
Потребляемая мощность, не более	кВт	0,6	0,6	1,2	2,4

The sludge dewatering unit is a container with a vacuum chamber in which a fabric filter element is installed. The chamber is equipped with a system for supplying and selecting clarified liquid. When the pump is turned on in the chamber, a vacuum is created and the filtration process begins, during which the liquid is sucked through the filter discharge rod and, seeping through the filter fabric, is removed from the system. At the same time, suspended particles settle on the surface of the filter element, their volume fraction in the initial mixture increases, and the total volume of the mixture decreases. After filtration, the filtration process is completed by sludge of the filtered precipitate (pressing phase), during which the liquid residues are displaced from the pore space of the filtered precipitate (cake). Removal of the cake from the surface of the filter fabric is carried out by shaking the filter element. The cake is spontaneously dropped to the bottom of the chamber and removed from it along with the recycling bag.

Thus, according to the manufacturer, with a 3-hour dehydration cycle in an installation with a bag vacuum filter, the sediment humidity will be approximately 80%.

According to the calculation, the volume of dehydrated sediment per day amounted to 0.096 m3.

Then the mass of dehydrated sediment per day is 143.5 kg.

The sludge, pre-compacted and dehydrated on a bag vacuum filter, is handed over for disposal to a specialized one for disposal or elimination.

12.3. Disposal of foam product

The flotation combain works in two modes: in the mode of foam accumulation and in the mode of foam removal, so foam removal occurs periodically 1-2 times a day. Working in the foam accumulation mode allows you to get a foam product with less humidity.

The mass of isolated fats per day - 45.6 kg:

The volume of foam product per day will be 0.45 m3:

Removal of the foam product occurs 1-2 times a day. To dewater the sludge in the cleaning system, it is proposed to use a frame press filter FP-400/16. http://filter.vladbmt.ru/index.php/latt0001.html.

Selection of filter press:

The volume of dry matter per shift will be 45 dm3 / shift.

The volume of dehydrated sediment with a humidity of 70% per shift is 150 dm3/ shift

$$V = 45*100/(100 – 70) = 150 \text{ дм3/смена}$$

Thus, the estimated volume of dehydrated sludge with a humidity of 70% is 150 dm3 / shift (day). The standard working shift is 8 hours a day. The optimal time of one filter cycle is 2 hours (1 hour of suspension supply to the filter press, 40 minutes of disassembly and unloading of the filter press, 20 minutes of filter press collection) and, thus, 4 filter-cycles occur per shift. Then the estimated volume of dehydrated sludge with a humidity of 70% per cycle will be:

$$V_ч = 150/4 = 37.5 \text{ дм3}$$

According to the calculated value of the capacity of the filter press from Table. 12.5 with the technical characteristics of frame filter presses, we choose FP-400/16 with a capacity of 42 dm3.

Table. 12.5 Technical characteristics filter - press type FP – 400/16

Filter Press Model	Capacity, dm3	Filter surface, m2	Occupied area, m2
FP-400/11	29	2,4	1
FP-400/16	42	3,5	1
FP-400/21	54	4,6	1,5

During the two-hour working cycle, the installation allows you to get a foam product with a dry matter content of 20-30% (humidity 70-80%).

Advantages of frame filter presses in comparison with other installations for dewatering of sediments and sludge:

1) Low humidity of dehydrated sediment, not less than 75%, and with subsequent drying in the sediment collector to 60-65%;

2) Large filtration area relative to the area occupied by the equipment and the possibility of increasing the productivity of the equipment due to the modularity of its performance;

3) Possibility of full automation of the sediment dewatering process;

4) High corrosion wear resistance of structural materials of filter equipment;

5) Has a high degree of phase separation and the ability to filter any suspensions

6) Provides the possibility of performing the procedure of washing and drying the sediment directly on the filter press;

7) The service life of the equipment is up to 50 years when replacing the filter polypropylene fabric every 1-2 years.

Schematic diagram of the frame press filter is presented in Fig. 12.7.

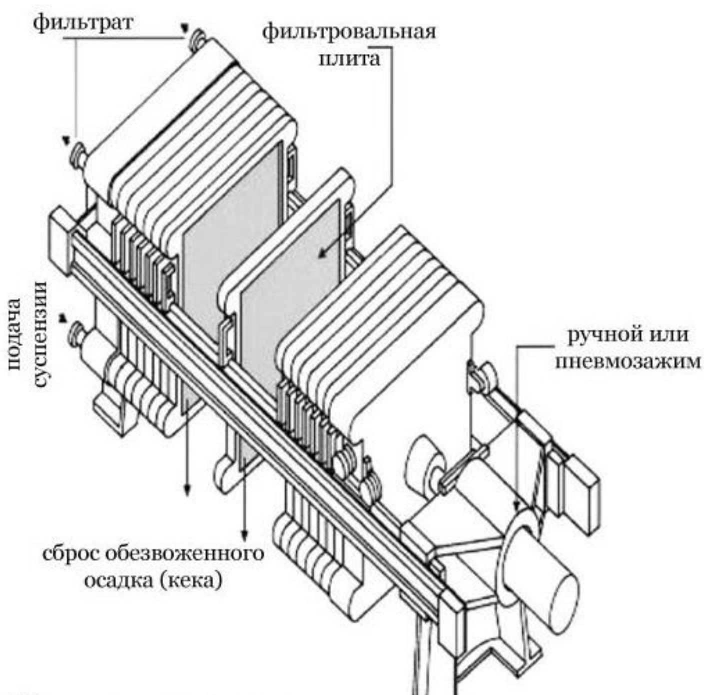


Fig. 12.7. Schematic diagram of frame filter

The principle of operation of filter presses of this type is as follows. The duty cycle of the frame press filter can be divided into separate stages:

1) Compression of the plate package (closure of the device)

2) Creation of pressure by the supply pump and supply of suspension to the filtration chambers (until the filter chambers are completely filled and the sediment is partially humidified);

3) Implementation of the procedure of pressing the sediment;

4) Sediment washing;

5) Performing additional pressing of the kek;

6) Drying of the sludge by supplying compressed gas or hot steam;

7) Disconnection of plates (opening of the filter), distribution of the cake;

8) Washing of filter blades under high pressure (automatic or manual regeneration)

The precipitate accumulated as a result of the operation of the filter press is removed by gravity created after the separation of the filter plates and the release of the filtration chambers.

The volume of dehydrated sludge per day agreedupon calculation will be: V = 0.15 m3, and massa of dewateredsediment per day - 147.2 kg.

The foam product, pre-compacted and dehydrated on a frame press filter, is handed over for disposal to a specialized organization.

12.4. Problems of sludge recycling

The problem of sediment treatment and disposal over the past decades is very relevant, and there are no universal ways to solve problems in this direction. As before, multi-tonnage waste is disposed of to a small extent, and their bulk is stored in landfills. In this regard, new technical solutions are extremely relevant for practical technologies for the treatment and disposal of various wastes, including oil sludge.

One of the most modern methods of treatment and disposal of sludge, for example, petrochemical industries, is their preliminary separation in a centrifuge of the OGSH type (settling horizontal screw) into a solid phase, oil and water (Figures 12.8-12.9).

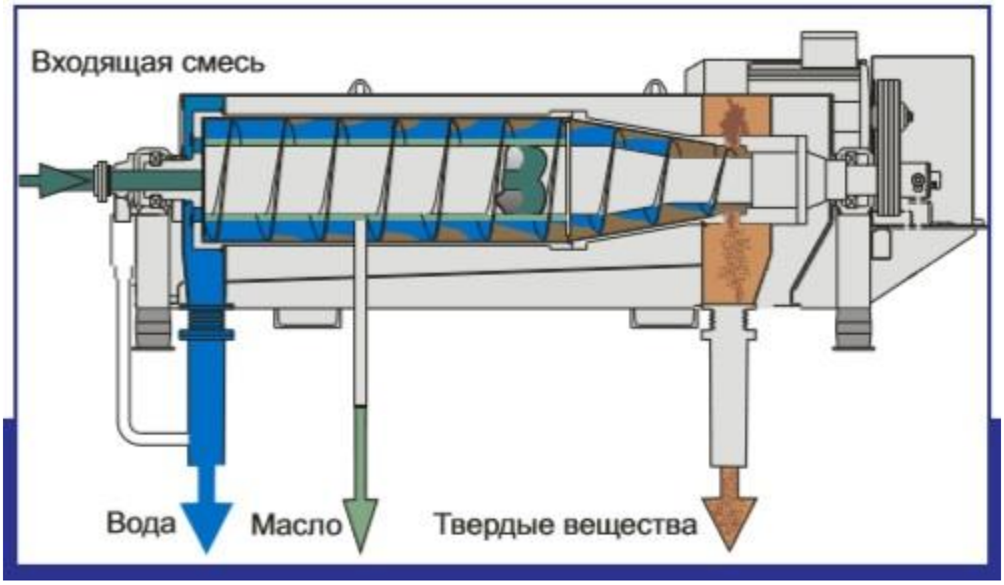
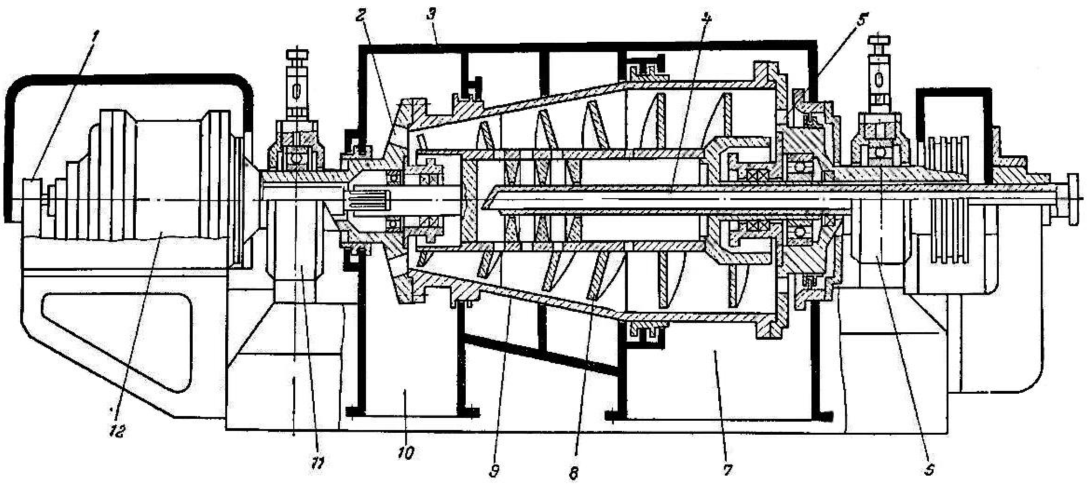


Fig. 12.8. Schematic diagram of separation of inhomogeneous systems in a centrifuge

In this case, the separation in the centrifuge can be carried out both with the addition of demulsifiers and without them, as well as with pre-heating of sludges. These methods of processing sludges contribute to a more effective separation of them into fractions.



1 - gearbox protective device; 2 – sludge discharge windows; 3 - casing; 4 - supply pipe; 5 - drain windows; 6, 11 - centrifuge supports; 7 -

fugate outlet fitting; 8 – screw; 9 – rotor; 10 - sludge discharge fitting; 12 - planetary gearbox

Fig. 12.9. OGSH type centrifuge

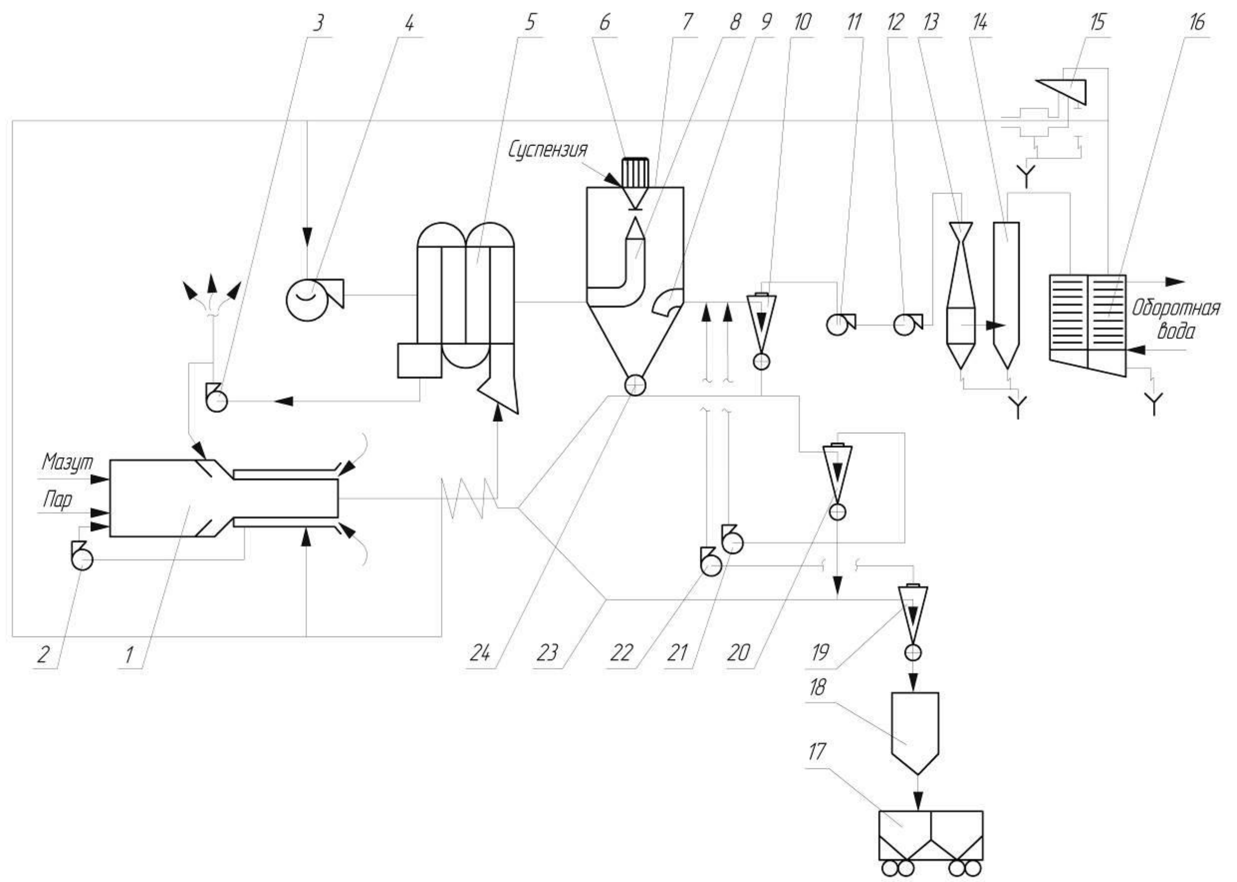
After the separation, for example, of oil sludge, three fractions are obtained in the centrifugal field. The first fraction has the following composition: oil - 98%, water - 1%, solid phase - 1%. This fraction, after centrifugation, can be re-directed to centrifugation and then to the refinery at the cracking stage as a secondary raw material.

The second fraction consists of about 98% water and it is sent to biological treatment plants or pumped into wells.

The third fraction, consisting of 60% liquid phase and 40% solid phase, can be used in road construction as an additive in the creation of asphalt pavements. At the same time, for the last fraction, the conditions for its use should be separately determined in each case.

Sludge disposal sometimes requires deep dewatering of the sludge using drying. In this case, it is better to use drying with a closed circuit for the coolant to exclude the ingress of toxic substances of sludge into the environment. The latter is extremely important, as many sludge treatment plants dry or burn sludge without such a neutralization system.

In Fig. 12.10 shown a schematic diagram of the drying process with a 100% closed cycle on the coolant. The installation includes a coolant preparation unit 1 (drying agent heater), a drying chamber 2 containing a spray mechanism 3 supplying 4 and 5 removing the gas ducts of the drying agent, a device for unloading the finished product including a cyclone 6 to bring the finished product from a small to a large circuit of the pneumatic transport system, a system for cleaning the spent drying agent in the form of a group of cyclones 7, a venturi scrubber 8 with a dropletlem 9, a condenser 10, a unit 11 for the post-treatment of the spent coolant, a dual-circuit system for pneumatic transport 12 of the finished product to the silo tower 13, a separation device in the form of a D-pad 14 (the D-pad scheme is shown in Figure 12.11, and the condenser is shown in Figure 12.12), a gas duct 15 for returning the drying agent to the heater and the coolant preparation unit (flue gases).



1, 5 - coolant preparation unit; 2, 3, 11, 12, 21, 22 - fan; 4 – gas duct for returning the drying agent to the heater and the coolant preparation unit; 6 - spraying mechanism; 7 - drying chamber; 8 – gas supply duct of drying agent; 9 – exhaust gas duct of the drying agent; 10 – group of cyclones; 13 – Venturi scrubber; 14 - drop separator; 15 – unit of after-treatment of the spent coolant; 16 - capacitor; 17 – product collection; 18 – silo tower; 20 – unloading cyclone; 23 – double-circuit pneumatic transport system of the finished product; 24 – separation device in the form of a D-pad

Fig. 12.10. Schematic diagram of the drying process with a 100% closed cycle for the coolant

The installation works as follows:

The dried suspension is fed by means of a spray mechanism 3 to the drying chamber 2, where the suspension sprayed to the smallest particles is dehydrated for a short period of time. The dried product enters the silo tower 13 via the unloading cyclone 6 and the dual-circuit pneumatic transport system 12. The spent drying agent with a temperature of 100-120 ° C through the exhaust gas duct 5 is cleaned in the group of cyclones 7 and in the venturi scrubber 8 with a drop separator 9. Further, the spent drying agent with a temperature of 65-85 ° C passes through the condenser 10, where its temperature is reduced to 45-55 ° C due to contact with the pipes arranged in a staggered manner through which the coolant circulates (Figure 12.12- 12.13).

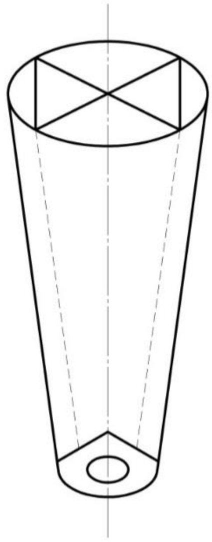


Fig. 12.11 – Type of D-pad

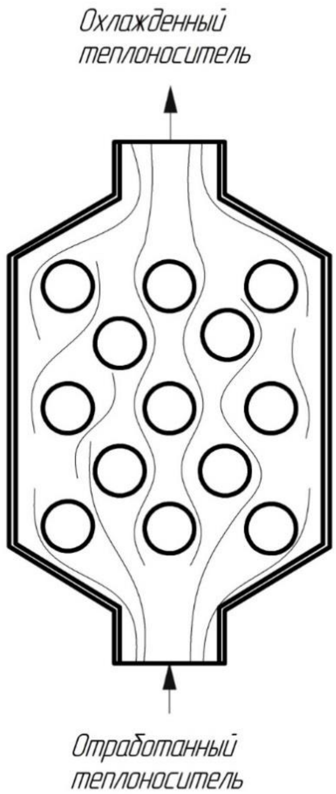


Fig. 12.12 – Capacitor diagram

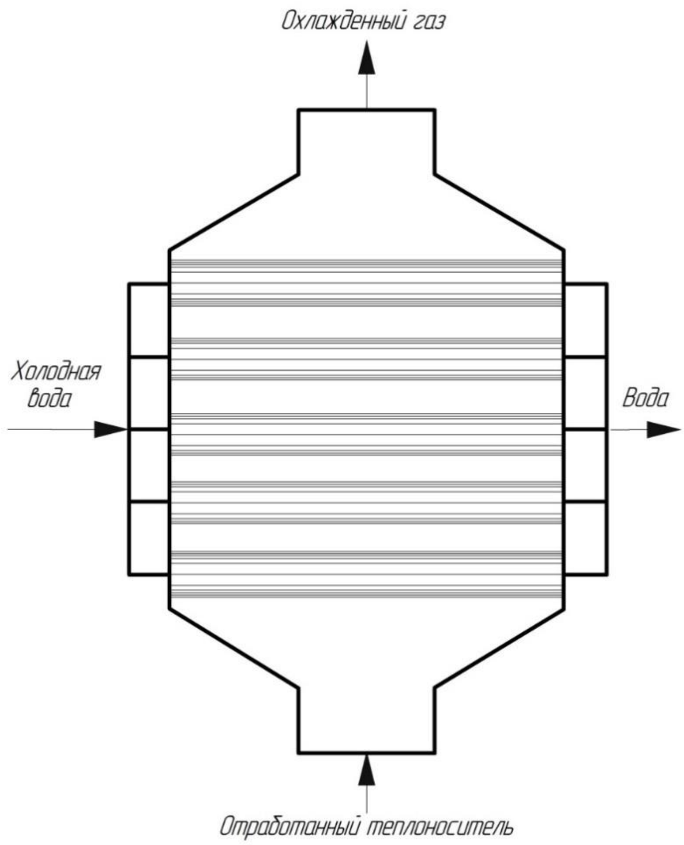


Fig. 12.13. Scheme of gas and water flows in the condenser

By reducing the temperature of the drying agent (in the condenser 10), partial condensation of the moisture contained therein occurs, which is removed from the condenser in liquid form. Further, the spent drying agent with a temperature of 45-55 °C, having passed the unit of post-treatment of the spent coolant, enters the drying agent heater through the gas duct 15. In part of it in the dual-circuit system of pneumatic transport of the product and then in the silo tower 13. At the same time, the spent coolant is completely (100%) reused without emission into the atmosphere. The use of a condenser 10, a unit 11 for post-treatment of the spent coolant allows to achieve a high degree of purification of the spent coolant, which makes it possible to carry out its 100% return to the drying stage.

