Technological foundations of water treatment and disposal

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Abstract

The proposed textbook presents the technological foundations of water treatment and disposal with a description of all the main processes using modern scientific data. Particular importance in the manual is given to the processes of separation by settling, flotation and filtration, including the use of flotation settling tanks and flotation combines. The use of such equipment allows you to significantly intensify the processes of water purification.

The proposed manual is intended for students of higher educational institutions, graduate students, teachers and researchers of environmental profile.

Contents

Part I. Water Treatment

1.1. General information about the properties of water and water treatment

1.1.1. Physical and chemical properties of water systems and requirements for water quality.

Almost all the elements of the periodic system of D.I. Mendeleev are found in natural waters, and the main element, as is known, is oxygen, since it predominates by mass in the formula of water, hydrogen is much less (only 11.2%).

The hydrogen and oxygen atoms in the water molecule are located at the corners of an isosceles triangle with a bond length of O - H of 0.0957 nm, while the valence angle H - O - H is 104.5. The physical properties of water are anomalous. Melting of ice at atmospheric pressure is accompanied by a decrease in volume by about 9%. The temperature coefficient of volume expansion of ice and water is negative at temperatures respectively below -210 C and 3.98 C. In addition, the proximity of the valence angle H - O - H to the tetrahedral (109 28') causes a rather loose structure of ice and water and, as a result, the anomaly of a number of physical properties, in particular the density from temperature.°°°°

Water molecules, having a sufficiently large dipole moment (6.1710-30· Klm), interact very strongly with each other and in general with the polar molecules of other substances. At the same time, hydrogen atoms can form hydrogen bonds with atoms O, N, Cl, etc. A three-dimensional grid of hydrogen bonds, built from tetrahedra, exists in the entire interval from the melting point to the critical. Increase in density during melting, as in the case of dense modifications of ice, it is explained by the curvature of hydrogen bonds and the deviation of the angles between them from tetrahedral. The curvature of the bonds increases with increasing temperature and pressure, which leads to an increase in density. On the other hand, when heated, the average length of hydrogen bonds becomes longer, resulting in a decrease in density. The combined action of two factors explains the presence of a maximum density of water at 4 C.·°

The chemical properties of water, as well as the physical properties,differ in certain features. It is known that only a small fraction of the molecules undergo electrolytic dissociationaccording to the scheme: $H_2O = H^+ OH^-$. Proton H^+ in an aqueous medium, interacting with water molecules, forms H_3O^+, combining with one molecule H_2O in H_5 $About_2^+$. Distance of... O in such complexes is noticeably shorter than the length of the normal hydrogen bond between neutral molecules. But at the same time, the proton is not exactly in the middle of this shortened bond, but closer to one of the O atoms, and therefore it can be considered that there is a hydrated oxonium oxonium H_3O^+ in water. This phenomenon plays a very important role in the course of chemical processes.

Water is a fairly reactive compound. It is oxidized by atomic oxygen: $H_2O + O - H_2O_2$. When water interacts with F_2, HF is formed, as well as O, O_2, O_3, H_2O_2 and other compounds. With the remaining halogens, water reacts to form a mixture of acids. Under normal conditions, up to half of the chlorine dissolved in it interacts with water, in much smaller quantities - bromine and iodine. At elevated temperatures, chlorine and bromine decompose water to form acids and O_2. When water vapor is passed, for example, through hot coal, it decomposes and water gas is formed:

$$H_2O + C = CO + H_2$$

At elevated temperatures, in the presence of a catalyst, water reacts with CO, CH_4 and other hydrocarbons. As an example, we give reactions representing practical energy, in particular, in the presence of the catalyst Fe: $H_2O + CO = CO_2 + H_2$, in the presence of Ni or Co: $H_2O + CH_4 = CO + 3H_2$.

These reactions are used in technological processes of industrial production of hydrogen. These reactions are also of some interest for the neutralization of gas emissions containing CO and hydrocarbons.

Phosphorus, when heated with pressurized water in the presence of a catalyst, is oxidized into metaphosphoric acid:

$$6H_2O + 3P - 2NRO_3 + 5N_2$$

Water reacts with many metals to form hydrogen and the corresponding hydroxide. At the same time, with alkali and alkaline-earth metals, with the exception of magnesium, this reaction takes place at room temperature. Less chemically active metals decompose water at elevated temperatures, for example, iron at temperatures above 600 ° C:°

$$2Fe + 3H_2O - Fe_2O_3 + 3H_2$$

When oxides interact with water, acids or bases are formed. Water can act as a catalyst, for example, hydrogen and alkali metals react with chlorine only in the presence of traces of water.