As a result of the drying process with a 100% closed circuit in the device, a product with a humidity of not more than 10% is obtained. At the same time, the drying process is environmentally friendly, without releasing gas into the atmosphere, and moisture from the waste coolant is removed in liquid form.

The presented drying scheme guarantees the exclusion of particularly hazardous substances of sludge into the environment, which is very important especially when drying liquid sludge containing toxic substances.

Sludge of activated sludge belongs to hard-to-thicken systems, which is explained by the weak water transfer of activated sludge biomass, as well as the presence of a large number of abrasive impurities. In our opinion, in the absence of these impurities and the use of fresh biomass of activated sludge, the thickening of activated sludge can be carried out similarly to the thickening of most suspensions.

We experimentally investigated the process of thickening of the sludge sludge after secondary settling tanks in type A, B and C centrifuges, selected optimal parameters, centrifugation and thermoagent treatment modes.

To assess the effectiveness of the thermoagent treatment of activated sludge, tests were carried out on a laboratory cup centrifuge of type A. The test results are given in Table. 12.6 and 12.7.

Table 12.6. Dependence of the efficiency of separation of the sludge of activated sludge on the centrifugation mode

Centrifugation	Biomass concentration, % DIA (absolutely dry matter)

Number of revolutions, min-1	Duration of separation, min	In the original suspension	In sediment	In clarified liquid
1500	3	0.62	1.50	0.44
2000	3	0.62	1.76	0.38
2500	3	0.62	1.98	0
3000	3	0.62	2.47	0.25
3500	3	0.62	2.66	0.21
1500	6	0.62	2.14	0.30
2000	6	0.62	3.30	0.24
2500	6	0.62	3.97	0.16
3000	6	0.62	4.86	0.15
3500	6	0.62	4.90	0.15

Table 12.7 Effect of pretreatment of activated sludge sludge on centrifugation efficiency (at n = 3500 min-1, τ = 6 min)

Preprocessing			Biomass concentration, % ADM		
Concentration of reagents, % (wt)		Heat treatment temperature, °C	In the original suspension	In sediment	In clarified liquid
Iron sulfate	Export				
0.5	-	22	7.6	5.10	0.12
0.8	-	22	7.6	5.14	0.12
0.8	0.5	22	7.6	6.70	0.10
0.8	1.0	22	7.6	6.93	0.10
0.8	1.0	40	7.6	6.96	0.11
0.8	1.0	50	7.6	6.94	0.12
0.8	1.0	60	7.6	7.10	0.14
0.8	1.0	70	7.6	7.30	0.18
0.8	1.0	80	7.6	7.60	0.19

Given in Table. 12.6 and 12.7 data indicate the efficiency of pre-reactive treatment at a predetermined optimal mode of centrifugation of activated sludge.

In addition, in order to study the thickening of activated sludge after secondary settling tanks, tests of industrial centrifuges of type B and C were carried out.

In a straight-flow, sedimentation, screw centrifuge of type B, at the interface of the cylindrical and conical parts of the rotor shell, two diametrically opposite holes are made for installing replaceable nozzles through which the sediment is discharged. On the screw body there is a control disk, which in the process of operation of the centrifuge rotates synchronously with the screw and at certain intervals overlaps the discharge holes. The duration and frequency of opening the discharge holes for the sludge are regulated by changing the difference in the rotation speeds of the screw and the rotor.

In a countercurrent, sedimentation, screw centrifuge of type C, the rotor speed is regulated by a current frequency converter. This allows, with a constant gear ratio, to smoothly and quickly set the desired speed of its rotation in a fairly wide range. The speed difference between the screw and the rotor can be changed without stopping the machine by means of a stepless hydraulic system, which is very convenient when working with suspensions with unstable properties. The gap between the screw and the rotor walls is not more than 1 mm, i.e. there is practically no sublayer of non-removable sediment.

The suspension is fed into the rotor at the beginning of its cylindrical part. Under the action of centrifugal forces, the heavy phase is moved by the auger to the periphery along the forming rotor in the direction of the discharge holes, gradually dehydrated and compacted. Upon reaching the discharge holes, sediment is ejected from the rotor. The fugate moves in the same direction as the sludge, but at a smaller radius, enters special channels made in the body of the auger, and is diverted along them to the drain windows. Directness contributes to a higher quality of clarification, especially for finely dispersed easily digestible suspensions, and also allows you to reduce consumption or completely abandon the use of flocculants.

The test results of type B and C centrifuges are presented in Table. 12.8 and 12.9.

Table 12.8. Experimental data on the thickening of activated sludge on a type B centrifuge

Conditions	Experience					
	1	2	3	4	5	6
Flocculant consumption, l/h	300	200	100	200	300	300
Dose of flocculant:						
g/m3	60	40	20	20	27.3	23.1
kg/t SV	5.5	3.6	2.0	1.8	2.57	2.2
Suspension flow rate, m3/h	5	5	5	10	11	13
Initial suspension concentration, % ADM	1.09	1.11	1.00	1.11	1.06	1.06
Content, % ADM:						
solid phase in concentrate	5.53	5.7	5.24	9.3	10.08	10.2

solid phase in fugate	-	0.16	-	0.2	-	0.3
soluble substances in suspension	-	-	-	-	-	-
soluble substances in fugate	-	-	-	-	-	-

Table 12.9. Experimental data on the thickening of activated sludge on a type C centrifuge

Conditions	Experience			
	1	2	3	4
Flocculant consumption, l/h	400	400	800	600
Dose of flocculant:				
g/m3	40	50	100	120
kg/t SV	4.0	4.42	8.47	10.43
Suspension flow rate, m3/h	10	8	8	5
Initial suspension concentration, % ADM	1.00	1.13	1.18	1.15
Content, % ADM:				
solid phase in concentrate	9.78	11.41	11.91	10.92
solid phase in fugate	-	-	-	-
soluble substances in suspension	-	-	-	-
soluble substances in fugate	-	-	-	-

In experiments 1 – 6 on a type B centrifuge with thickening of activated sludge after secondary settling tanks with a concentration of 1.0 – 1.1% ADM, the precipitate was discharged through one nozzle with a diameter of 5 mm. Suspension capacity was from 5 to 13 m3 / h. The solid phase content in the microbial biomass concentrate at a load of 10-13 m3 / h was 9-10% ADM. With maximum performance, one nozzle with a diameter of 6 mm was used. The minimum specific dosage of flocculant is about 2 kg per 1 ton of dry product. When the centrifuge was underloaded on suspension (5 m3/h), the amount of ADM in the concentrate did not exceed 5.5%.

In experiments 1 – 4 on a type C centrifuge with the same initial suspension, a similar thickening was obtained only at a flocculant dosage of 4-10 kg per 1 ton of dry product. The clarification of the fugate was worse, the productivity was 5-10 m3 / h.

In general, the efficiency of pre-reactive treatment with a predetermined optimal mode of centrifugation of activated sludge should be noted.

At the same time, deep dewatering of various sludges, including activated sludge, can be carried out by using a drying method developed and tested in industrial conditions, which guarantees the exclusion of especially hazardous substances of sludge into the environment, which is very important especially when drying particularly toxic sludges.

12.5. Disposal of wastewater sediment in the small settlements

It is known thatmost of the settlements of the Russian Federation are small towns and settlements with a population of up to 50 thousand people (88.4%) at the treatment facilities of which up to 30% of sediment is formed. The problem of processing and utilization of which is no less acute than in large industrially developed cities.

At the Department of Ecology and Nature Management of the Nizhny Novgorod State University of Architecture and Civil Engineering (NNGASU) Gubanov L.N. and Kotov A.V. a technology has been developed that makes it possible to neutralize wastewater sediment from settlements with amino acid reagents according to various schemes, including: only disinfection, only detoxification, as well as joint disinfection and detoxification

According to the developers, the small settlements (SST), being at a great distance from large cities, as a rule, have little effective, morally and technically obsolete systems for wastewater treatment (NE) and sediment treatment. The sediments of neb formed at these treatment facilities, in composition, nature of pollution and bacterial contamination, differ significantly from the sediments of industrial cities.

To solve this problem, the possibility and expediency of solving an important ecological and economic problem - the utilization of environmentally hazardous wastewater sediment of the MNE by processing them into a soil-improving composition using amino acid reagents obtained from wastewater sediment - was theoretically substantiated and experimentally confirmed.

The above developersalso propose a fundamentally new environmentally safe integrated technology for the neutralization and utilization of wastewater sludge of MNP with amino acid compositions, which makes it possible to use treated sediments as a soil-improving organomineral composition.

It should be noted that more than 30% of all sediments of domestic wastewater of the Russian Federation are formed at the State Waste Of the MNP. They are waste of III-IV hazard class and pose a real threat to human and animal health, as well as the state of the environment. SALT MNP, despite the proximity in composition to the wastewater sediment of large industrial centers, differ significantly from them: greater bacterial contamination (1.2-1.5 times); small volume; SALT MNP are less toxic, and also contain more nutrients and protein (by 10-20%). Therefore, the most promising method of utilization is their use as an organomineral soil-improving composition in agriculture.

Tosolve this problem, according to the author, it is advisable to use simpler technologies for the disposal of wastewater sediment. For example, composting wastewater sediment with local waste. Since the Russian Federation is a leading peat power, it is advisable to use this type of natural raw material for composting with wastewater sediment in combination with other local waste. At the same time, bioheating occurs due to the vital activity of microorganisms to temperatures at which the death of helminth eggs occurs. The resulting compost should be evaluated by the local sanitary service before use, which will avoid unforeseen negative phenomena in the cultivation of crops using such composts.

12.6. Complex installations for dewatering of wastewater sediment for small settlements

A long-term analysis of the work of wastewater sludge dewatering shops, according to the author, shows that in some cases it is possible to use complex installations for the dewatering of wastewater sediment. As an example, consider some types of dehydration plants both without and with thermal dewatering using drying of sediments.

Installation for mechanical dewatering of sediments

The installation for mechanical dewatering of sediments includes (Figure 12.14) a settling chamber 1 connected to the screw dehydrator 2, with the further supply of the pre-condensed sludge to the belt filter 3 and then the supply of the dehydrated sludge to the collector 4 and the tractor trolley 5. Figure 12.14 presents a schematic diagram of the machinesand for mechanical dewatering of sediments.

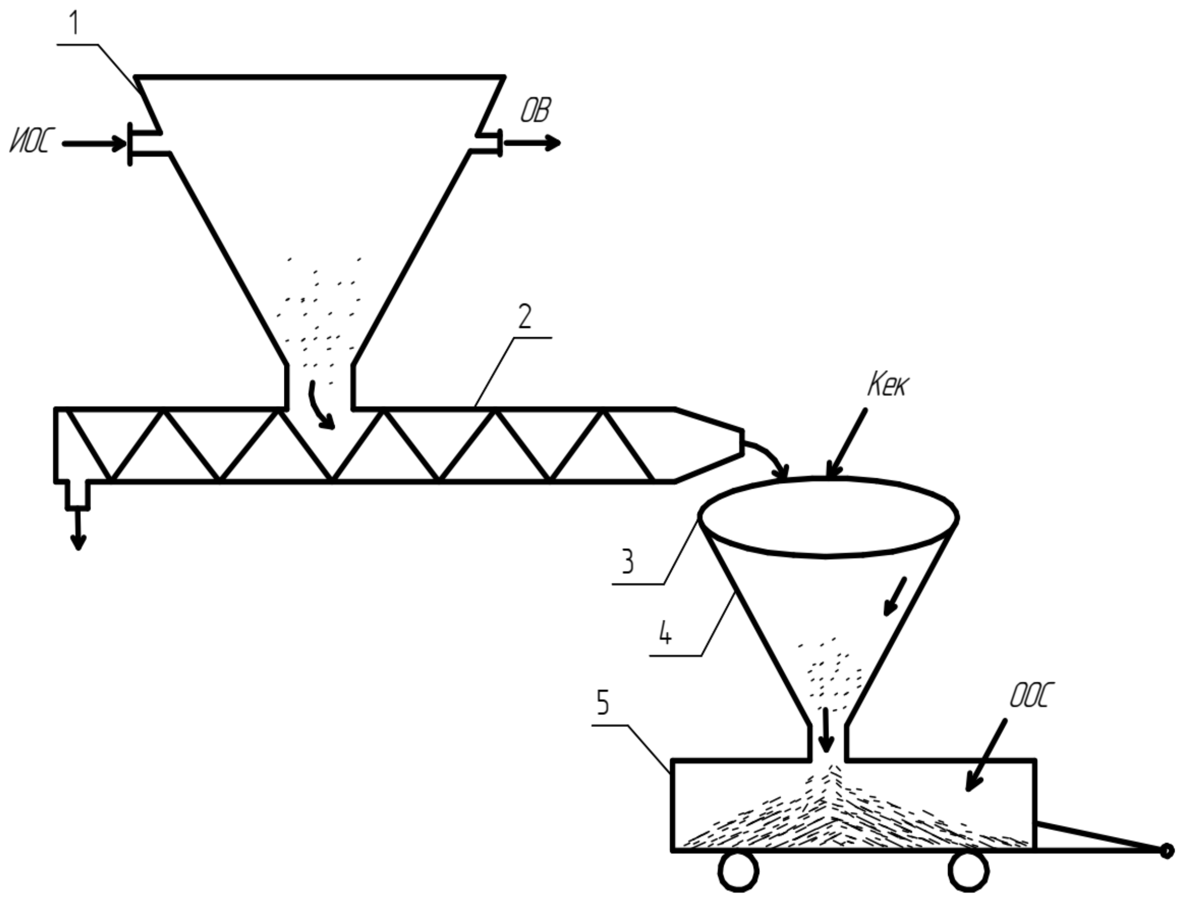


Fig. 12.14. Installation for mechanical dewatering of sediments

The principle of operation atthe machinesand for mechanical dewatering of sediments includes the supply of the initial sludge (IS) to the settling chamber 1, from which clarified water (CW) is separately removed. Further, the pre-condensed sediment is fed into the screw dehydrator 2, in which the precipitate thickens to a humidity of 80-85% and then the precipitate is further condensed on a belt filter 3 to a cake with a residual humidity of about 70-75%. Next, the dehydrated sediment (DHS) is collected in a conical collection 4 and it then enters the body of the tractor trolley 5, by which it is transported to the site of recycling or disposal of the sediment.

Wastewater sediment dewatering plant using drying

In practice, complex installations are sometimes used with the use of drying to dehydrate wastewater sediment with their subsequent disposal.

In Fig. 12.15 presents a schematic diagram of a plant for dewatering wastewater sediment using drying.

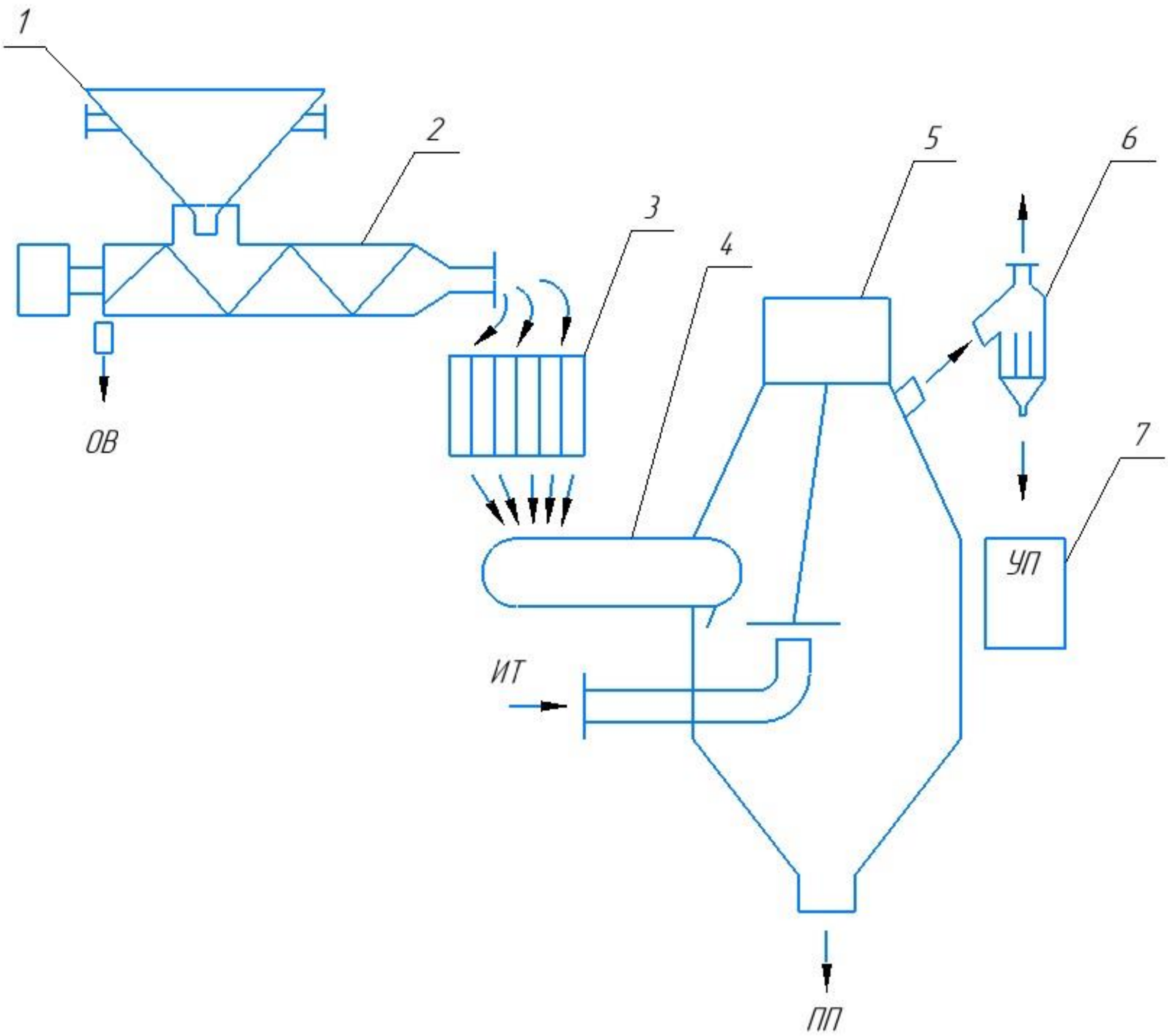


Fig. 12.15 Schematic diagram of a wastewater sediment dewatering plant using drying:

The proposed installation for wastewater sediment dewatering includes (figure 12.15) a settling chamber 1, a screw thickener 2, a distribution chamber 3, a belt filter 4, a dryer chamber 5, a cyclone battery 6, a pulverized product collection 7.

The principle of operation of the plant for dewatering wastewater sediment is as follows. The initial suspension sludge from the settling chamber 1 enters the screw thickener 2 and further through the distribution chamber 3 to the belt filter 4 and then to the drying chamber 5, in which the parent coolant (IT) heats the condensed product and then the dried industrial product (IP) is discharged with a humidity of 10-15%. When dehydrated in a screw thickener, clarified water (CW) is excreted through a special branch pipe.

The exhaust gases are discharged from the drying chamber through the cyclone battery 6 and the captured product (CP) is collected in col. 7.

The option of dewatering sediments using drying is advisable to use when the sediment is disposed of

13. Application

Annex 1. Examples of calculations of apparatus, equipment and structures

Recommendations for the use of sludge pads

The most common are sludge pads on a natural base of the cascade type with sedimentation and surface removal of sludge water. After filling the sludge pad maps with sediment and draining with separated sludge water, further dewatering of the sludge is carried out by evaporation of the remaining moisture from the surface.

An improved version of the cascade type sites are sealing platforms. Sludge compaction pads are rectangular reinforced concrete tanks (maps) with holes located in the longitudinal wall at different depths and overlapped with gates. For the release of sludge water released during sedimentation, holes are arranged along the height of the longitudinal walls of the tank maps, overlapping with gates. Sludge water is sent for purification to the head of structures by analogy with sludge pads with sedimentation and surface removal of water. The distance between the releases of sludge water is set to no more than 18 m. For mechanized cleaning of dried sediment, ramps with a slope of up to 12% are arranged.

One possible method to accelerate the natural drying of sediment at sludge sites is the irrigation process. At the same time, the vegetation cover is removed and the surface crust is destroyed, which contributes to the accelerated drying of the sediment in the warm dry time and deeper freezing in the winter.

A characteristic feature of the sites of the natural cycle is their complete dependence on climatic factors. When designing and operating such sites, it is especially necessary to take into account these factors to obtain the desired result - dehydrated sediment of a certain humidity.

Sludge sites for intensive dewatering and drying can be divided into traditional and advanced. The first category includes sludge pads with vertical and horizontal drainage, the second - sites with the creation of a vacuum in the drainage system, an artificial waterproof coating with air purging, heating.

Cascade-type sludge platforms with a natural base and surface drainage of water through monk wells installed at the ends of the maps are transitional sludge pads. The walls of the monk wells on the side of the cards are drainage walls of double reinforcing mesh with a gravel load of 15-20 mm.

Sludge sites with artificial drainage are designed to obtain pure filtrate and increase the rate of dehydration.

Filtration through a horizontal drainage system can be carried out by filter panels with special holes or drainage pipes.

For the reconstruction of existing sites, a drainage system containing vertical filter elements and pipes for the drainage of sludge water can be used. Such a drainage system is carried out in the form of sectional pipes distributed over the surface of the site and a common one, having seats with mesh bottoms in which vertical filter elements are installed.

A common pipe is connected to a pipe to drain sludge water.

Filter-glass plastic pipes can be used as filter elements of drainage systems. Such filter pipes are used for the arrangement of wells. The design of the horizontal drainage system consists of a filter-glass plastic pipe. The vertical filter element is made of a similar pipe, but of a larger diameter, covered with filter material. It is connected to horizontal drainage pipelines by means of steel tees and flange joints.

Visual observations of the operation of the drainage system at various types of loading showed that a layer with high filtration resistance is formed at the sediment-drainage loading boundary.

It is noted that in the initial period, the specific filtration rates through the vertical drainage system are higher than through the horizontal drainage system, then they are equalized. At the final stage of drying, only horizontal drainage works. When re-pouring sediment on an already dried layer, the filtration rate is significantly reduced.

The study of the composition and properties of urban wastewater sediments, conducted by I.S. Turovsky, showed that the load on sludge sites largely depends on the type and water recovery of the sludge. Analysis of the operating data of a number of treatment plants showed that there is a certain relationship between the values of sludge resistivity and the operation of sludge sites. Thus, at the aeration station of Kaliningrad (Moscow region), with the humidity of the fermented mixture of 94.8% and its specific resistance of 25800-1010 cm / g, the load on 1 m2 of sludge sites was 0.35 m3 per year. The drainage quickly colmatized, and the pads worked only to evaporate the liquid.

Colmatation of the base occurs the faster the worse the sediments are filtered, which is due to the high content of finely dispersed and colloidal particles in them. The layer of one-time sludge overlay on sludge pads can be the larger the lower the value of the specific resistance of the sludge. With large values of the resistivity of the sediment, the main moisture is removed by evaporation.

To intensify the drying process of the sludge, it is proposed to blow it with air directly on the site.

The sludge pad contains a waterproof bottom, side walls, drainage loading, perforated pipes placed on the bottom, air duct and pipelines of washing and filtered water. Blowing with air is carried out to the required degree of dehydration.

Abroad, sludge pads are often protected from sediment by a glass coating. Such a coating can significantly improve the operation of sites, especially in cold and humid climates. Experience has shown that in some cases the coating device can reduce the area required for drying sediment by 33%.

Asphalt sludge platforms with central drainage and heating are used in Dunedin (USA, Florida). These sites are of interest due to the use of a heating system on them. The thermal energy obtained by burning the biogas of sewage treatment plants is used to heat the water that circulates in pipes located in the asphalted part of the sites. Sludge pads are heated but not closed. Polyelectrolytes are used for sediment conditioning. The drying time of the sediment is on average 5 days and increases to 12 days during the rainy season. The annual load on sludge sites for dry matter ranges from 87.9 to 209.9 kg / (m2.year).

Conditioning the sludge before dewatering the sludge at the sludge sites significantly reduces the duration of the dewatering process and improves the indicators of the dried sludge. The method of conditioning the sludge with organic flocculants before feeding it to sludge sites is currently widely used in Germany. The humidity of the fermented sediments of one of the stations after dehydration at the sludge sites, respectively, was: after 2 days 76 and 87%, after 5 days 73 and 86%, after 10 days 72 and 83%, after 15 days 71 and 80%, after 20-25 days about 70-77%). Under normal atmospheric conditions (FRG), the conditioned sediment is dried on sludge sites after 3-4 weeks to a humidity of about 75% > and can be removed without difficulty by mechanisms. Due to the coagulation of colloids and the smallest particles, the phenomenon of drainage sludgeation is reduced. Dehydrated sediment has a "permeable hydrophobic structure" and even in rain does not absorb water, its humidity does not increase.

Studies of the use of domestic flocculants to intensify the operation of sludge sites were carried out on a fermented mixture of sediments and aerobic-stabilized active sludge on laboratory models and in pilot industrial conditions on a sludge site measuring 600 m2, equipped with vertical and horizontal drainage systems made of fiberglass filters. The best results were obtained using flocculant brands KNF and K-100. At the same time, the moisture content of the sediment of 78-81% was achieved about twice as fast as when drying the sediment untreated with flocculants. The specific productivity of the site during dewatering of sludge treated with flocculants was 4.5-6 m3 / (m2-year). Drainage loading consisted of a layer of sand 50-150 mm with fraction sizes of 1-3 mm and 3 layers of crushed stone with fraction sizes from top to bottom 5-3 mm, 10-5 mm, 15-10 mm. Studies have shown that the load on sludge sites when drying stabilized activated sludge and fermented sediment for the conditions of the central strip of Russia is 4.5 and 5 m3 / (m2-year), respectively.

To intensify the operation of sludge sites, in addition to treatment with flocculants, it is possible to carry out preliminary washing of difficult-to-profile sediments with purified wastewater, coagulation of sediments with chemical reagents, as well as freezing and subsequent thawing of sediments. All these types of treatment reduce the specific resistance of sediment filtration. Preliminary washing of the sludge allows to increase the load on the sludge sites by 70%, and the use of chemical reagents or filler materials when drying the sediments contributes to an increase in the load on the sludge sites by 2-3 times. The resistivity of aerobically stabilized sediment is significantly lower than that of fermented sediment. In sludge sites on an artificial basis with drainage and surface water drainage at an average annual air temperature of 3-6 ° C and an average annual amount of atmospheric sediment up to 500 mm after aerobic stabilizers, according to the Research Institute of VODGEO, the load is 3-5 m3 / (m2 years) with a humidity of the incoming sediment of 96.5-97%. In this case, the drainage area is 8-10% of the site area. The size of the card is taken on the basis of filling it to a working depth of 1-2 m for no more than 3 days. An additional increase in the productivity of the sludge site can be achieved by subjecting the aerobically stabilized wastewater sediment to ammonium nitrate treatment, in an amount of 100-150 mg / L. Ammonium nitrate is injected into the aerobically stabilized precipitate (at the exit from the aerobic stabilizer) and fed to the sludge site. In the filled sludge area, thebiological process of denitrification of the nitrate compound, i.e. ammonium nitrate introduced into the precipitate, descends. The process is spontaneously carried out by denitrifying bacteria that are part of the bacterial flora of the sediment, and is accompanied by intensive nitrogen gas production, which ensures flotation and thickening of sediment particles. The volume of sediment decreases by 5-6 times, its concentration is approximately 50 g / l. Under the compacted layer of sediment is located sludge water containing 6-10 mg/l of suspended solids. After the completion of the process of compaction of the sediment (4-7 hours), the drainage is opened and sludge water is released. The condensed precipitate sinks to the bottom and dries quickly, because it has a good structure due to the presence of a large number of pores formed by gas

bubbles. One cycle of the site from the moment of loading to the unloading of dry sludge is no more than 1 month. The load reaches 8-10 m3/m2 per year with a depth of 1.0-1.5 m.

Principles of calculation of sludge sites. The method of calculating sludge sites was developed in the twenties by Imhoff and has existed almost unchanged to this day. The calculation is based on the load Kf> m3 / (m2 years), which establishes the permissible amount of sediment placed on a unit of the surface of the sludge site per year.

The total area of sludge pads should be increased by 20-40% for the installation of enclosing rollers and access roads.

During the period of negative temperatures, the supplied precipitate of the namora is resurfaced. For winter frosting, 80% of the area of sludge sites is allocated, and 20% are intended for placing sediment during the melting period of previously frozen.

Recent studies of the work of sludge sites have shown that the process of dehydration should be considered as complex, consisting of several elementary processes.

The rate of removal of moisture as a result of drying, according to research, depends on the wind speed and the deficit of humidity in the air above the sites.The filtration stage is due to the properties of the sediment and the features of the drainage system, and the decantation rate is due to the ability of the sediment to compact.

Intensification of the work of sludge sites. Increasing the productivity of the sites is possible due to the following activities: – compaction of the sludge fed to the sites; – ensuring mechanical irrigation and removal of dried sediment from the site; – conditioning of the sediment before feeding it to the site; – blowing of sediment with air directly on the site; – devices above the site of a translucent coating or a general coating of the greenhouse type with appropriate ventilation systems; – the use of vacuum systems to speed up filtration; – devices of sludge heating systems directly on sludge sites.

The irrigation process significantly accelerates the natural drying of sediment at sludge sites. The wind speed above the surface of the sediment overgrown with vegetation is almost zero, the elasticity deficit of water vapor is characterized by a decrease from the upper tier of leaves to the lower tier to virtually zero, therefore, the rate of evaporation of water from sediment densely overgrown with vegetation is zero. The formation of a crust on the surface of the precipitate from the overdried sediment reduces the drying rate by 4 times.

During irrigation, the vegetation cover is removed and the surface crust is destroyed, which contributes to the accelerated drying of the sediment in the warm dry time and deeper freezing in the winter.

Dewatering of fermented sediment having a specific filtration resistance of the order of 4000 -1010 cm / g on maps with horizontal drainage has low efficiency. Filtration rates do not exceed 0.48 kg / (m day), which is 1.5 times less than the evaporation rate with a moisture deficit of 6 mbar. The drainage of the site quickly becomes colmatized and ceases to pass the filtrate. The specific resistance of filtration of aerobically stabilized activated activated sludge is 20-100 times less than the specific resistance of filtration of fermented sludge, therefore, for dehydration of aerobically stabilized activated activated sludge, it is rational to use sites with drainage.

Choosing the optimal sediment dewatering technology can significantly increase the productivity of sludge sites. The overlay mode, primarily the height and multiplicity of loading, depend on the type of sediment, its concentration, preparation characteristics and time of year. When supplying stabilized activated sludge to the site with an initial humidity of up to 98%, the filling height should be 0.8-1 m. In this case, a significant amount of drainage water is withdrawn through the vertical drainage system.

The author proposed mixing devices for the intensification of natural dewatering of wastewater sediment at sludge sites, which make it possible to increase the rate of removal of the liquid phase by about 1, 5 - 2 times. While such devices are at the stage of pilot tests, after the end of which the prospects for their use in practice will be determined.

Calculation of radial gravity sludge compactor

To calculate the radial gravity sludge compactor, we will take the recommended characteristics:

1. The smallest diameter of the sludge compactor D= 18 m;
2. The ratio of diameter to working depth 6..7;
3. To remove sediment, seals are equipped with sludge pumps or sludge scrapers;
4. The discharge of compacted sludge is carried out continuously under a hydrostatic head of at least 1 m;
5. Drain water from the seals is sent to the aeration tanks.

Table 13.1. Data for the calculation of gravity sludge compactors

Nature of excess activated sludge	Moisture content of compacted activated sludge in %		Duration of compaction T in h		Fluid velocity in the settling zone of the vertical seal, mm/s
	seal type				
	vertical	radial	vertical	radial	
Sludge mixture from aeration tanks with C = 1.5-3 g/l	-	97,3	-	5 - 8	-
Activated sludge from secondary sedimentation tanks with C - 4 g/l	98	97,3	10 - 12	9-11	not more than 0,1
Activated sludge from the sedimentation zone of aeration tanks-settling tanks with C = 4.5-6.5 g / l	98	97	16	12- 15	See also

We calculate the sludge compactor for the station with aeration tanks for complete biological treatment Q= 24000 m3 / day. BPKful of treated effluents L1 = 15 mg / l; increase in activated sludge in the aeration tank P = 180 mg / l; concentration of excess sludge after secondary settling tanks C = 4 g / l.

Table 13.2. Removal of suspended solids

Settling time in hours in time	Removal of suspended substances in mg / l with BPCP completed purified water in mg/l					
1	15	20	25	50	7	100
1,5	15	20	25	51	7	83
2	12	16	21	45	6	75

The hourly amount of excess activated sludge, taking into account the seasonal unevenness of its growth, is determined by the formula:

$$Q_{ил} = 1{,}3 \cdot \frac{U \cdot Q}{24 \cdot C} = 1{,}3 \cdot \frac{168 \cdot 24000}{24 \cdot 4000} = 182 \text{ m}^3/\text{h} ,$$

Where Q is the daily wastewater flow rate;

C – concentration of excess sludge, C = 4000 g/m3;

U – the amount of excess activated sludge in g/m3, taking into account the removal of sludge from secondary sedimentation tanks according to Table 2 U = 180 – 12 = 168 g/m3.

We take the depth of the compaction zone Hp = 3.1 and the duration of compaction T = 9 hours. Then the calculated hydraulic load on the surface of the seal will be equal to

q 0 = $\frac{H_p}{T} = \frac{3{,}1}{9} = 0{,}34 \text{ m}^3/(\text{m}^3/h).$

Required area of sludge compactors

$$F = \frac{Q_{ил}}{q_o} = \frac{182}{0,34} = 523,5 \text{ m}^2.$$

Take the number of seals n = 2. Then the diameter of the sludge compactors will be equal to

$$D = 1,128 \cdot \sqrt{\frac{F}{n}} = 1,128 \cdot \sqrt{\frac{523,5}{2}} = 18,4\, m.$$

We accept D = 18 m (according to the standard project No. 902-5-10,84). Attitude $\frac{D}{H_p} = \frac{18}{3,1} \approx 6.$

Total height of the sludge compactor

$$H = h_б + H_р + h_{ил} + h_н = 0,3 + 3,1 + 0,5 + 0,3 = 4,2 \text{ m},$$

where is the height of the construction board;$h_б = 0,3 \text{ m}$

$h_{ил} = 0,5 \text{ m}$ – the height of the sludge layer;

$h_н = 0,3 \text{ m}$ is the height of the neutral layer.

Daily amount of excess activated sludge with humidity = 97.3% and volumetric weight $W_{уп}\gamma = 1,005 \text{ т/м}^3$

$$Q_{упл} = \frac{U \cdot Q}{\gamma \cdot 10^6} \cdot \frac{100}{100 - 97,3} = \frac{168 \cdot 24000}{1,005 \cdot 10^6} \cdot \frac{100}{100 - 97,3} = 500 \text{ m}^3/day$$

The radial type sludge seal is presented in Fig. 13.1.

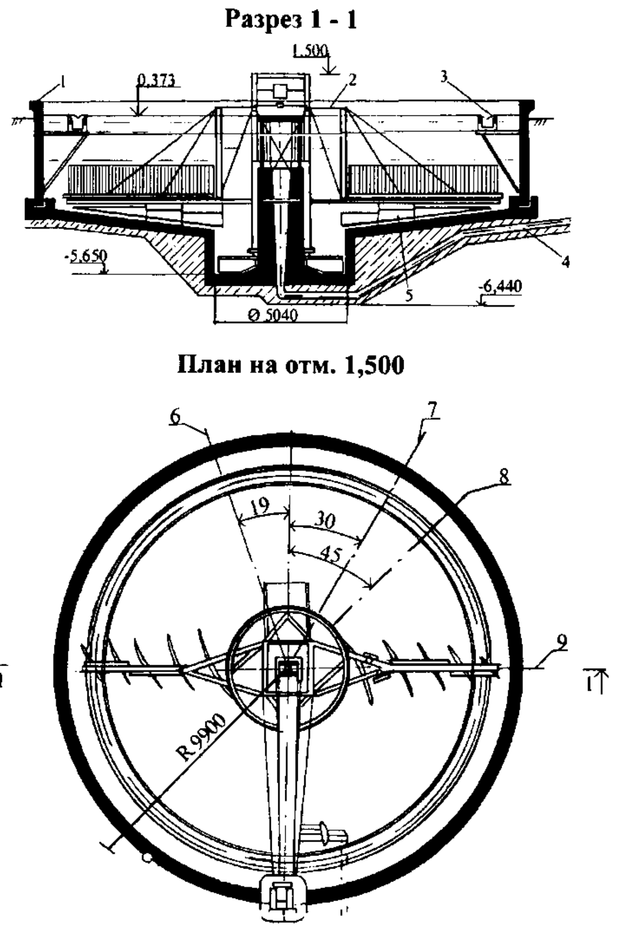


Fig. 13.1. Radial sludge compactor

1 – tank, 2 – sludge scraper, 3 – spillway with filter screen, 4 – supply pipeline, 5 – scraper device, 6 – compacted mixture pipeline, 7 floating substances pipeline, 8 – supply pipeline, 9 – drain water pipeline

Calculation of flotation sludge compactor

1. sludge consumption - 100 cubic meters/ h;
2. initial concentration of activated sludge in the starting suspension - 8 g/l;
3. concentration of activated sludge in condensed suspension (concentrate) - 36 g/l.

Air consumption

The amount of required air in m3/s supplied by the ejector

$$q_{возд} = \frac{Q_{max} \cdot С \cdot а}{1000 \cdot К_В} = \frac{100 \cdot 8 \cdot 3}{1000 \cdot 0,3} = 8$$

Q_{max} – maximum hourly flow rate of sludge, [m3/h],

C is the concentration of activated sludge entering the seal, [kg/m3],

a – the required air content in the ilov-air mixture in l/kg of dry matter of the activated sludge (3-4 l/kg is accepted)

HF – air utilization coefficient (0.2 – 0.3 is taken)

Calculation of the sludge compactor tank

Useful volume of the sludge compactor, m3

$$W = Q_{max} \cdot T = 100 \cdot 2,5 = 250,$$

T - the duration of sludge compaction in h (usually taken is equal to 2.5 hours).

Total depth of the tank in m

H = h + hн + hб = 2+0.3+0.2 = 2.5 м,

where h is the working height (1.5 - 2 m), hn is the height of the neutral layer (0.25 -0.3 m), hb is the height of the board (0.15 - 0.20 m).

Thus, the area of the resulting flotation sludge compactor should be equal to 100 m2. This area is too large for one flotation sludge compactor, let's choose a parallel installation of two sludge compactors.

The ratio of length to width of a flotation sludge compactor is taken to be approximately 3:1.

For one sludge compactor, we assume a length of 12.6 m and a width of 4.2 m.

The volume of the resulting sludge compactor. m3:

$$2{,}5 \cdot 12{,}6 \cdot 4{,}2 = 132{,}3 \geq 125$$

Collection and removal of compacted sludge

Amount of compacted sludge in m3/h

$$q_{\text{у.и.}} = Q_{max} \cdot \frac{100 - p1}{100 - p2} = 100 \cdot \frac{100 - 99{,}2}{100 - 96{,}4} = 22{,}2\ ,$$

p1 and p2 are the moisture content of incoming and compacted sludge.

$$p1 = 99{,}2\%\ ,$$

$$p2 = 96{,}4\%\ ,$$

Collection and removal is carried out by a scraper conveyor, its speed of movement is taken to be 1.2 - 1.8 m / min, the number of scrapers is taken from the condition of their placement by 2.5 - 3 m from each other (in our case 12 pcs.), the depth of their immersion is 7 - 10 cm.

The platform for draining compacted sludge is made with a length of 2.5 - 3 m, with a rise to the collected sludge tray by 0.2 m.

Removal of clarified liquid

Amount of clarified wastewater in m3/h

$$q_{\text{о.в.}} = Q_{max} - q_{\text{у.и.}} = 100 - 22{,}2 = 77{,}8\ ,$$

The clarified liquid is discharged by transverse pipes laid at the bottom of the tank 5-6 m from each other. On top of the pipes have slots with a width of 20-25 mm and a length in the width of the sludge compactor.

A sketch of the resulting sludge compactor with basic dimensions is presented in Fig. 13.2.

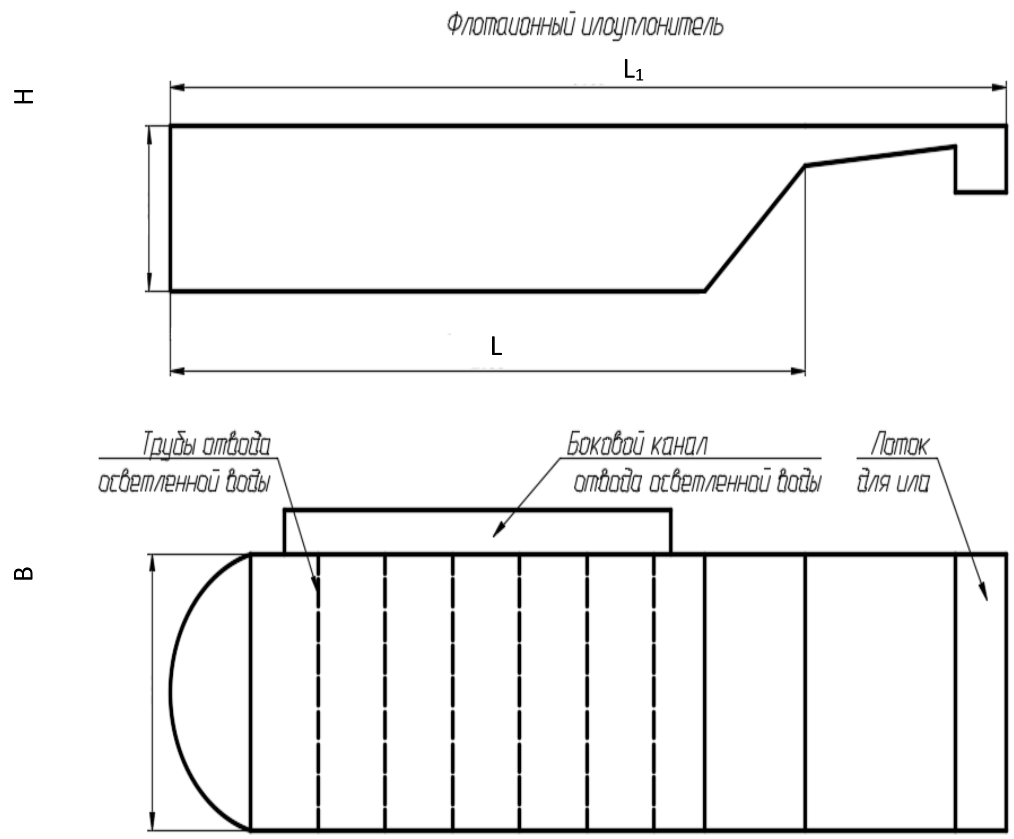


Fig. 13.2. Sketch of a pressure flotation apparatus for activated sludge compaction

Where L=12600 mm is the length of the flotation part, L1=15600 mm is the overall size in length, H=2500 mm is the height of the device, B=4200 mm is the width of the device.

Example of calculating a screw sludge thickener

Given: performance - Q and concentration of solid phase in Sisch sludge

$$Q = 15\frac{m^3}{h};$$

$$C_{\text{исх}} = 15\frac{g}{l}.$$

Required screw diameter, m:

$$D = 0{,}275\sqrt[3]{\frac{Q}{k_D n_{\text{в}} \psi \rho k_\beta}},$$

where Q is the calculated capacity of the thickener, ; $\frac{m^3}{h}$

kD is the ratio of propeller pitch to diameter: kD = 0.8;

nv is the rotational speed of the propeller, : nv = 1800;$\frac{1}{\text{h}}$

ψ— коэффициент заполнения желоба: ψ = 0.125;

$C_{\text{исх}}$ is the initial concentration, ;$\frac{\text{t}}{\text{m}^3}$

kβ is the coefficient of decrease in performance depending on the angle of inclination of the screw: β = 20, kβ = 0.6.

$$D = 0{,}275\sqrt[3]{\frac{25{,}5}{0{,}8 \cdot 1800 \cdot 0{,}125 \cdot 0{,}015 \cdot 0{,}6}} = 0{,}689, \text{m}.$$

According to the standard values according to GOST 2037-82, we take the diameter of the screw equal to 650 mm.

Required power on the propeller shaft, kW:

$$P_0 = 0{,}0027Q(L_{\text{г}} w \pm H),$$

where Lg is the length of the horizontal projection of the thickener, Lg = 1.029 m (L = 1.095 m);

w is the coefficient of resistance to the movement of the load, w = 2.5;

H is the height of lifting (plus) or lowering (minus) the load, H = 0.4 m.

$$P_0 = 0{,}0027 \cdot 25{,}5 \cdot (1{,}029 \cdot 4 + 0{,}4) = 0{,}3, \text{кВт}.$$

Motor power for screw thickener drive:

$$P = \frac{k \cdot P_0}{\eta},$$

где k — коэффициент запаса: k — 1,1...1,3: k = 1,25;

P0 — design power on the drive shaft of the conveyor;

η is the efficiency of transmissions from the motor to the drive shaft: η = 0.74.

$$P = \frac{1{,}25 \cdot 0{,}3}{0{,}74} = 5 \text{ кВт}.$$

We choose a 4A100V motor with a power of 5 kW, rotational speed of 3000 rpm.

The required gear ratio between the engine shaft and the screw shaft is determined by the formula:

$$u = \frac{n}{n_{\text{в}}},$$

where n is the motor shaft speed: n = 3000 rpm.

$$u = \frac{3000 \cdot 0{,}9}{30} = 90.$$

Taking into account the standard gear ratio series, we choose $u_{\text{ф}} = 90.$

Actual propeller speed, : $\frac{1}{\text{min}}$

$$n_{\text{в}}^{\text{ф}} = \frac{n}{u_{\text{ф}}},$$

where n is the motor shaft speed, ; $\frac{1}{\text{min}}$

uf is the actual gear ratio of the drive.

$$n_{\text{в}}^{\text{ф}} = \frac{3000 \cdot 0{,}9}{90} = 30.$$

Actual condenser capacity, :$\frac{т}{ч}$

$$Q_ф = 47D^2 S\psi k_D n_в^ф \rho k_\beta,$$

где S — средний ход шнека, м: S = t (t — средний шаг шнека, t = 0,325).

$$Q_ф = 47 \cdot 0{,}65^2 \cdot 0{,}325 \cdot 0{,}125 \cdot 0{,}8 \cdot 30 \cdot 0{,}015 \cdot 0{,}6 = 0{,}174\ \frac{\mathrm{t}}{\mathrm{h}} = 19{,}72\ \frac{m^3}{\mathrm{h}}.$$

Torque on the screw shaft, Nm:

$$T_0 = \frac{9550 \cdot P_0}{n_в^ф}.$$

$$T_0 = \frac{9550 \cdot 0{,}3}{30} = 95{,}5\ \text{Нм}.$$

Axial force per screw, N:

$$F_{ос} = \frac{2 \cdot T_0}{k \cdot D \cdot tg(\alpha)},$$

where k is a coefficient taking into account that the force is applied at the average diameter of the screw: k = 0.7 to 0.0.8;

D — screw diameter, m;

α is the angle of elevation of the screw line of the screw;

$$F_{ос} = \frac{2 \cdot 95{,}5}{0{,}75 \cdot 0{,}65 \cdot tg(20°)} = 1076\ \text{Н}.$$

Transverse load (H) on the auger section between the two supports:

$$F_{попер} = \frac{2 \cdot T_0 \cdot l}{k \cdot D \cdot L},$$

where l is the distance between the supports of the screw shaft, l = 1 m;

L is the total length of the screw shaft, L = 1.095 m.

$$F_{попер} = \frac{2 \cdot 95{,}5 \cdot 1}{0{,}75 \cdot 0{,}65 \cdot 1{,}095} = 358\ \text{Н}.$$

The calculated dimensions are shown in the diagram of the screw thickener (Fig. 13.3).

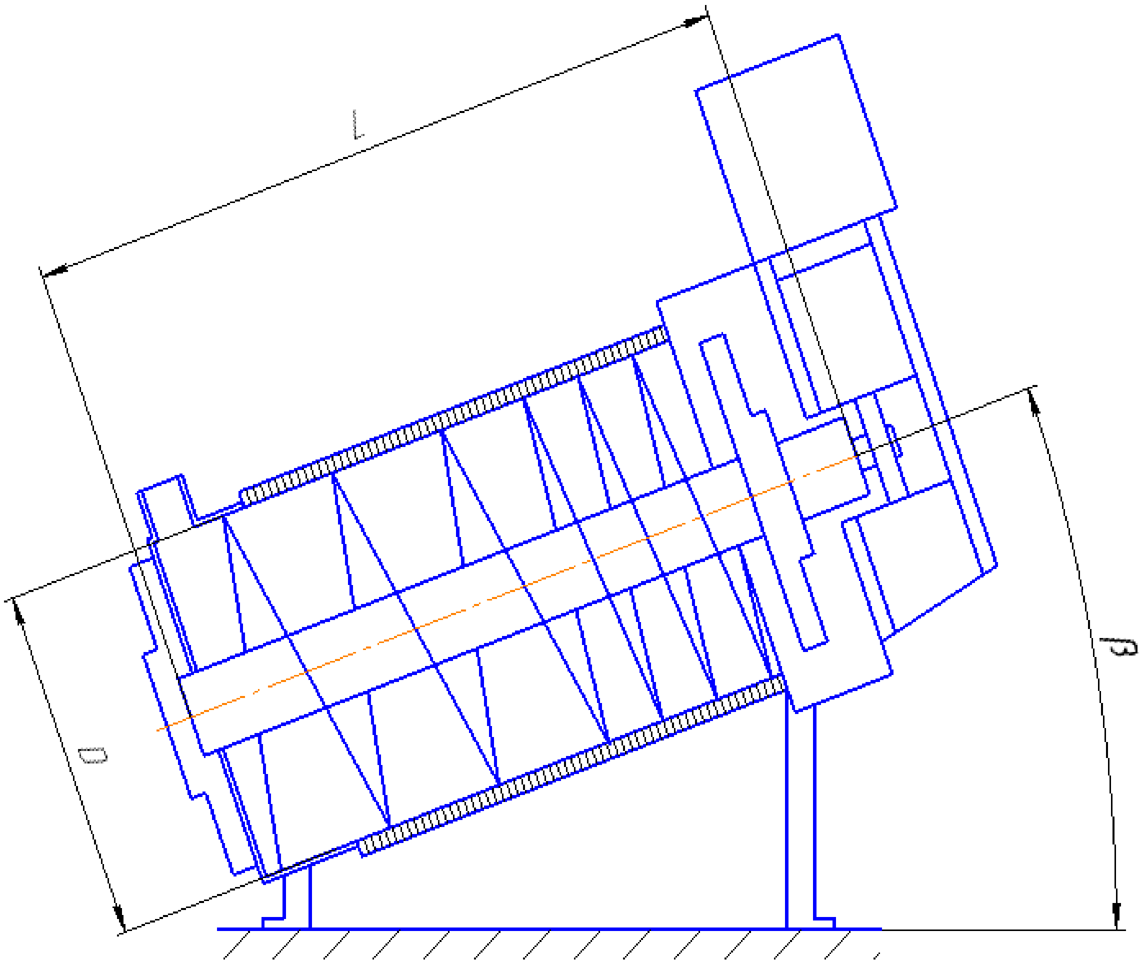


Fig. 13.3. Scheme of screw thickener

Table 13.3. Main parameters of the screw thickener

Options	Designation	Meaning
Diameter, mm	D	650
Screw shaft n	L	1095
Screw angle, deg	B	20

Calculation of the hydrocyclone

We determine the specific hydraulic load:

$q_{hc}=3.6\ K_{hc}\ u_0 = 3{,}6 \cdot 0{,}61 \cdot 5 = 10{,}98$ м3/м2ч,

where K_{hc} = 0.61 is for hydrocyclones without internal devices.

$D' = \sqrt{\frac{Q}{0.785 \cdot q_{hc}}} = \sqrt{\frac{100}{0{,}785 \cdot 10{,}98}} = 3.4$ м - the estimated diameter of the hydrocyclone.

Choose a standard hydrocyclone GC-360K, for which:

D=350 mm – inner diameter of the device;

d_{pit}=90mm – diameter of the supply pipe;

$\alpha=20^{o}$ - угол конусности;

d_{sl}=115 mm – diameter of the drain pipe;

P = 0.15 MPa - pressure drop in the apparatus.

The calculated parameters are indicated in Fig. 13.4.

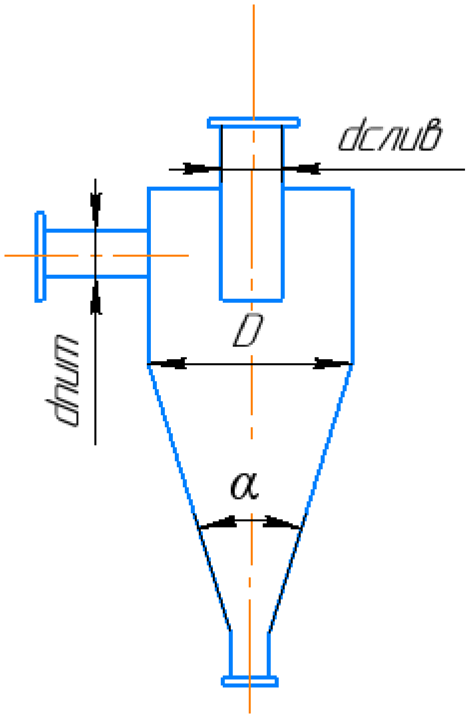


Fig. 13.4. Design scheme of the hydrocyclone

Let's determine the performance of the selected hydrocyclone of the assigned sizes:

Q’$= 15{,}5 \cdot k_d \cdot k_\alpha \cdot d\text{пит} \cdot d\text{сл} \cdot \sqrt{\text{P}} \;\; = 15{,}5 \cdot 1{,}07 \cdot 0{,}996 \cdot 9 \cdot 11{,}5 \cdot \sqrt{0{,}15 \cdot 10{,}2} = 2114{,}7\,\frac{l}{\min} = 126{,}9\,\frac{\text{м}^3}{\text{ч}}$,

where =0.8+=0.8+=1.07, =0.79+=0.996$k_d\,\frac{1{,}2}{1+0{,}1\cdot D}\,\frac{1.2}{1+0.1\cdot 35}\,k_\alpha\,\frac{0.044}{0.0379+tan\frac{\alpha}{2}}$

The calculated performance Q' ≥ Q is preset, so the selected hydrocyclone is suitable.

Calculation of the area of the hopper-sealer

50% of the solids (fine particulate matter) are carried away with the water into the centrifuge. The remaining 50% is sent to the hopper-compactor.

Sediment heading into the seal by weight - 1.25 t / h, humidity after the hydrocyclone - 65%. By volume of sediment with water:

Qосад=0,04*Q’=0,04*126,9=5м3/ч=120 м3/сут=0,0014 м3/с

Seal area:

F== =12, where v=0.0001 m/s$\frac{Q\text{осад}}{v}\frac{0{,}0014}{0{,}0001}\,\mathrm{m}^2$

We accept single-section hopper 3×4.m^2

The selection of the centrifuge is carried out according to the productivity.

Qc=95m3/h, Stv.v = 12.5 g/l

We choose a centrifuge OGSH-631K-2 with a capacity of Qc' = 25-35 m3 / h.

We determine the number of centrifuges:

n= = 2.71 $\frac{Q\text{ц}}{Q\text{ц}'} = \frac{95}{35}$

We accept the number of centrifuges OGSH-631K-2 - 3 pcs.

Example of calculation of centrifuges

Find centrifuges for sludge dewatering. The amount of wet sediment qmud=50 m3/h with humidity Wmud,eu=95%. The amount of excess activated sludge qi=20 m3/h.

Centrifugation of crude sludge

(a) Dry matter quantity of sludge

$$Gmud = \frac{qmud(100 - Wmud, en)}{100} = 2{,}5\ \text{t/day}$$

b) Duration of operation of one centrifuge OGSH-631K-2 at capacity qcf=30 m3/h according to the initial sediment

$$t = \frac{qmud}{qef} = 1{,}6\ \text{ч}$$

в) The amount of dehydrated sediment (cake) with the effectiveness of dry matter retention Emud = 55%

on dry matter

$Gmud,ex = k * Gmud = 1{,}375\ \text{t/day}$

Where k=55/100=0.55-efficiency factor

By volume $qmud,ex = \frac{Gmud,ex*100}{100-Wmud,ex}\gamma mud,ex = 3{,}89\ \text{m3/day}$

Where is the humidity of the dehydrated sediment, $Wmud,ex\gamma mud,ex = 0{,}85\frac{\text{т}}{\text{м3}} - \text{volumetric weight of the } k\text{eka}$

(d) Quantity of joint

dry matter content

Gf=Gmud-Gmud,ex=1,125 т/сут

By volume

qf=qmud-qmud,ex=46,11 м3/сут

e) Concentration of dry matter in the fugate $Cf = \frac{Gf*1000}{qf} = 24{,}4\ \text{г/л}$

(e) Number of centrifuges OGSH-631K-2 at a capacity of 30 m3/h

n=qif,en/q24=0.5. Accept 1.

g) Amount of dehydrated mixture

on dry matter

Gif,ex=Gif=1,325 t/day

By volume (at humidity pif,ex=70% and)$\gamma if,ex = 0{,}85\frac{\text{t}}{\text{m3}}$

$$qif,ex = \frac{Gif,ex*100}{100-Wif,ex}\gamma if,ex = 3{,}75\ \text{m3/day}$$

h) Amount of fugate returning to the mineralizer

dry matter content Gf,ex=Gif,en-Gif=3,095 t/day

By volume Qf,ex=qif,en-qif,ex=143,25 m3/day

(i) Concentration of dry matter in the fugate $Cf,ex = \frac{Gf,ex*1000}{qf,ex} =$ 21,6 g/l

Filter press calculation

Objective: To determine the type and quantity of filter presses for sludge dewatering, the flow rate of which Q = 10 m3/h and the initial concentration of C0 = 20 g/l or 2 %. Additional data are presented in Fig. 37 -38.

The moisture content of the sediment is determined based on the initial concentration

$$W_{en} = 100\% - 2\% = 98\%$$

Determination of the amount of sludge from dry matter

$$G_{mud} = Q \cdot C_0 = 200 кг/ч$$

The actual performance of the filter press is determined by the formula

$$q_{hc} = \frac{nk_1k_2C_0 \cdot 100 \cdot 3600}{1000 \cdot S(t_z + t_r + t_p)},$$

where n is a coefficient depending on the humidity of the initial sediment and is determined from the graph in Fig. 36, n = 1.3;

k1 – coefficient depending on the volume of the chambers of the filter-press FPKM-50U with the area of the chambers S = 50 m2, k1 = 20;

k2 – the ratio of the volume supplied to the sludge filter press to the volume of the working chambers, taken k2 = 1.25;

tz – load, purge and auxiliary operations time, tz = 140 s;

tr – filtration time determined on the laboratory funnel depending on the type of sediment, tr = 3000 s;

tp – spin time, determined by the graph in Fig. 13.5, tp= 120 s;

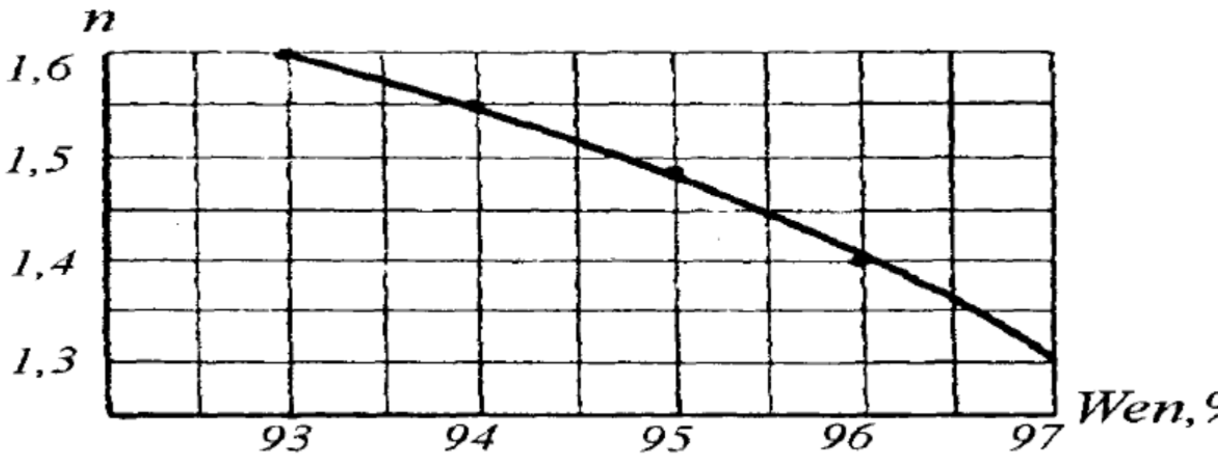


Fig. 13.5. Graph of the dependence of the coefficient n on the humidity of the original Wen sediment

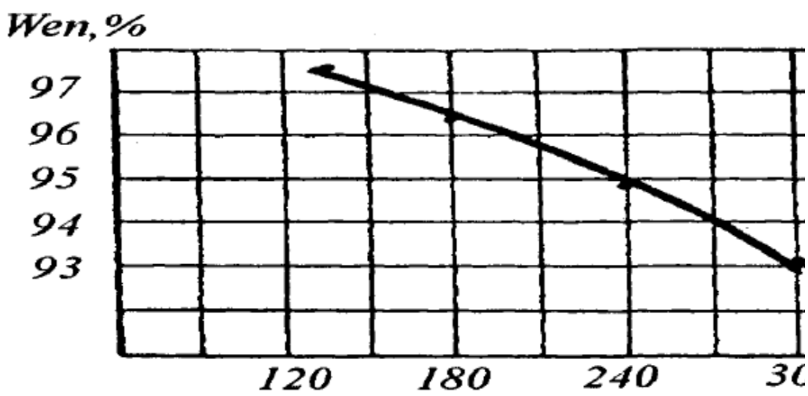


Fig. 13.6 – Graph of the dependence of the humidity of the initial Wen sludge on the spin time tp (Fig. 13.5 - 13.6 according to the data of the educational settlement Alekseev V.I., Vinokurova T.E., Pugachev E.A. Design of facilities for the processing and disposal of wastewater sediment using elements of computer information technologies. – M.: Publishing House of the ADM, 2003. – P. 107-108)

$q_{hc} = 1.44 кг/(м^2 ч)$

,

The number of filter presses is defined as

$$m = \frac{G_{mud}}{S \cdot q_{hc}} = 2.78шт.$$

We take m = 4 filter presses, one of which is redundant.

In Fig. Figure 13.7 provides a diagram for the calculation of a diaphragm-free chamber filter press.

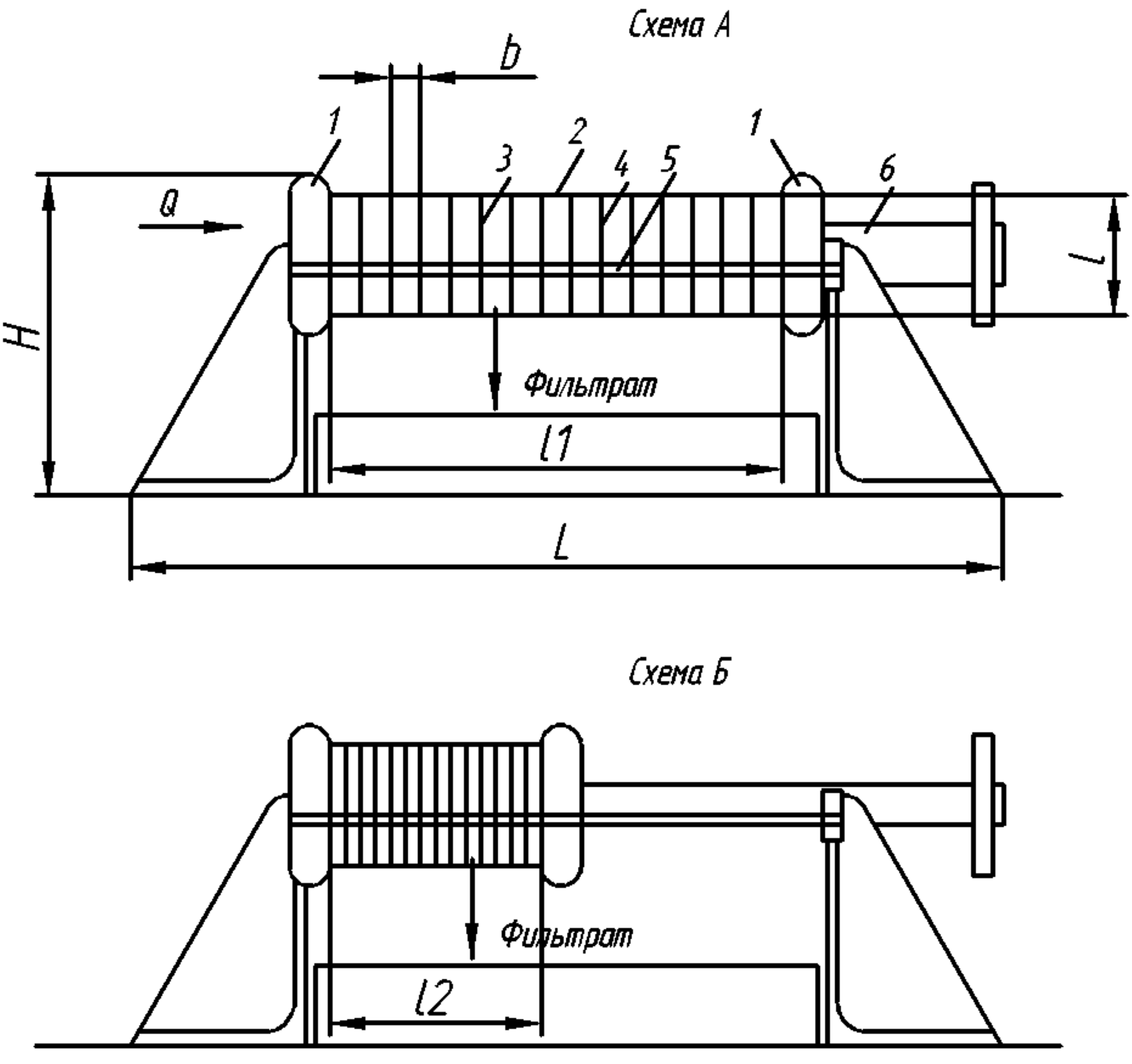


Fig. 13.7 – Scheme of diaphragm-free chamber filter-press: 1 – refractory plates; 2 – frame; 3 – stove; 4 – filter fabric; 5 – guides; 6 – screw; scheme A – sludge loading mode; Scheme B – sludge extraction mode

Appendix 2

Excerpts from SP 32.13330.2012. External networks and structures (Updated version of SNiP 2.04.03-85). M.: 2012

9.2.9. Sludge disposal facilities

9.2.9.1. To separate purified water from activated sludge (biofilm), sludge separation facilities should be used: secondary settling tanks, clarifiers with a suspended sediment layer, flotation plants, membrane modules, etc. To intensify the work of gravity sludge separation structures, the use of thin-layer modules is allowed.

9.2.9.2 The type of secondary settling tank (vertical, radial, horizontal) should be selected taking into account the capacity of the station, the layout of the structures, the number of units in operation, the configuration and relief of the site, geological conditions, the level of groundwater, etc.

9.2.9.3 Secondary sedimentation tanks for the separation of sludge and biofilm shall be calculated from the hydraulic load on the surface of m3/(m2 h), taking into account the coefficient of use of the volume of the structure, the sludge index and the concentration of sludge (biofilm). When determining the area of sedimentation tanks after biofilters, it is necessary to take into account the recirculation flow rate.

When calculating the values of the removal of activated sludge from settling tanks, at least 10 mg / l should be taken.

When designing facilities for joint biological removal of nitrogen and phosphorus, the sludge index should be taken at least 150 cm3 / g, and the hydraulic load on secondary sedimentation tanks - not more than 1.5 m3 / (m2 ⋅ h) according to the maximum hourly inflow per day of maximum water disposal.

9.2.9.4 The basic design parameters of secondary sumps should be taken:

intake of sludge mixture and collection of purified water - uniform along the perimeter of the intake and collection devices;

the height of the neutral layer is 0.3 m above the bottom at the outlet, the depth of the sludge layer is 0.3 - 0.5 m;

the angle of inclination of the conical bottom of vertical sumps and the walls of sludge pits of horizontal and radial settling tanks shall be 55 - 60 °.

It is allowed to specify the main design parameters of sedimentation tanks when combining mathematical and hydraulic modeling.

9.2.9.5 Removal of sludge that has fallen on the bottom of radial and horizontal sedimentation tanks should be carried out either through pits where the sludge is moved mechanically (sludge scraper) or directly from the bottom by means of sludge pumps. When using sludge pumps, each receiver must have an individual outlet to the collection chute. Sludge scrapers should be used to remove biofilms in settling tanks of these types.

Removal of sludge and biofilm in vertical settling tanks must be carried out spontaneously by creating an angle of inclination of the bottom of 50 - 60 °.

9.2.9.6 The capacity of the pits of secondary sedimentation tanks for hydrostatic sediment removal after biofilters should be provided for not more than two days of the sediment removed, after aeration tanks - not more than two hours of stay of the removed activated sludge.

Removal of sediment from the pit of the settling tank is recommended to be provided by gravity, under hydrostatic pressure.

Hydrostatic pressure when removing sediment from secondary settling tanks should be taken, not less than:

12 kPa (1.2 m of water level) - after biofilters;

9 kPa (0.9 m of water level) - after aeration tanks.

For secondary sumps, it is recommended to provide for the possibility of adjusting the height of the hydrostatic head. The diameter of the pipes for sediment removal take at least 200 mm.

9.2.9.7 The moisture content of the sludge removed should be determined by calculation taking into account the recirculation factor, the type of collecting device and the sludge index.

9.2.9.8 Sludge removal from secondary sedimentation tanks is allowed to be continuous or periodic (unacceptable when using biological phosphorus removal).

The time interval for periodic removal of sediment should be established on the basis of the volume of sediment formed and the capacity of the zone of its accumulation, but not more than three hours.

The capacity of the pits of secondary sedimentation tanks after biofilters with periodic removal of sediment should be provided for no more than two days of its volume, secondary sedimentation tanks after aeration tanks - no more than a two-hour stay of activated sludge.

9.2.9.9 The height of the side of the secondary sump above the surface of the water shall be taken to be at least 0.3 m.

9.2.9.10 The edge of the spillway on water intake (collection) trays should be provided with a height-adjustable one. The load on 1 m of the spillway in the secondary sedimentation tanks shall not exceed 10 l/s.

It is allowed to use submersible perforated pipes to collect purified water.

9.2.14 Wastewater sediment treatment facilities

9.2.14.1 Sediments formed during wastewater treatment (sand from sand traps, sediment of primary sedimentation tanks, excess activated sludge, etc.) should be treated for the purpose of dehydration, stabilization, odor reduction, disinfection, improvement of physical and mechanical properties that make it possible to dispose of them in an environmentally sound manner or place (storage or disposal) in the environment.

9.2.14.2 The choice of technological schemes for the treatment of sediments should be made on the basis of the results of technical and economic calculations, taking into account their composition and properties, physicochemical and thermophysical characteristics and taking into account subsequent methods of use or placement in the environment.

When justifying, it is allowed to pump (transport by road) sediments for treatment at other treatment facilities.

9.2.14.3 In the calculation of sediment treatment facilities, account shall be taken of the seasonal and diurnal unevenness of their formation. In the calculation of the amounts of sediment produced in accordance with

9.1.5 and 9.2.5.11, the accounting for unevenness can be determined using an additional coefficient of 1.2.

9.2.14.4 In order to increase the concentration of excess activated sludge, it is recommended to compact (thicken) it in structures and equipment of various types (gravity, mechanical, or flotation seals, etc.) before further processing. The dry matter content before applying sludge to the methane tanks should be at least 4.5%.

9.2.14.5 When treating excess activated sludge from phosphorus biological diversion facilities, measures should be taken to prevent the release of phosphates into sludge water: to prevent the occurrence of anaerobic conditions in the sludge. Gravitational compaction of such sludge is not allowed with a residence time of more than three hours. It is not allowed to mix such sludge with the sediment of the primary settling tanks, with the exception of the mixing chamber before the methane tanks and the mixing chamber, or the expendable tank before dehydration (thickening). In the latter case, it is recommended to supply air to the mixing chamber and flow tank.

9.2.14.6 Sediments of sewage treatment plants with a load of more than 50,000 ECW shall be stabilized. It is allowed to use biological, chemical, thermal and thermo-chemical methods of stabilization. Liquid or dehydrated (or dried in natural conditions) wastewater sediment can be stabilized.

When thermal drying or incineration plants (pyrolysis, etc.) are used at treatment facilities, as well as for the disposal of sediment in landfills equipped with a system for collecting and disposing of landfill biogas, preliminary stabilization of the sediment is not mandatory.

9.2.14.7 Liquid sediments may be stabilized by anaerobic methane digestion, anaerobic-aerobic, aerobic-anaerobic treatment; aerobic stabilization.

Mechanically dehydrated sediments, as well as sediments dried in natural conditions, can be stabilized by composting methods with organ-containing fillers and/or by soaking in vivo at stabilization and decontamination sites for 1 to 3 years, depending on the climatic regions (I and II climatic regions - at least three years; III climatic region - at least two years; IV climatic region - at least one year). The stabilization time, if sufficient areas are available, may be extended in order to improve the quality of sediment and reduce the final amount of sediment to be further disposed of or placed in the environment.

9.2.14.8 Anaerobic (methane) digestion is recommended for the stabilization of sediment at treatment plants with a load of more than 100 thousand EPh (when justified, it is also allowed at facilities with a load of 50 - 100 thousand ECG). The fermentation process should be carried out in methane tanks. In the feasibility study, the use of anaerobic digestion during subsequent incineration or pyrolysis is allowed.

9.2.14.9 Other types of fermentable waste (manure, bird droppings, liquid organic food waste, substandard food products, specially prepared (deeply crushed) organic components of municipal solid waste, other industrial wastes that are similar to them in composition are not toxic to the process) may be added to the methane tanks. Coarse impurities and sedimentary inorganic inclusions should be removed from these wastes, as well as the necessary homogenization of the mixture supplied to the methane tanks.

9.2.14.10 Fermentation is allowed in mesophilic (temperature about 35 ° C) and thermophilic (temperature 50 - 60 ° C) modes. In substantiation, the use of a two-phase thermophilic-mesophilic fermentation mode is also allowed. The choice of the temperature regime should be made according to the results of technical and economic studies, taking into account the methods of further processing and utilization of the sediment, sanitary requirements, the method of utilization of the resulting biogas and thermal calculations.

9.2.14.11 The sediment supplied to the methane tanks shall be filtered on grates (sieves) with gaps of not more than 6 mm in order to further remove coarse inclusions.

9.2.14.12 Methods of preliminary thermal (up to 180 °C), mechanical, enzymatic and ultrasonic treatment of sediments, as well as a combination thereof, before fermentation, are allowed to increase the degree of decay of organic matter and increase the yield of biogas.

9.2.14.13 The volume of methane tanks should be determined by calculating the organic load on the working volume of the structure. The volumetric dose of sediment loading should not exceed 15% for the thermophilic process and 7% for the mesophilic process.

The degree of decay of the organic matter of the sediment should be determined by calculation taking into account the types of sediment, process temperature, availability and pretreatment methods.

9.2.14.14 In order to ensure the efficiency and reliability of the sediment digestion process, the design of methane tanks should include:

the possibility of flushing all pipelines;

mixing of methane tanks with agitators or gas (the use of pumps for mixing is allowed only as backup equipment);

installation of defoamation systems;

two pipelines for unloading fermented sediment - from the lower and upper parts of the structure;

emergency overflow system;

hermetically sealed hatches-manholes both in the upper part of the structure (on the gas cap) and in the lower;

effective thermal insulation;

the use of recuperation heat exchangers when applying the thermophilic fermentation mode, with a recovery of at least 15 ° C.

9.2.14.15 The weight amount of the gas obtained during fermentation (biogas) should be taken 0.9 l per 1 g of the disintegrated ash-free substance of the sediment, the calorific value - 5500 kcal / m3.

9.2.14.16 Mandatory utilization of biogas produced during fermentation by the following methods shall be provided:

combustion in boiler houses for the production of steam and hot water, both separately and in conjunction with natural gas;

use as a motor fuel in electric generators, as well as in the justification of blower drives in engines and on motor vehicles;

use as fuel in thermal drying and sediment combustion plants.

9.2.14.17 When using biogas as a motor fuel, it is recommended to provide for its purification from impurities that have an adverse effect on the operation of internal combustion engines (water, suspended particles, hydrogen sulfide, siloxanes, etc.).

9.2.14.18 The design of methane tanks should include:

measures for the explosion and fire safety of the complex as a whole, equipment and service facilities;

tightness of tanks of methane tanks designed for overpressure up to 5 kPa (500 mm of water);

automatic control of the pressure sediment level in the methane tanks;

distance from methane tanks to high-voltage lines - not less than 1.5 of the height of the support;

fencing of the territory of methane tanks;

gas tanks for averaging biogas consumption. It is allowed to use "wet" and dry gas tanks at a pressure of 1.5 - 2.5 kPa (0.15 - 0.25 m of water, designed for a 2-hour yield of biogas. In the feasibility study, the use of spherical gas tanks under higher pressure is allowed. They should be designed in accordance with the requirements for natural gas storage facilities.

9.2.14.19 The design of the gas facilities of methane tanks (gas collection points, gas network, gas tanks, etc.) must be carried out in accordance with SP 62.13330.

9.2.14.20 Aerobic stabilization of the sediment is allowed without heating the sludge (in the submesophilic mode at a temperature of at least 15 - 20 °C), and in the autothermophilic mode.

When calculating submesophilic aerobic conditioning, it should be assumed: the degree of decay of the organic matter of the sediment is not more than 20%. When using the autothermophilic mode, it is allowed to take a degree of decay of up to 45%. When calculating, it is necessary to determine: the time of aerobic treatment, the required air flow, and for thermophilic aerobic stabilization - the conditions of the autothermicity of the process.

9.2.14.21 Mechanical and pneumatic-mechanical aeration shall be provided for in the aerobic stabilization of a highly concentrated mixture of sediments.

9.2.14.22 All liquid sediment shall be dehydrated to a humidity of not more than 82 % by natural or mechanical methods (using dewatering equipment, or using filter bags or geotubes).

In the new design of treatment facilities with a load of more than 15 thousand ECF, it is necessary to provide for the dewatering of sediments by mechanical methods, sludge sites are allowed only as backup facilities.

Periodic dewatering of the sediment is allowed with the help of mobile installations serving several treatment facilities. In this case, it is necessary to provide a sufficient capacity of the liquid sediment reservoir, in which measures should be taken to prevent decay and deterioration of the water-giving properties of the sediment.

9.2.14.23 For all types of sediment, it is recommended that intermediate consumables be provided before dewatering. In order to average the sediment and prevent the fermentation of unstabilized sediments (taking into account 9.2.14.3) and their surfacing, air mixing is recommended.

The residence time of sediment in intermediate storage tanks should not exceed 24 hours.

9.2.14.24 Centrifuges and belt filter presses are recommended for mechanical dewatering of sediments. For justification, it is allowed to use chamber filter presses, screw presses and other equipment. The type of equipment and the number of operating and backup devices should be determined according to the characteristics and requirements of the equipment manufacturers.

9.2.14.25 Organic polymers (flocculants) are recommended to be used as reagents to improve the water-dissipation properties of municipal wastewater sediment and similar in composition. In the feasibility study, it is allowed to use reagents and additives that improve the dewatering process, as well as heating the sediment by utilizing low-potential heat from other processes.

9.2.14.26 In the case of mechanical dewatering of sediments thermophilic-fermented at a loading dose of less than 10%, it should be envisaged to wash the fermented sediment with process water at a volume ratio of 1: 2.5 - 1: 3, followed by compaction at a compaction time (according to the initial sediment) of at least 96 h.

It is allowed to carry out a two-stage compaction of washed fermented sediments (with additional gravitational compaction of drain water), as well as the use of leachate from mechanical thickening (dehydration) of the sludge as part of the washing water.

9.2.14.27 When designing sediment washing facilities (mixing it with process water), devices should be provided for the removal and subsequent treatment of the sand discharged therein.

9.2.14.28 The moisture content of the fermented washed and compacted sediment shall be taken from 95.0 to 96.5 % depending on the proportion of activated sludge and water treatment sediment in the fermented mixture, as well as the load on the methane tanks by organic matter. The content of suspended substances in the drain water of the seals of the fermented sediment is allowed to be taken: for suspended substances 800 - 1300 mg / l, for BOD5 - 400 - 600 mg / l.

9.2.14.29 The feasibility study may include aerobic treatment of fermented sediments in order to improve their water-dissipation capacity and reduce the nutrient recycling.

9.2.14.30 The methods used to improve the water-dissipation properties of the sediment shall ensure the maximum dry matter content in the dehydrated sediment in accordance with the dehydration equipment used. The concentration of suspended solids in the filtrate (fugate) from dewatering of the sediment should not exceed 500 mg / l.

9.2.14.31 If there are requirements to limit the content of sand and coarse impurities in the sediment supplied to mechanical dewatering apparatuses, appropriate treatment of the sediment should be provided to ensure a decrease in their content: sand extraction, filtering, or grinding of the sediment, etc.

9.2.14.32 When designing mechanical sediment dewatering facilities, the following shall be taken into account:

in the presence of reserve sludge sites (by 20% of the annual sediment consumption): 1 backup filter press with the number of workers up to three inclusive, and 2 - with four or more working units, 1 backup centrifuge with the number of workers up to two inclusive, and 2 - with the number of workers three or more;

in the case of a feasibility study, it is allowed to refuse to use reserve sludge sites (in the absence of the possibility or economic inexpediency of creating or operating existing sludge sites), subject to the application of a set of measures to ensure the reception and treatment of sediment in emergency situations, which should include, at a minimum: sediment accumulators with a residence time of at least 2 days, increased by at least 1 apparatus the amount of reserve dewatering equipment, redundancy of all auxiliary units of the dewatering department (conveyor equipment, bunkers, pumps, compressors, reagent units, etc.).

9.2.14.33 Provision should be made for the redundancy of dewatering systems common to several mechanical dewatering appliances for the transport of dehydrated sediment. It is allowed to use pumping of dehydrated sediment.

9.2.14.34 Bunkers may be used for the storage and subsequent loading of dehydrated sludge into motor vehicles. In this case, the hopper shall have a conical bottom with an angle of inclination of 55 - 60 °, or a bottom equipped with screws for unloading sediment.

It is allowed to use for the accumulation and subsequent transportation of dehydrated sediment replaceable special bunkers with lids, as well as rail systems for feeding these bunkers for loading with sediment and for loading into vehicles.

9.2.14.35 The feasibility study may include facilities for the local purification of leachate and fugate, as well as drain water from compactors of fermented sediment from suspended solids, ammonium nitrogen and/or phosphates (in particular by nitri-denitrification, ammonium anaerobic oxidation, extraction of phosphates in the form of struvite, etc.)

9.2.14.36 For the preparation of mechanically dehydrated sediments not subjected to thermophilic fermentation for further disposal as organic fertilizers or for the technical reclamation of disturbed lands, it is allowed to provide for the retention of sediments at stabilization and decontamination sites for a period of 1 to 5 years or composting. In the process of aging, additional drying, mineralization of organic substances, disinfection, improvement of the structure are achieved.

In the first year of exposure, the height of the sediment layer is recommended to take 0.5 - 0.8 m, in subsequent years the sediment should be kept in burts.

Stabilization and decontamination sites should be artificially based. Provision should be made for the diversion of leachate, rainwater and meltwater to treatment plants.

9.2.14.37 When drying the sediment under natural conditions, the load on the sludge sites in areas with an average annual air temperature of 3 - 6 ° C and a sediments of not more than 500 mm / year should be taken according to Table 20 , taking into account figure 1.

9.2.14.38 When using the natural sediment drying method, the following should be provided:

construction of sludge platforms (on a natural or artificial basis, with drainage, cascade, seals, etc.) - depending on the hydrogeological and climatic conditions, terrain;

number of cards - not less than four;

working depth of the maps - 0,7 - 1 m;

the height of the fence rollers is 0.3 m higher than the working level.

Table 20 - Permissible load on sludge pads for different types of sediment

Sediment characteristics	Sludge pads				
	on a natural basis	on a natural base with drainage	on an artificial asphalt concrete base with drainage	cascade with sedimentation and surface removal of sludge water on a natural basis	sealing pads
Anaerobically fermented mixture of sediment from primary settling tanks and activated sludge under mesophilic conditions	1,2	1,5	2,0	1,5	1,5
The same, under thermophilic conditions. Mixture of sediment from primary sedimentation tanks and activated sludge	0,8	1,0	1,5	1,0	1,0

Sediment characteristics	Sludge pads				
	on a natural basis	on a natural base with drainage	on an artificial asphalt concrete base with drainage	cascade with sedimentation and surface removal of sludge water on a natural basis	sealing pads
Anaerobically fermented sediment from primary sedimentation tanks and sludge from two-tier sedimentation tanks	2,0	2,3	2,5	2,0	2,3
Aerobically stabilized mixture of activated sludge and sediment from primary sedimentation tanks or stabilized activated sludge	1,2	1,5	2,0	1,5	1,5

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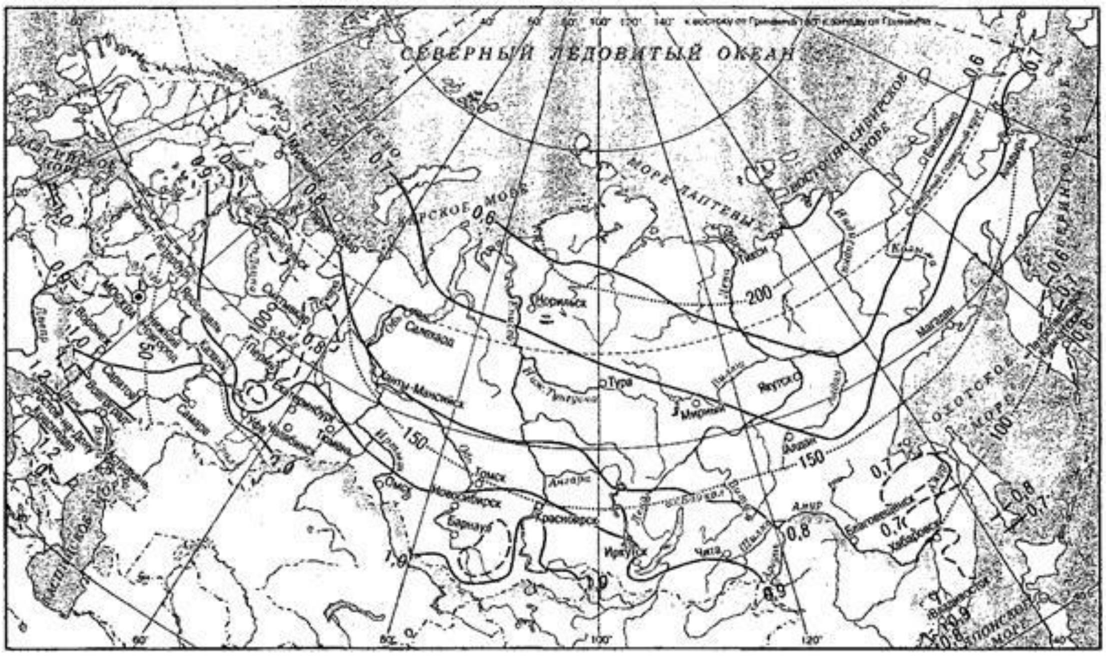

Fig. 1 - Climatic coefficients for determining the amount of load on sludge pads (solid and dotted lines) and the duration of the wetting period on sludge sites, days (point lines)

9.2.14.39 The area of sludge areas should be checked for defrosting. The duration of the freezing period should be taken equal to the number of days with an average daily air temperature below minus 10 °C. The amount of frozen sediment should be taken in the amount of 75% fed to the sludge sites for the period of freezing.

9.2.14.40 Periodic mixing and burrowing of dried sediment on sludge pads shall be provided.

9.2.14.41 Discharge water from sludge sites shall be supplied for treatment (directly to the treatment plant or to the sewage system). In the feasibility study, it is allowed to provide for local treatment of drain water, and, subject to purification and disinfection to the current requirements - the use of drain water for irrigation of crops, nurseries, etc. When using drain water for irrigation, in the absence of an additional possibility of supplying drain water to centralized treatment facilities during periods when irrigation is not performed, storage tanks should be provided. sufficient capacity.

9.2.14.42 It is permissible to mix sediment with sand trap sand, construction sand, infertile soil to obtain soil or reclamation for the technical reclamation of disturbed lands.

9.2.14.43 For the preparation of mechanically dehydrated sediments and sediments dried naturally on sludge sites, composting with organ-containing fillers (peat, sawdust, crushed tree bark and plant waste) is recommended as local organic fertilizers. It is allowed to use ready-made compost up to 30% of the filler volume to reduce the filler consumption.

Composting can be carried out: in piles on collapsed areas with a hard surface and on sites with an artificial base, as well as in corridor and other structures. Composting in fermenters is allowed. Mixing of sediments and filler can be carried out directly in the mechanical dewatering shop in mixing machines, or on composting sites.

9.2.14.44 When calculating the composting process, the ratio of the initial sediment to the fillers, the flow rate of the supplied air (during forced aeration) and the frequency of mixing, the processing time at each of the composting stages (depending on the season and the type of filler) should be determined.

9.2.14.45 In order to speed up the composting process, it is allowed to use special covering heat-insulating materials with unilateral permeability, as well as the addition of biological preparations that intensify the thermophilic stage and reduce the release of foul-smelling substances. To prepare the fermented sediment for soil disposal, it can also be composted. The composted sediment must be separated from the coarse inclusions.

9.2.14.46 The following treatment methods may also be used for the decontamination of wastewater sediment in liquid form or after dehydration:

warming up to 60 °C with exposure at this temperature for at least 20 minutes;

thermal drying in dryers (except for low-temperature dryers with a drying temperature of less than 60 °C);

the use of disinfecting reagents, as well as other methods.

For sediments subjected to anaerobic thermophilic fermentation at a temperature of at least 53 °C, composting, aging in natural conditions according to 9.2.14.10 , additional disinfection is not required.

9.2.14.47 Thermal drying may also be used to prepare the sediment for removal and disposal in landfills, incineration, disposal of sediment as fuel in other establishments. It is allowed to dry the sediment in the places of its further utilization, if there are appropriate thermal resources.

9.2.14.48 Thermal drying should provide:

the maximum possible dewatering of the sediment before feeding to the dryers;

use of available (possible) thermal resources for drying, with justification - obtaining and using low-potential heat from dryers;

separation of the dried sediment from large and dusty particles, with their return to the drying process;

cleaning of gas emissions from dryers;

measures to ensure the explosion and fire safety of the drying plant, as well as bunkers and warehouses of dried sediment.

9.2.14.49 For thermal disposal of sediment, it is allowed to use combustion furnaces of various types, pyrolysis plants, gasification, etc., joint use of drying of sediment and combustion is allowed. When using high-temperature pyrolysis and gasification of the sediment, it should first be dried.

9.2.14.50 It is necessary to provide for an autothermal regime for the thermal reclamation process or, as is justified, to minimize the supply of additional fuel. In the feasibility study for high-temperature treatment of the sediment, the use of additional fuel, including solid, as well as technical oxygen, is allowed.

9.2.14.51 Joint thermal disposal of dehydrated sediment and municipal solid waste, as well as industrial waste, is permitted.

9.2.14.52 Gas emissions from these installations shall be cleaned up to established emission standards.

9.2.14.53 Provision should be made for the utilization of thermal resources derived from heat treatment plants, especially for the needs of sediment pretreatment, heating and hot water supply of wastewater treatment plant buildings.

9.2.14.54 Temporary (before further processing or use) storage of dehydrated sediments should be provided for in specially equipped sites or warehouses with mechanization of loading and unloading operations.

9.2.14.55 It is permissible to bury sediments in places agreed with the supervisory authorities. When burying sediments, measures should be taken to protect against pollution of groundwater and surface water, atmospheric air and soils. The humidity of the buried sediment should not exceed 75%. Burial of sediments should be carried out section by section with sequential filling of sections.

9.2.14.56 A drainage system should be provided along the bottom of the disposal structure, pumping out the released leachate for cleaning.

9.2.14.57 Disposal of unstabilized sediments is permitted only when the disposal facility is equipped with a landfill biogas screening and utilization system. At the same time, individual sections of the disposal facility must be filled in a period of time not exceeding 3 months. During the completion of the section, measures should be taken to prevent the spread of foul-smelling substances.

Notes

1 In agreement with the regulatory authorities, long-term storage of dehydrated sediment in storage facilities equipped similarly to landfills is allowed, followed by disposal of the sediment, dismantling of the reservoir and reclamation of the disturbed territory.

2 It is allowed to bury the sediment in a specially prepared site directly in the geotubes in which it was dewatered.

9.2.14.58 It is allowed to place on the sites of treatment facilities installations for the preparation of soils (mixtures) using dehydrated and stabilized wastewater sediment, with the addition of other ingredients.

APPENDIX 3

Excerpts from the INFORMATION TECHNOLOGY HANDBOOK ON BEST AVAILABLE TECHNOLOGIES

WASTEWATER TREATMENT USING CENTRALIZED WASTEWATER DISPOSAL SYSTEMS OF SETTLEMENTS, URBAN DISTRICTS" (ITS - 15). M: Rosstandart.- 2015.

The vast majority of technological schemes of the GSV full cycle include the following basic (mandatory) subprocesses: - mechanical cleaning; - biological treatment; - disinfection of purified water; - Sediment dewatering. All other technological processes may or may not be present. A minimal process flow does not necessarily mean incomplete, inefficient, or the cheapest. It can also be very effective and/or very expensive. Any technology that does not contain the above stages is incomplete and insufficient. Such technologies are also used, but they are justified exclusively in special conditions, for example: technology without biological treatment - using physicochemical treatment and filtration purification. This process is forced to be applied at some remote sites with a temporary (seasonal) stay, where biological treatment facilities cannot be used, since they require a long start-up (biomass build-up within 2-3 months). In more complex situations, where the OCs are also used to treat significant volumes of industrial wastewater, the flowchart may be more complex to ensure the removal of specific contaminants of the latter. In this situation, GSV may not come at the beginning of the technological scheme. Also, some streams (for example, low-polluted industrial wastewater) may not be fed at the beginning of the technological scheme for the treatment of GSV, but may be connected at subsequent stages. The criteria for assigning fixed assets to the scope of its application of the relevant industries are defined in industry directories. The criteria for attribution to the scope of this handbook in such situations are defined in the relevant section. The obligation to disinfect treated water is a very debatable issue. Regulatory legal acts of the Russian Federation require disinfection of all volumes of discharged wastewater. However, until recently, the TASK of decontamination itself was not set in the EU, including in connection with the rather significant effect of the biological treatment process in this regard. For decades, the country's largest os GSV - Kuryanovsk and Lyuberetsky treatment facilities in Moscow did not have disinfection. This was justified by the fact that they form from 30% to 90% of the flow of water bodies where the discharge occurs. In this situation, the use of chlorination would have an extremely negative impact on the state of the ecosystem of these water bodies. In the actual absence of chlorination during the above period of time, there were no sanitary and epidemiological incidents in the lower reaches of these water bodies, after discharges of biologically treated wastewater.

In St. Petersburg, until now, only 19% of treated effluents undergo disinfection, the introduction of the entire consumption is planned by 2024. Currently, environmentally friendly technology of UV disinfection is available for any scale of objects and the choice between disinfection and the ecological state of the water body is no longer worth it. It is important to note that disinfection has no environmental significance (for water bodies, the concept of pathogenic microorganisms is meaningless), but only sanitary and epidemiological. Therefore, in those regions and in those seasons (cold seasons), where and when there is no human contact with the water of the water body, and the dilution is high, there is no justification for the use of decontamination, except for the regulatory requirement. All the main equipment of the CSV os belongs to the environmental (hereinafter referred to as the main environmental equipment). Equipment for cleaning emissions into the atmosphere (hereinafter referred to as auxiliary environmental equipment) can also be used on the OS. It should be noted that many subprocesses of the OS, starting with a small scale, are implemented not in equipment, but in capacitive technological structures made by the construction method. This is done solely because of the large volume of tanks, which does not allow the use of equipment manufactured by the factory method for the implementation of these stages. At the same time, the equipment is used as an integral part of technological structures, performing important technological functions (movement of water and sediment, aeration, mixing, etc.). Further, the equipment in a general sense means a set of capacitive structures and equipment that implement this subprocess.

Table 2.1 - Summary description of the SCW cleaning process

Input stream	Process stage (sub-process)	Output stream	Main technological equipment	Issue
1	2	3	4	5
Incoming wastewater	N 1. Separation of floating coarse impurities (straining). Mandatory sub-process	Stochennaya water	Lattices (sieves). With high productivity - complete transportation equipment (screws, belt conveyors, etc.)	Organized emission of air pollutants
1. Coarse impurities retained on the grates or sieves	N 1-1. Treatment (washing and dehydration	1. Treated (washed and pressed) coarse	Hydraulic presses, screw presses, containers.	Organized emission of air pollutants

(garbage from the grates). 2. Washing water	) of coarse impurities detained on grates or sieves. In practice, an optional sub-process	impurities (garbage).2. Flushing water in the stream untreated wastewater	Often, coarse impurity treatment equipment is blocked with wastewater treatment equipment.	
Coarse impurities trapped on grates or sieves (waste from the grates)	N 1-2. Collection of waste from grates (sieves) into containers; (mandatory sub-process)	Untreated or processed coarse impurities (waste)Untreated or processed coarse impurities (waste)	Containers	Waste - waste for placement.Organized release of substances that pollute the atmosphere
Strained wastewater. Compressed air (in some	N 2. Removal of settling coarse impurities	Unlit water	Sand traps (capacitive structures or complete equipment)	Fugitive emissions of air pollutants

cases)	(sand).Mandatory sub-process.Removal of pop-up fatty impurities (optional, for some designs)		.1. Compressors for aerated sand traps. 2. Hydraulic elevators for pumping sand pulp.3. Pumps for pumping sand pulp. Scraper or screw equipment for transporting sand to pits (not in all structures)	

Sand pulp (sand sludge).According to option B - also industrial water	N 3. Sand sludge treatment. Mandatory sub-process in one version or another.Variant A. on sand pads.Variant B. In bunkers Option B. In sand washing and separation machines	Dehydrated (dried) sand.B. Washed and dehydrated sand	A. Peskovye pady.B. Sand Bunkers.V. Sand washing and separation machines	If the isolated and treated sand does not find application - waste for placement.Unorganized release of substances that pollute the atmosphere
Unlit water	N 4. Accumulation (averaging of flow) of wastewater Adding sub-	Unclarified wastewater (average flow)	Regulating tanks (tank structures). Agitators, aeration	Organized release of air pollutants (through the "breathing" openings of

	process		systems can be used	tanks)
Unlightened wastewater.Reagent solution for intensification of suspended solids deposition and phosphorus deposition from sub-process 10	N 5. Sediment of suspended solids (clarification, primary settling).Removal of fat floating contaminants. The feasibility of sub-process No. 5 is determined on the basis of the qualitative and quantitative composition	Clarified wastewater. Sediment of primary sedimentation tanks.Fat mass	Primary settling tanks (tank structures), scraper equipment, pumps for sludge pumping. Grease collectors	Fugitive emissions of air pollutants

	of wastewater and the technology of biological treatment. Primary sedimentation can be implemented with sediment acidification (see section 4)			
Clarified wastewater.Compressed air.Phosphorus deposition reagent solution	N 6. Treatment in bioreactors of biological purification: option A - biofilters; option B - aeration	A. Treated water with biofilm on separation. Sludge mixture for separation	Capacitive structures - bioreactors. Aerators (very diverse devices for dispersing air in a	Fugitive emissions of air pollutants

	tanks. Biochemical reactions occurring in bioreactors in different embodimen ts of the sub-process may differ significantly.		sludge mixture). For nitrogen (nitrogen and phosphorus) removal technologie s - also agitators and internal recirculatio n pumps	
Atmospheric air	N 7. Compressed air supply. Man datory sub-process for aeration tanks (except for exceptions to)	Compressed air	Compressor s (blowers)	Noise.High power consumption

From sub-process 6A - treated water.From sub-process 6B - sludge mixture	N 8. Separation of purified water from biomass removed from the bioreactor. Mandatory sub-process	Purified waterFor 6A - precipitate (biofilm). For 6B - return active SL (from which excess active SL is removed)	Pumps for pumping out activated sludge (biofilm), partly for return to the aeration tank, partly as excess for processing. Secondary settling tanks (tank structures), scraper equipment	
Purified water. Solution of reagent for phosphorus removalSolution of reagent	N 9. Post-treatmentThe mandatory sub-process is determined by the	Purified waterWashing water (not in all variants)Sediment (not in all	Optional: Loading filters that provide separation of suspended	Periodic - spent loading (not for all variants).Sludge (not for all variants)

for flocculation of suspended substances	conditions of discharge of treated water	variants)	solids and/or oxidation of organic and nitrogenous compounds. Membrane disc filters. Mechanical filters. Sedimentation tanks with slats (thin-layer modules).Biopurds (tanks in the ground)	
Commercial reagent (reagents): salts of iron,	N 10. Preparation and dosing of reagent	Solutions of reagents for application	Tanks for storage of liquid reagent	

aluminum. Polyelectrolyte (flocculant).Sodium hypochlorite.Process water	solutions. Complex subprocess - can be carried out on several different threads. Optional sub-process		stock, rooms for storage of dry reagent. Solution-flow units with dosing equipment	
Purified (purified) water	N 11. Disinfection of purified or purified water. According to regulatory documents - a mandatory sub-process. However, there is no environmen			Discharge of treated wastewater into a water body

	tal feasibility, and sanitary and epidemiological depends on local water use conditions and the discharge season.			
Also: Liquid Chlorine, Tap Water	N 11A. Chlorine decontamination	Disinfected water. It can also be supplied for use as industrial water:- for the own needs of the enterprise; - other consumers	Liquid chlorine warehouse. Chlorinators. Mixer.Contact tank	Risk of an accident with the release of chlorine gas. Discharge of active chlorine, chloramines, organochlorine compounds into a water body from

				disinfected water (in the absence of dechlorination)
See also: Option 1. Commercial sodium hypochlorite. WaterVariant 2. Table salt.Industrial water	N 11B. Disinfection with sodium hypochlorite. Option 1. Using Commercial Sodium Hypochlorite Option 2. With the production of electrolytic solution of sodium hypochlorite		Option 1. Warehouse of commercial sodium hypochlorite, dosing system. Option 2. Electrolyzer, mortar and flow tanks, dosing system	Discharge of active chlorine, chloramines, organochlorine compounds into a water body from disinfected water (in the absence of dechlorination)

	N 11B. UV disinfection		UV decontamination plants	SpentUF lamps (mercury-containing waste)

Excess active sludge (or other liquid precipitates). According to option B - flocculant solution from subprocess N 10	N 12 Concentration of excess activated sludge (sediment). A. Gravity compaction. B. Mechanical thickening. Mandatory sub-process (there are exceptions)	Compacted/condensed active sludge (precipitate). Drain water	A. Sealant (settling tank structure), scraper equipment B. Mechanical sludge thickener. For all variants - pumps for pumping compacted/ condensed	Fugitive emissions of air pollutants

			sludge	
	N 13. Stabilization of liquid sediment.Optional sub-process	Stabilized sediment mixture		
Sediment of primary sedimentation tanks. Excess active sludge.Compressed air	N 13A. Aerobic Stabilization. Optional Subprocess	Aerobically stabilized sediment mixture	Tank structures - stabilizers. Aerators (very diverse devices for dispersing air in a liquid)	Fugitive emissions of air pollutants
Sediment of primary sedimentation tanks (from subprocesses N 5 or N 12). Redundant	N 13B. Anaerobic stabilization (methane digestion). Optional	Fermented mixture of sediment. Biogas (mixture of methane, carbon dioxide, with	Capacitive structures are methane tanks. Dosing and unloading	Fugitive emission of air pollutants, especially from

active sludge (from subprocess N 12)	subprocess	impurities)	chambers. Agitators, pumps, heat exchangers	loading and unloading chambers
Biogas.Air for combustion	N 13B-1. Processing and utilization of biogasAdditional sub-process in the presence of biogas	Energy.Drain water from drying and purification of biogas	Gasholders. Reset "candle". Power plants	Organized emission of substances that pollute the atmosphere from the pipe of the power plant. Periodically - waste for placeme

				nt (triggered loading to purify biogas from hydrogen sulfide)
Sediment of primary sedimentation tanks. Excess active sludge. Mesophilic fermented sediments.Solution of the drug for disinfection.Tap water	N 14A. Reagent disinfection of sedimentsAdditional sub-process	Sediments treated with the drug	System of preparation and dosing of the solution of the drug for disinfection	

Sediment of primary sedimentation tanks. Excess active sludge.Mesophilically fermented sediments.Dehydrated sediments	N 14B. Thermal disinfection of sedimentsAdditional sub-process	Heat-treated sediments	Heating, sludge recovery and heat recovery system (reactor and heat exchangers). Or infrared dehydrated sludge heaters	
Stabilized sediment mixture	N 15. Compaction of stabilized sediments. Optional sub-process	Compacted mixture of sediments. Drain water	Sealant (sedimentation tank structure), scraper equipment, pumps for pumping compacted sludge	Fugitive emissions of air pollutants

A mixture of sediment or one type of sediment, depending on different subprocesses	N 16. Sludge dewatering. Mandatory sub-process			In the absence of subprocesses for further processing of the sludge to produce the product, the dehydrated sludge is removed as a waste for placement.
Also: Flocculant solution from	N 16A. Mechanical dewatering	Dehydrated precipitate (kek). Filtrate	Complete equipment for	Organized emission

sub-process N 10. Process water		or fugate	mechanical dewatering: dewatering apparatus (centrifuges, filter presses, screw presses, etc.), transport lines (screws, belt conveyors), bunkers	of air pollutants
	N 16B. Drying and exposure of sediments on sludge sites in natural conditions	Dried sediment. Drain water	Concrete or earthen structures - sludge platforms.Loading and unloading equipment for cleaning and	Unorganized emission of substances that pollute the atmosphere.

			removal of sediment	Periodically - emissions from moving sources (motor vehicles). On earthen sites - filtration of sludge water of sediment into ground water
Also:Flocculant solution from subprocess N 10	N 16B. Flocculant treatment, thickening, drying and sediment	Dried sediment.Drain water	Concrete or earthen structures - sludge platforms. Slotted	Disorganized release of substances that

	retention, on sludge sites in natural conditions		wells for filtering out separated water. Loading and unloading equipment for cleaning and removal of sediment	pollute the atmosphere. Periodically - emissions from moving sources (vehicles). On earthen sites - filtration into ground water
Dehydrated sediment from sub-process N 16	N 17. Additional long-term exposure in natural conditions of sediment,	Treated precipitate	Outdoor areas	Fugitive emissions of air pollutants. Periodically -

	dried on sludge sites, or mechanically dehydrated			emissions from moving sources (motor vehicles)
Dehydrated precipitate from sub-process N 16. Organic fillers	N 18. Composting of dehydrated or dried sediments	Compost	The equipment is very diverse - from open areas to closed bioreactors	Unorganized emission of substances that pollute the atmosphere (when carried out in open areas. Periodically -

				emissions from moving sources (vehicles). Organized release - when the process is carried out in closed bioreactors and (or) indoors
Dehydrated or dried sediment after subprocesses N 13 and 16, or	N 19. Production of soils from sediments	Soil	Cooking sites on an artificial basis; mixing unit	Emissions from moving sources

16 and 17, 16 and 18. Other components of soils (in accordance with the specific technology), including: clay, sand, peat. Special additives, including for disinfection			(including drum mixers) and separation; loading and unloading equipment	of motor vehicles
Dehydrated sediment from sub-process N 16	N 20. Thermal drying of sediments	Thermally dried precipitate. In some variants - evaporation condensate	Complete heat drying units. Transport lines (screws, pneumatic conveyors), bunkers	Organized emission of substances that pollute the atmosphere.

				During dry gas cleaning - spent sorbents
Variantly or partially: dehydrated sludge from sub-process N 16- dried sediment from sub-process N 20.Technical water.Alkaline reagent (for wet purification of gas emissions).Sorbents for dry gas cleaning	N 21. Incineration (thermal disposal) of sludge	Sludge ash. Drain water from the purification of gas emissions	Complete combustion plants. Transport lines (screws, pneumatic conveyors), bunkers. Gas emission cleaning systems	Organized emission of air pollutants
There are exceptions (see section 2.2). Sand treatment technology can be more complicated. More details are described in				

2.2. Not for all varieties of the sub-process. In order to remove phosphorus phosphates, the reagent can be introduced to other points of the main process, as well as into return streams. Only in some technologies. Complex technological process with its own subprocesses. Detailed below. Except for compaction after joint aerobic stabilization (N 13A) and dewatering on screw presses (N 16A).

2.1.2 Brief description of basic environmental equipment. Typical wastewater treatment processes used in the industry

Sub-process N 1. Separation of floating coarse impurities (filtering)

It is necessary to ensure the normal operation of structures and equipment, to prevent accidents. Disposal of waste also (partially) delays those floating inclusions that may enter water bodies with treated water that are not delayed in the main stages of treatment. Properly designed and well-functioning pre-mechanical treatment facilities ensure the efficient operation of subsequent stages of wastewater treatment and sludge treatment. The absence or improper operation of pre-mechanical treatment facilities has a negative impact on the GSV fixed asset as a whole. A list of the most common filtering equipment is given in Table 2.2.

Table 2.2 - List of the most common filtering equipment

Equipment	Synopsis	Technological characteristics
Rack and pin grates	Wastewater flows through a collection of rods installed at an incline to the stream with fixed distances between them and a moving scraper for cleaning and lifting up the detained garbage.	The width of the prozors is from 60-80 mm (when used for preliminary coarse filtering) to 5-6 mm.Provide the so-called one-dimensional filtering, in which long narrow inclusions can pass through the grates
Stepped	Wastewater flows through a set of sloped	Provides a prosor size of up to 3 mm. Works effectively

	stepped canvases with fixed distances between them. One set of canvases - (through one) movable, one - stationary. The lifting of waste is carried out due to the reciprocating movement of a set of canvases - from step to step	with a washout layer of garbage for more efficient retention
Ribbon (slatted and perforated)	Wastewater flows through a set of plastic sections of small length (or fragments of sieves), equipped with hooks and hinged together in an endless tape	Perforated devices provide deep filtering with a two-dimensional effect (all inclusions that are larger than the size of the holes are delayed). Rack and pinion devices occupy an intermediate position between the sieves and the rod grates in terms of efficiency.
Drum (screw)	Wastewater flows from the inside to the outside through a drum rotating sieve. Caught garbage	The most efficient devices. Require prior removal of large inclusions. Performance applicable up

	through the central channel is diverted by an auger	to and including large operating systems

The technological efficiency of the filtering equipment is virtually immeasurable, since the content of coarse inclusions in wastewater is not subject to production control due to the practical impossibility of adequate sampling. Therefore, the effectiveness of the equipment is judged by the mass of retained garbage. According to the current standards [2], it is allowed not to provide for grates in the case of sewage supply to the pumping station when installing grates with gaps of not more than 16 mm or crushing grates in front of the pumps, while the length of the pressure pipeline should not exceed 500 m and pumping stations provide for the removal of waste detained on the grate. Pre-mechanical treatment plants are among the most intensive emitters of IO into the atmosphere, especially in cases where water on the OS is supplied by pressure pumping. Starting from the receiving chamber, the pressure in the liquid decreases and volatile substances dissolved in the wastewater are released with their intensive release into the air. Crushing of waste at the entrance to the GSV OS is not recommended, as this leads to an increase in the discharge of garbage particles with purified water.

Sub-process N 1-1.

Treatment (washing and dewatering) of coarse impurities detained on the grates. Waste from the grates (sieves) has a small bulk weight, and their transportation is more expensive. They contain a significant amount of organic contaminants. Placing this mass on landfills will lead to their decay with the release of foul-smelling substances. This problem is more pronounced the smaller the size of the prozors (cells) of the filtering devices. Dewatering (pressing) with pre-washing allows: - to reduce the mass of exported waste; - ensure higher stability of waste (resistance to decay); - with wash water, return to the main process part of the organic matter necessary for the intensification of biological treatment processes. To disinfect garbage, as a rule, sprinkled with chlorine lime (CaOCl) is used. A list of the most common equipment for washing and dewatering waste from the grates is given in Table 2.3.

Table 2.3 - List of the most common equipment for washing and dewatering waste from grates

Equipment	Synopsis	Technological characteristics
Garbage press	Dehydration is performed in a perforated cylinder using a piston or auger	Reduce waste by up to 2 times
Press with pre-washing chamber	Before feeding for dehydration, the waste is washed with process water (mixing in a closed container)	Almost complete washing of waste from suspended substances. Deeper dehydration of waste

Sub-process N 2. Removal of settling coarse impurities (sand)

The release of coarse impurities (sand) is necessary so that it does not settle in subsequent structures, preventing their work. Uncaptured sand in the presence of primary sedimentation tanks will settle in them in the absence of biological treatment facilities. At the same time, the sand removal facility (sand trap) should retain a maximum of sand and a minimum of organic pollution. As with coarse impurities, the measurement of the effectiveness of sand retention is not practiced. This task is challenging even for research purposes. The effectiveness of sand retention is judged by the sand content in the sediment of primary sedimentation tanks (if any). The sand content, which does not create difficulties for operation, is not more than 6% of the dry matter of the sludge (not more than 3% when using high-speed centrifuges for sludge dewatering). A list of the most common equipment for the discharge of sand from wastewater is given in Table 2.4.

Table 2.4 - List of the most common equipment for the discharge of sand from wastewater

Equipment	Synopsis	Technological characteristics
Horizontal sand trap	Wastewater moves in a rectangular container at a certain flow rate. Sand settles under the influence of gravity to the bottom and is transported (by scrapers or hydraulically) to the pit, from where it is pumped out by an airlift or pump	Effective retention of the sand fraction, but a high content in the sediment of small inorganic (clay, etc.) and organic particles. High dependence on the speed in the structure (flow). Special equipment is needed for raking sand.It is used starting from the average os

Horizontal sand trap with circular water movement	Wastewater moves along a ring tray located in a conical container. Sand settles to the bottom of the cone through a slot in the bottom of the ring tray	Effective retention of sand, but a high content of organic and other mineral particles in it. High dependence on the speed in the structure (flow rate).No special equipment is required for raking sand.However, the working volume in which the flow of wastewater directly moves occupies only about 15% of the construction volume.It is used in the range of small - medium os
Aerated sand trap	Wastewater moves in a rectangular or radial container, which is aerated by wall-mounted pneumatic aerators. Air forms a spiral flow in the structure. The sand settles to the bottom and	The use of air allows you not to depend on the speed (flow) of water. Reduced organic content in the sand.Maximum release of foul-smelling substances due to aeration of incoming wastewater. Undesirable

	is transported (by scrapers or hydraulically) to the pit, from where it is pumped out by an airlift or pump	before the structures of biological removal of phosphorus. It is used starting with small os, but the efficiency of sand retention in the lower range of PP is low, and generally lower than in other designs.
Tangential (vortex) sand trap	Wastewater in conical or circular in terms of capacity moves in a tangential direction. The subsidence of sand occurs under the influence of gravity and centrifugal forces. Sand is removed, as a rule, by hydro elevators	Compact and efficient construction. Applicable on ultra-small and small operating systems

Sub-process N 3. Treatment of sand sludge (pulp)

Variants A and B. Sand pads and bunkers Carry out dehydration and drying of the pescopulp, without changing the composition of the dry matter. Option B. Sand washing machines Washing from organic inclusions. Dehydration of sand. A list of the most common sand treatment equipment is given in Table 2.5.

Table 2.5 - List of the most common equipment for sand treatment

Equipment	Synopsis	Technological characteristics
Sand pads	The sand pulp pumped out of the sand traps is separated in shallow concrete or earthen tanks equipped with a drainage system to drain the drain water into the sand and drain water. Then the sand dries (in the appropriate season) and is removed	A source of foul-smelling odors. Sanitary unsafe.Does not reduce the content of organic substances in the sand, the latter can be up to 30%
Sand bunkers	In bunkers, in the process of accumulation of sand, its natural pressing takes	Does not change the composition of the sand,

	place. Separated wastewater by gravity through the pipeline returns to the trays in front of the sand traps	but provides a dry matter content of about 70%
Sand washing and dewatering devices	Sand pulp pumped out of sand traps enters the devices for washing sand from organic substances. Apply: - pressure gybrocyclones, - open conical containers in which mixing and (or) aeration are carried out. Drain water from these containers leaves through the overflow, the washed sand with an auger rises from the pit, while the surface area is dehydrated	Washing of sand to the content of organic substances not more than 5%. Dry matter content - not less than 80%

Для подготовки песка к использованию как строительного материала он обрабатывается на виброгрохотах, deworming and disinfected by steaming (Kuryanovskiye sewage treatment plants, Moscow).

Sub-process N 12 Concentration of liquid sludge

Excess activated sludge, which is part of the flow of return activated sludge discharged from secondary settling tanks, has too low a concentration (4-8 kg dry matter/m). To optimize most subsequent subprocesses, it is necessary to increase its concentration to 30-60 kg / m. In a number of variations of the technology, a mixture of sediment of primary sedimentation tanks and excess activated sludge is subjected to compaction. Sometimes technologies with separate compaction of the sediment of primary sedimentation tanks are used. The main equipment for compacting and thickening the sludge is shown in Table 2.14.

Table 2.14 - Basic equipment for compaction and thickening of sludge

Equipment	Synopsis	Technological characteristics
13A. Aerobic stabilizers	Open containers, structurally similar to aeration tanks (N 5B). Part of the organic matter of the sediment mixture (or only excess activated sludge) is oxidized as a result of an aerobic biochemical process carried out by activated sludge bacteria	The decay of the organic matter of the sediment does not exceed 20% - 25%. High power consumption
13B. Methane tanks	Closed containers without air access, stirred by agitators (preferably) and pumps. The contents of the methane tanks are heated by steam (less often in heat exchangers) to 53 ° C (thermophilic process) or to 35 ° C (mesophilic process, twice as slow). Part of the organic matter of the sediment mixture decomposes to a mixture of methane and carbon dioxide	Decay of organic matter up to 45%-48%. Biogas yield of about 900 liters per ton of decayed organic matter of the sludge.Very low energy costs.Thermal energy costs up to 160 GJ/1000 moped sludge

	(biogas) as a result of an anaerobic biochemical process (fermentation), carried out, among other things, by methane bacteria.	
Note: These liquid sludge treatment processes are not the only ways to stabilize them. The same effect is achieved by using subprocesses of composting (N 18) and drying (N 19). The combustion sub-process (N 21) completely eliminates the organic matter of the sludge.		

Sub-process No. 13. Stabilization of liquid sediment

Decomposition of easily degradable organic substances under aerobic or anaerobic conditions, reduction of odor during subsequent processing or use, production of biogas. The main equipment for the stabilization of liquid sediment is shown in Table 2.15.

Table 2.15 - Basic equipment for stabilization of liquid sediment

Equipment	Synopsis	Technological characteristics
13A. Aerobic stabilizers	Open containers, structurally similar to aeration tanks (N 5B). Part of the organic matter of the	The decay of the organic matter of the sediment does not exceed 20% - 25%. High energy

	sediment mixture (or only excess activated sludge) is oxidized as a result of an aerobic biochemical process carried out by active sludge bacteria	consumption (about 1/2 of the need for complete biological treatment)
13B. Methane tanks	Closed containers without air access, stirred by agitators (preferably) and pumps. The contents of the methane tanks are heated by steam (less often in heat exchangers) to 53 °C (thermophilic process), or to 35 °C (mesophilic process, twice as slow). Part of the organic matter of the sediment mixture decomposes to a mixture of methane and carbon dioxide (biogas) as a result of an anaerobic biochemical process (fermentation), carried out, among other things, by methane bacteria.	The decay of organic matter is up to 45%-48%. The yield of biogas is about 900 liters per ton of decayed organic matter of the sediment. Methane content - about 65%. Very low energy costs. The cost of thermal energy for heating the sludge to 160 GJ / 1000 mopurable sludge (thermophilic process without recovery). Can be reduced up to 15-20% of this value, through the use of heat recovery, as well as a mesophilic process.

		Secondary heat from the subprocesses of drying, incineration, cogeneration (in the utilization of biogas) can be used.
NOTE Treatment of liquid sludge is not the only way to stabilize it. The same effect is achieved by using subprocesses of composting (N 18) and drying (N 19). The combustion sub-process (N 21) completely eliminates the organic matter of the sludge.		

Subprocess N 13B-1. Processing and utilization of biogas

The biogas released during anaerobic digestion is a fuel with an energy value of about 2/3 of methane (21-23 kJ/m). Its utilization can provide the GSV os with a heat source to cover all thermal needs (the main thing is the cost of heating methane tanks) or at least half of the electricity consumption at the GSV os and most of the heat costs. Since the yield of biogas is uneven, it needs to be averaged before disposal. Biogas contains a number of contaminants and inclusions, so it needs pre-treatment before some types of disposal. In particular, before combustion in internal combustion engines, it is necessary to remove hydrogen sulfide and siloxanes (organosilicon compounds). The latter are able, when burned, to release silicon oxide, which forms vitreous deposits. The main equipment for the processing and utilization of biogas is shown in Table 2.16.

Table 2.16 - Basic equipment for processing and utilization of biogas

Equipment	Synopsis	Technological characteristics
To average the flow rate		
Gasholders	Unspent biogas at the utilization plant accumulates in a container of variable volume	Meet the needs of the OS
For cleaning		
Filters for hydrogen sulfide purification	Biogas is passed through a filter with granules of enriched iron ore. Hydrogen sulfide, reacting, is retained in the form of iron sulfide. Triggered	The efficiency meets the requirements for the subsequent utilization of biogas in internal combustion engines. As a rule, it is not used for disposal in steam boilers

	loading is removed as waste	
Filters for cleaning from siloxanes	Biogas is passed through a filter with an active carbon that sorbs siloxanes. Activated active carbon is removed as waste	The efficiency meets the requirements for the subsequent utilization of biogas in internal combustion engines. Not used for disposal in steam boilers
For recycling		
Special steam boilers for biogas (or double-burner boilers)	Biogas is burned in the boiler room to produce steam and hot water	Efficiency of 80% -85%. From preparation for disposal, only condensate removal is required
Cogeneration plants based on internal combustion engines (ICE)	Biogas is burned in internal combustion engines, which transmit energy to electric generators. Heat from the cooling of the ice is removed in the form of steam or hot water	The efficiency of electricity is about 45%, for heat about 40%. Require pre-purification from hydrogen sulfide and siloxanes (described above)

Sub-process No. 14. Sediment disinfection

Purpose: Disinfection of liquid sediments from bacteria of the Escherichia coli group, pathogenic microorganisms, deworming. The main equipment for sediment disinfection is shown in Table 2.17. Disinfection of wastewater sediment is also ensured by the proper application of the thermophilic digestion subprocesses in methane tanks and composting, as well as by a sufficient tracking period during the implementation of the sub-process 17.

Table 2.17 - Main equipment for sediment disinfection

Equipment	Synopsis	Technological characteristics
14A. Reagent disinfection		
Reagent dosing system	For dosing of reagents into a liquid precipitate, a reagent consumption-solvent tank and a dosing pump are used	In the case of using a stimulant inhibitor reagent, only sediment disinvasion is provided
14B. Thermal disinfection		

Thermal decontamination unit	Tank for withstanding at a temperature of 65 °C-70 °C of at least 30 minutes of liquid sludge, with a system of heat exchangers for heating and recovery (when heated by hot water) or only recovery (when heated by steam supply) Either installations for disinfection of dehydrated sediments with steam, or infrared irradiation	Provides complete disinfection of sludge

Sub-process No. 15. Compaction of stabilized sediments

Purpose: during the stabilization of liquid sediment, a significant part of the organic matter disintegrates, which leads to a decrease in the dry matter content in the sediment. To optimize subsequent dehydration, compaction is performed. The equipment used is identical to that used in sub-process N 12.

Sub-process No. 16. Sediment dewatering

Purpose: removal of free moisture to residual moisture of 70% -85% by drying in natural conditions on sludge sites or mechanical dehydration on mechanical dewatering apparatus. The main equipment for sludge dewatering is shown in Table 2.18.

Table 2.18 - Basic equipment for sludge dewatering

Equipment	Synopsis	Technological characteristics
16A. Apparatus of mechanical dehydration	Liquid sediment is treated with reagents (in the vast majority of cases - organic flocculants). As a result of the violation of the colloidal structure of the sediment particles, free water is released. It is separated under pressure (in belt or chamber filter presses, or screw presses) or in a centrifugal field (in centrifuges). The resulting filter (fugate) is removed. The dewatering process can be periodic (chamber filter	Flocculant consumption is determined by its properties and type of dehydration equipment and varies in the range of 3-9 kg/t of dry matter. Dry matter content of the dehydrated sludge also depends on the type and properties of the sludge, as well as the type of equipment. The practical range is 18%-30%

	presses) or continuous (all other types of equipment)	
16B. Sludge pads	Liquid sediment is poured into shallow containers (usually concrete or earthen) - sludge pads equipped with a system for draining water. After delamination of the sediment, the separated drain water is removed to the OS GSV for purification. After water drainage, the sediment dries up (or freezes) under the influence of climatic factors. Tossing and then picking up this process accelerates this process.	The dry matter content of the dehydrated sludge depends mainly on compliance with regulatory procedures and site loads. The practical range is 25%-40%
16V	In a sub-process similar to N 16B to accelerate stratification at the site, the precipitate is treated with cationic flocculant before filling. This greatly accelerates the separation of drain water and the subsequent drying of the sludge.	Dry matter content in dehydrated sludge - 30% -40%

Sub-process No. 17. Additional exposure in natural conditions of sediment, dried on sludge pads or mechanically dehydrated

Purpose: preparation of sediments for further use as organic fertilizers, soils, recultivant, etc. In the process of aging for several years, additional drying, freezing, stabilization and mineralization of organic substances, disinfection through the development of natural microbiological processes are achieved. The sub-process is advisable if thermophilic digestion is not used in the technological scheme before dehydration, or composting is not used after dehydration.

Appendix 4

National legislation on wastewater sediment management in the countries of the Baltic Sea Region (SLUDGE TREATMENT: GOOD EXPERIENCE AND PRACTICAL ADVICE. Project on Urban Reduction of

Eutrophication, PURE. Commission for the Environment of the Union of Baltic Cities, Vanha Suurtori 7, 20500 Turku,

Finland. 2012).

This section examines in detail the legislation of each of the countries in the Baltic Sea Region in comparison with the EU regulatory documents. Taking into account the similarity of legislation, the countries are grouped as follows: 1) the three Scandinavian states - Denmark, Finland and Sweden, as well as Germany, which has established the most stringent requirements for the treatment of sediment; 2) Poland and the Baltic States; 3) two non-EU member states in the Baltic Sea region – Russia and Belarus.The analysis of the legislation of each of the countries in the field of sediment management is based on the following factors:

general environmental legal acts and competent authorities;

regulatory and legal documents on the agricultural use of draught:

types of sediment;

mandatory or preferred processing methods;

maximum permissible concentrations of heavy metals, the content of pathogenic microorganisms and organic compounds;

the maximum permissible rates of application of sediment or a specific element (for example, total phosphorus) per year;

surfaces on which the use of sediment is prohibited;

laboratory studies of sediment and soils and sampling frequency.

regulatory and legal documents on the possibility of other use of sediment, for example, in forestry, landscaping, reclamation, landscaping;

specific rules regarding the incineration and disposal of sludge in landfills.

Information for each group of countries is collected in two comparative tables – one on the maximum permissible concentrations of heavy metals and the second on a review of key legal requirements – to better demonstrate the similarities, differences and degrees of stringency of the legal measures chosen in each country to regulate wastewater sediment management.

Scandinavian countries and Germany

Baltic States and Poland

Russia and Belarus

Scandinavian countries and Germany

Страна (анализируемое вещество)	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
	в мг/кг сухого вещества							
ФИНЛЯНДИЯ (в осадке)	3	300	600	2	100	150	1 500	-
ШВЕЦИЯ (в осадке)	2	100	600	2,5	50	100	800	-
ДАНИЯ (в осадке)	0,8	100	1 000	0.8	30	120	4 000	25 садоводство
ГЕРМАНИЯ (в осадке)	10 (5)*	900	800	8	200	900	2500 (2000)*	-
Директива ЕС 86/278 (в осадке)	20-40	-	1 000 - 1 750	16-25	300-400	750-1 200	2 500 - 4 000	-
ФИНЛЯНДИЯ (в почве, pH>5,8 (при стабилизации известью 5,5))	0,5	200	100	0,2	60	60	150	-
ШВЕЦИЯ (в почве)	0,4	60	40	0.3	30	40	100–150	-
ДАНИЯ (в почве)	0,5	30	40	0.5	15	40	100	-
ГЕРМАНИЯ (в почве)	1,5 (1)*	100	60	1	50	100	200 (150)*	
Директива ЕС 86/278 (в почве, pH 6-7)	1-3	-	50-140	1-1.5	30-75	50-300	150-300	-
в г/га/год								
ФИНЛЯНДИЯ (среднегодовая нагрузка на почву)	1,5	300	600	1	100	100	1 500	-
ШВЕЦИЯ (среднегодовая нагрузка на почву)	1,75	100	600	2,5	50	100	800	-
ДАНИЯ (среднегодовая нагрузка на почву)	Законодательством Дании ПДК не установлены							
ГЕРМАНИЯ (среднегодовая нагрузка на почву)	Законодательством Германии ПДК не установлены							
Директива ЕС 86/278 (ежегодные нагрузки)	150	-	12 000	100	3 000	15 000	30 000	-

Comparative analysis of the maximum permissible concentrations of heavy metals established by the current legislation of Finland, Sweden, Denmark and Germany when using sediment for agricultural purposes. If a state has several regulations with different requirements for heavy metal concentrations, a regulation implementing the provisions of the Wastewater Sediment Directive has been selected as the data source for the table.

For light soils with a clay content of <5% and a pH of 5–6

	Методы обработки (при использовании в сельском хозяйстве)	Применение необработанного осадка (при использовании в сельском хозяйстве)	Предельно допустимое содержание патогенных микроорганизмов (при использовании в сельском хозяйстве)	ПДК органических соединений (при использовании в сельском хозяйстве)	Предельная норма внесения осадка (при использовании в сельском хозяйстве)	Периодичность пробоотбора (при использовании в сельском хозяйстве)	Использование в лесном хозяйстве, лесоводстве, при рекультивации земель, озеленении Сжигание/сброс на полигоны ТБО	Сжигание/ сброс на полигоны ТБО
ФИНЛЯНДИЯ	Сбраживание, стабилизация известью или другой метод, значительно снижающий содержание патогенных микроорганизмов	Запрещено	---	---	Определяется на основании качественного состава почвы и потребности культивируемых культур в питательных веществах	Осадок: 12 раз в год в течение первого года, затем 4 раза в год Почва: перед первым внесением	Решение Министерства сельского и лесного хозяйства – те же ПДК, что и для сельского хозяйства + мышьяк	Сбор, обработка и использование «свалочного» газа. Сжигание: предпочтительно с рекуперацией энергии
ШВЕЦИЯ	Биологическая, химическая, тепловая обработка, длительное хранение или другой процесс, значительно снижающий опасность для здоровья	Допускается при внесении в почву в течение суток после распределения по поверхности	---	---	Макс. содержание общего P: в соответствии с классом почвы в зависимости от обеспеченности подвижными формами P и общим содержанием NH4-N: 150 кг/га при периодичности внесения не менее 1 года	Осадок: 1, 4 или 12 раз в год Почва: перед первым внесением	Рекомендации SEPA	Захоронение на полигонах ТБО с 2005 г. запрещено Сжигание: по разрешению региональных органов власти
ДАНИЯ	Стабилизация, компостирование, пастеризация	Запрещено	Отсутствие Salmonella; содержание фекальных стрептококков менее 100 на 1 г	Диэтилгексилфталаты (ДЭГФ), полиароматические углероды (ПАУ) (9), нонилфенол этоксилаты (НФЭ), линейные алкилбензол сульфонаты (ЛАС)	7 т сухого вещества /га при периодичности внесения не менее 1 года	Осадок: для тяжелых металлов – каждые 3 месяца, органических соединений – ежегодно Почва: перед первым внесением	В сельском хозяйстве – по решению местных органов власти; в зеленых зонах – пастеризованный осадок	---
ГЕРМАНИЯ	---	Запрещено	---	Адсорбируемые органические халиды (АОХ), полихлорированные дифенилы (ПХД) (6), полихлорированные дибензодиоксины (ДХДД)/ полихлорированные дибензофураны (ПХДФ)	5 т сухого вещества/га при периодичности внесения не менее 3 лет	Осадок: для тяжелых металлов, органических соединений – 2 раз в год, Почва: перед первым внесением, каждые 10 лет	Запрет на использование в лесах, лесопарковых и зеленых зонах	С 2005 г. на полигоны ТБО принимаются лишь отходы с содержанием органического вещества менее 5%
ЕС	Биологическая, химическая, тепловая обработка, длительное хранение или другой процесс, значительно снижающий опасность для здоровья	Государства-члены ЕС могут наложить условия использования необработанного осадка (при внутрипочвенном инжектировании или запашке в почву)	---	---	Государства-члены ЕС самостоятельно устанавливают максимально допустимую норму внесения осадка	Осадок: 1–2 раз в год Почва: перед первым внесением (государства-члены ЕС могут устанавливать более частую периодичность пробоотбора)	Не регламентировано Директивой по осадкам сточных вод (86/278/EEC)	Директива о полигонах (1999/31/EC) Директива по сжиганию (2000/76/EC)

A brief overview of the requirements of the current legislation of Finland, Sweden, Denmark and Germany in the field of wastewater management in comparison with the EU Directives (--- = "not established")

Baltic States and Poland

Страна (анализируемое вещество)	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
	в мг/кг сухого вещества							
ЭСТОНИЯ (в осадке)	20	1 000	1 000	16	300	750	2 500	-
ЛАТВИЯ (в осадке)	10	600	800	10	200	500	2 500	-
ЛИТВА (в осадке: I категория/II категория)	1,5/20	140/400	75/1000	1/8	50/300	140/750	300/2 500	-
ПОЛЬША (в осадке)	20	1 000	500	16	300	750	2 500	-
Директива ЕС 86/278 (в осадке)	20–40	-	1 000–1750	16–25	300–400	750–1200	2 500–4000	-
ЭСТОНИЯ (в почве)	3	100	50	1,5	50	100	300	-
ЛАТВИЯ (в почве)*	0,5–0,9	40–90	15–70	0.1-0.5	15–70	20–40	50–100	-
ЛИТВА (в почве: песчаная, песчанистый суглинок/суглинок, глинистая)	1/1.5	50/80	50/80	0.6/1.0	50/60	50/80	160/260	-
ПОЛЬША (в почве: легкая/средняя/тяжелая)	1/2/3	50/75/100	25/50/75	0,8/1,2/1,5	20/35/50	40/60/80	80/120/180	-
Директива ЕС 86/278 (в почве, 6<pH<7)	1–3	-	50–140	1–1,5	30–75	50–300	150–300	-
в г/га/год								
ЭСТОНИЯ (среднегодовая нагрузка на почву)	150	4 500	12 000	100	3 000	15 000	30 000	-
ЛАТВИЯ (среднегодовая нагрузка на почву: песчаная, песчаный суглинок/суглинок, глинистая)	30/35	600/700	1 000/1200	8/10	250/300	300/350	5 000/6000	-
ЛИТВА (среднегодовая нагрузка на почву: песчаная, песчанистый суглинок/суглинок, глинистая)	100/150	7 000/ 10 000	8 000/ 12 000	50/100	2 000/ 3 000	10 000/ 15 000	20 000/ 30 000	-
ПОЛЬША (среднегодовая нагрузка на почву)	Законодательством Польши ПДК не установлены							

Comparative analysis of the maximum permissible concentrations of heavy metals established by the current legislation of Estonia, Latvia, Lithuania and Poland when using sediment for agricultural purposes.

The LATVIAN MPCs of heavy metals in the soil differ depending on the type of soil (sandy soil / sandy loam, loam / clay soil) and pH (5-6; 6.1-7 and >7), so for each heavy metal there are 6 different MPC. In this table, theyare presented as a range of values from minimum (for sandy soils / sandy loams with a pH of 5-6) to a maximum (for loam / clay soils with a pH of >7).

	Методы обработки (при использовании в сельском хозяйстве)	Применение необработанного осадка (при использовании в сельском хозяйстве)	Предельно допустимое содержание патогенных микроорганизмов (при использовании в сельском хозяйстве)	ПДК органических соединений (при использовании в сельском хозяйстве)	Предельная норма внесения осадка (при использовании в сельском хозяйстве)	Периодичность пробоотбора (при использовании в сельском хозяйстве)	Использование в лесном хозяйстве, лесоводстве, рекультивации земель, озеленении	Сжигание/ сброс на полигоны ТБО
ЭСТОНИЯ	Анаэробное/аэробное сбраживание, включая компостирование; химическая или термическая обработка	Допускается только для благоустройства территорий, озеленения и рекультивации при внесении в почву в течение 2 суток после распределения по поверхности	Бактерии группы кишечной палочки <1000 КОЕ, отсутствие яиц гельминтов в 1 л	---	---	Осадок: 2, 4, 6 или 12 раз в год в течение первого года, затем 4, 3, 2, 1 раз в последующие годы Почва: перед первым внесением + каждые 5 лет	При использовании осадка при благоустройстве территорий, озеленении и рекультивации применяются те же требования, что и при использовании в сельском хозяйстве; применяются все требования.	---
ЛАТВИЯ	Хранение, анаэробное сбраживание, аэробная стабилизация и стабилизация известью, компостирование, пастеризация, сушка при температуре 100°C	Определено нормативными требованиями, однако сфера применения не указана	---	---	Макс. содержание общего P: 40 кг/га при периодичности внесения не менее 1 года, общего NH_4-N: 30 кг/га при периодичности внесения не менее 1 года	Осадок: 1, 2, 3, 4 или 12 раз в год Почва: перед первым внесением	При использовании осадка в лесном хозяйстве и рекультивации земель в том же нормативном акте установлены особые условия + макс. содержание; при озеленении – дополнительные ПДК по тяжелым металлам	Захоронение на полигонах ТБО: в нормативном акте по сельскому хозяйству установлены особые условия Сжигание: ---
ЛИТВА	Биологическая, химическая или термическая обработка, долговременное хранение или другие процессы, значительно снижающие опасность для здоровья	Запрещено, как и осадок III категории или класса C	*Escherichia coli*, *Clostridium perfringens*, яйца и личинки гельминтов, патогенные энтеробактерии[6]	---	Макс. содержание общего P: 40 кг/га при периодичности внесения не менее 1 года, общего N: 170 кг/га при периодичности внесения не менее 1 года	Осадок: 1, 4 или 12 раз в год Почва: перед первым внесением, в дальнейшем в зависимости от результатов	При использовании для рекультивации и в качестве удобрения для сельскохозяйственных культур, выращиваемых с целью их дальнейшего использования в качестве энергетического сырья, в том же нормативном акте установлены особые условия + максимальное количество 100 т/га/год	Захоронение на полигонах ТБО: (Национальный стратегически план управления отходами) снижение количества биологических отходов, вывозимых на полигоны ТБО Сжигание: ---
ПОЛЬША	Стабилизация + биологические, химические, тепловые или другие процессы, значительно снижающие опасность для здоровья	Запрещено	Отсутствие *Salmonella* в 100 г, а также яиц аскарид, власоглава и токсокары	---	3 т/га при периодичности внесения не менее 1 года	SОсадок: 2, 3 или 6 раз в год Почва: перед первым внесением	Любое другое использование, кроме применения в сельском хозяйстве, зеленых зонах, рекультивации, компостировании запрещено + максимальное количество 15 т/га/год	З ахоронение на полигонах ТБО: (Закон об отходах) снижение количества биологических отходов, вывозимых на полигоны ТБО Сжигание: ---
ЕС	Биологическая, химическая, тепловая обработка, длительное хранение или другой процесс, значительно снижающий опасность для здоровья	Государства-члены ЕС могут изложить условия использования необработанного осадка (при внутрипочвенном инжектировании или запашке в почву	---	---	Государства-члены ЕС самостоятельно устанавливают максимально допустимую норму внесения осадка	Осадок: 1-2 раз в год Почва: перед первым внесением (государства-члены ЕС могут устанавливать более частую периодичность пробоотбора)	Не регламентировано Директивой по осадкам сточных вод (86/278/EEC)	Директива о полигонах (1999/31/ЕС) Директива по сжиганию (2000/76/ЕС)

A brief overview of the requirements of the current legislation of Estonia, Latvia, Lithuania and Poland in the field of wastewater sediment management in comparison with the EU Directives.

Russia and Belarus

Страна (анализируемое вещество)	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As
	в мг/кг сухого вещества							
РОССИЯ (в осадке: группа I/группа II)	15/30	500/1 000	750/ 15 000	7,5/15	200/ 400	250/500	1 750/ 3 500	421
Директива ЕС 86/278 (в осадке)	20–40	-	1000–1750	16–25	300–400	750–1 200	2 500–4 000	-
РОССИЯ (в почве, pH>5,5)								
Максимальные допустимые концентрации	-	6**	3*	2.1	4*	32/6*	23*	2
Временно допустимые концентрации (песчанистый суглинок/глинистая почва)	0,5/2	-	33/132	-	20/80	32/130	55/220	55/
Директива ЕС 86/278 (в почве, pH 6-7)	1–3	-	50–140	1–1.5	30–75	50–300	150–300	-
	в г/га/год							
РОССИЯ (среднегодовая нагрузка на почву)	Российским законодательством ПДК не установлены							
Директива ЕС 86/278 (ежегодные нагрузки)	150	-	12 000	100	3 000	15 000	30 000	-

Comparative analysis of the maximum permissible concentrations of heavy metals established by the current legislation of Russia and Belarus when using sediment for agricultural purposes in comparison with the EU Directives. In Russia and Belarus, the same standards are used, the requirements of which are compared in this table with the requirements of the Wastewater Sediment Directive.

Indicators for unstable form of chemical elements

Index for unstable form Cr (III)

	Методы обработки (при использовании в сельском хозяйстве)	Применение необработанного осадка (при использовании в сельском хозяйстве)	Предельно допустимое содержание патогенных микроорганизмов (при использовании в сельском хозяйстве)	ПДК органических соединений (при использовании в сельском хозяйстве)	Предельная норма внесения осадка (сельское хозяйство) (при использовании в сельском хозяйстве)	Периодичность пробоотбора (при использовании в сельском хозяйстве)	Использование в лесном хозяйстве, лесоводстве, рекультивации земель, озеленении	Сжигание/сброс на полигоны ТБО
РОССИЯ	Биологическая, тепловая обработка, аэробная стабилизация, длительное хранение, пастеризация, компостирование	Конкретные требования не установлены	*Escherichia coli* >100/1000*, Salmonella, яйца гельминтов и цисты патогенных простейших кишечника	Органическое вещество >20%, общий N>0,6% сухого вещества, P_2O_5 >1,5% сухого вещества	Макс. содержание общего N - 300 кг/га при периодичности внесения не менее 1 года; макс. количество сухого вещества: тяжелые почвы - 10 т/га при периодичности внесения не менее 5 лет, легкие песчаные почвы - 7 т/га при периодичности внесения не менее 3 лет	Осадок: не определено Почва: перед первым внесением осадка	Допускается использование в промышленном садоводстве, лесоводстве, при озеленении и рекультивации почв и захоронение на полигонах ТБО	Захоронение на полигонах ТБО: осадок принимается на городские полигоны ТБО, обработка не требуется Сжигание: ---
ЕС	Биологическая, химическая, тепловая обработка, длительное хранение или другой процесс, значительно снижающий опасность для здоровья	Государства-члены ЕС могут изложить условия использования необработанного осадка (при внутрипочвенном инжектировании или запашке в почву	---	---	Государства-члены ЕС самостоятельно устанавливают максимально допустимую норму внесения осадка	Осадок: 1–2 раз в год Почва: перед первым внесением (государства-члены ЕС могут устанавливать более частую периодичность пробоотбора)	Не регламентировано Директивой по осадкам сточных вод (86/278/ EEC)	Директива о полигонах (1999/31/EC) Директива по сжиганию (2000/76/EC)

A brief overview of the requirements of the current legislation of Russia and Belarus in the field of wastewater management in comparison with the EU Directives (N = nitrogen).

For group I / group II sediment

The legislative and regulatory framework in the field of draught management in the countries of the Baltic Sea region is divided into three categories: Directives and other EU legal acts; the national legislation of the Member States implementing these Directives; standards and regulations of non-EU countries. All of the above can be studied from the point of view of two aspects: the form of legal acts and their content. Although the significance of the content is obvious, when assessing legal restrictions, it is also important to take into account the form (type) of the legal document.Legal restrictions in the field of draught management in the countries of the Baltic Sea Region can be divided into general for all countries and specific, which are present in the legislation of only some countries, and sometimes only one of them. Common limitations include:

pre-treatment methods;

maximum permissible concentrations of heavy metals in sediment and soil;

types of cultures and surfaces for which sediment can be applied;

regulatory compliance.

Main incentives and obstacles in the application of different methods of wastewater sludge management

Operational solutions and future challenges in sludge treatment depend not only on water management issues, but also on restrictions, incentives and policies in agriculture, energy, etc. Therefore, they need to be considered in the broader context of political leadership and governance. Nevertheless, water and sewerage companies in the Baltic Sea Region already have the opportunity to move forward towards a modern concept of obtaining resources from biomass, producing renewable energy and recycling nutrients.

The costs of collecting and disposing of sludge can account for up to 50% of the total operating costs of treatment facilities, so optimizing the treatment and disposal of sludge will significantly improve the economic efficiency of water resources management in general (Starberg et al., 2005). Rising energy prices, as well as preferential tariffs for supply to the grid and other mechanisms to support renewable energy sources, stimulate the use of anaerobic digestion and biogas production at treatment plants. Water supply and sewerage enterprises can transfer the sludge for disposal to contractors who are engaged in the cultivation of soils or the production of fertilizers, and biogas can be sold to enterprises of power grids. In addition to microorganisms, the sediment in small quantities contains many chemicals. Maximum permissible concentrations of heavy metals have been regulated for a number of years by both EU and national legislation, which has significantly reduced their amount in the sediment of urban wastewater. Recently, there have been active discussions about the content of hazardous organic compounds in urban wastewater and sludge. For decades, such a valuable resource as phosphorus has been discharged into watercourses with insufficiently treated wastewater. Since the 70s and 80s of the XX century, the efficiency of urban wastewater treatment in the Baltic Sea region has been continuously increasing. However, the rational use of nutrients extracted from wastewater has not yet been established. To increase the efficiency of phosphorus utilization, it must be perceived not as a pollutant, but as a resource to be extracted. Currently, general restrictions on how sediment can be handled and disposed of relate to pretreatment methods, maximum allowable concentrations of heavy metals in sediment and soil, selection of crops and surfaces where sediment can be applied, and regulatory compliance. Sediment management in eight of the nine Baltic Sea countries is governed by a wide range of EU regulations. In addition to the Directives, the European Union has other management tools. For example, the Inter-State Commission for the Protection of the Marine Environment of the Baltic Sea (HELCOM) is implementing various regulatory instruments and recommendations based on the ecosystem approach with a view to improving the vulnerable marine environment and reducing pollution. All nine riparian countries are required to implement HELCOM's recommendations, including Russia, which is a signatory to the Helsinki Convention.

For a more detailed description of national legislation on sludge hanging in the Baltic Sea Countries see annex to this publication. It should be noted that the operation of urban sewage treatment plants does not end with wastewater treatment. An important component for them is the treatment and disposal of the resulting sludge. Despite the fact that the processes of wastewater treatment and wastewater treatment In large cities with a population of several million people, the amount of municipal wastewater is calculated in millions of cubic meters per day, and the amount of sediment after treatment is hundreds of tons of dry matter. Increased requirements for wastewater treatment have led to an increase in the amount of dehydrated sediment placed in landfills. Further construction of landfills is impractical for several reasons: limited ability to allocate land for the construction of landfills; high costs for their construction and subsequent reclamation; environmental problems arising from the operation of existing landfills as potential sources of pollution of the atmosphere and groundwater. The only solution to the problem in some cases is the heat treatment of dehydrated sediments, that is, its combustion. Preliminary dehydration of sediments is of great importance in this case. One of the main requirements for the sediment mixture supplied for dehydration is a constant for a certain period (at least a day) and a controlled ratio of excess sludge and wet sediment (usually in terms of dry matter). Technological indicators of both dehydration and combustion depend on this ratio - the more sludge, the worse the dehydration indicators - the moisture content of the cake and the effect of retention, in connection with which it is necessary to increase the dose of flocculant and reduce the performance of the centrifuge. An increase in the content of excess sludge in dehydrated sludge due to its lower calorific stability than wet sludge leads to a deterioration in the combustion process and an increase in the consumption of natural gas. Indicators of dehydration and combustion processes depend on the concentration of dry substances in the incoming sludge, the lower the concentration, the worse the indicators of this process. All these factors necessary for successful combustion place higher demands on the organization of the technological process of water purification and preparation of the sediment for subsequent treatment.

Conclusion

The problem of treatment and disposal of wastewater sediment is still extremely relevant for almost all countries of the world. However, approaches to solving this problem differ from country to country. This is mainly due to the difference in the industrial development of individual countries. However, there are some common approaches. For example, the use of wastewater sediment as organomineral fertilizers is used in many countries, but the proportion of sludge recovered varies from country to country.

In addition, there has been a trend towards increased sludge recovery through incineration and pyrolysis using modern gas cleaning systems.

The ambiguous attitude towards wastewater sludge incineration plants in our country will change for the better, provided that the most advanced gas treatment systems are used. The experience of SUE "Vodokanal of St. Petersburg" confirms the effectiveness of the method of burning wastewater sediment, which is confirmed by the more than 20-year service life of sediment combustion plants. In the near future, the number of such plants in our country will increase, which will reduce the load on landfills for storing wastewater sediment.

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