Water dissolves substances with pronounced polar properties quite well, while the solubility of low-polar substances in it is quite low and has a complex dependence on temperature. It is known that many substances, dissolving in water, interact with it and ion-dipole interactions are established between ions dissolved in water that do not enter into chemical reactions with it. In addition, the interaction is also observed between molecules and atoms of solutes in water substances and water molecules. This phenomenon is called hydration. It should be noted that hydration can occur both with the destruction of water molecules and without it. Hydration is caused by electrostatic and van der Waals interactions, coordination and hydrogen bonds.

In aqueous solutions, multi-charge ions (e.g., Al^{3+}) and single-charged (Li^+) bind nearby water molecules. This produces aquacations, such as $(Al(H_2O)_6)^{3+}$. Salt crystal hydrates are usually formed when cations in their crystal lattice form stronger bonds with water molecules than with anions in the anhydrous salt lattice.

At low temperatures, the water in the crystal hydrates can be bound to both the cation and the salt anion. Water, which is part of crystal hydrates, is called crystallization. Pseudohydrates are also known to exist in which all or part of the water molecules are converted into hydroxides - ions or hydroxonium ions, for example, $HClO_4\ H_2O$ or $(H_3O)\ ClO_4$. The water that is part of such pseudohydrates is usually called constitutional. At the same time, in each crystal hydrate, water molecules are arranged in a fairly strict order. Water can bind an aquacation to anion by hydrogen bonds. There are crystal hydrates, in which water forms layers combined by salt ions. Fromthe west hydrate, in which water molecules have a structure similar to that of ice.

Of scientific and practical interest is a peculiar classification of the state of water in various compounds. Water, depending on the distribution among other substances, is divided into five different groups:

1) constitutional water - its molecules are part of the anion or cation of some complexes of cobalt, iron, platinum; the release of such water under the influence of heating usually causes the destruction of the crystal structure of the metal;

2) crystallization water - corresponds to a certain numberof molecules $H\ 2\ O$, which are part of some substances; it can be released when heated, but re-attached to the anhydrous

substance if it is again brought closer to water; at the same time, genuine hydrates are stripped, the crystal structure of which differs from the crystal structure of anhydrous substance;

3) soaking water - is found in zeolites, opals, clays;

4) wetting water, sometimes called adsorption water, is found on the surface of glass, quartz, mercury, in the "cavities" of iron;

5) physiologically bound water - is found in the tissues of living beings and is very different from crystallization water.

Thus, water is one of the rather complex substances both in physical and chemical indicators.

The chemical composition of natural waters according to the predominant ionic composition is divided into three classes: chloride, sulfate and bicarbonate. Each class is divided, in turn, into three groups: calcium, magnesium and sodium, i.e. classification is carried out by cations.

Many natural waters contain significant amounts of calcium, magnesium, sodium, chlorine, sulfur, and other elements, called macronutrients in this case. Their number, as a rule, does not exceed 10. But the number of trace elements, the content of which in water does not exceed 0.01%, is in most cases dozens of items.

The amount of substances dissolved in natural waters varies widely. For example, in marine waters their content is 3.5%, in river waters - in some cases only 0.005%, and in underground brines - more than 50%. The amount of dissolved substances depends on the possibility of using water for drinking, irrigation of fields, etc.

Russian geochemist A. Ovchinnikov proposed the following classification.

Total mineralization, g/l:	Name of waters:
less than 0,2	Ultra fresh
0,2 - 0,5	Fresh
0,5 - 1,0	with increased mineralization

1,0 - 3,0	Slightly salted
3,0 - 10,0	Salted
10,0 - 35,0	with high salinity
35,0 - 50,0	waters transitioning to brines
50,0 - 400,0	Brines

The hydrosphere is dominated by salt waters, which include the Oceans. Among the groundwater, salt water and brines predominate, and among the surface waters of the continents - most often fresh and ultra-fresh.

Drinking water of good quality, according to A. Ovchinnikov, contains no more than 500 mg of salts per 1 liter, while water with mineralization up to 1 g / l, and in some areas even up to 3 g / l, is also widely used.

It should be noted that many scientists lower the upper limit of ultrapresic waters to 0.1 g / l. Waters with such a salt content are common in areas with a predominant distribution of silicate rocks. The most detailed classification of natural waters by the presence of salts was developed by the famous hydrogeologist N. Tolstikhin. It emits, for example, superpresic waters with a mineralization of 0.01 - 0.03 g / l, which include ice and snow of the center of Antarctica. The division of waters by total mineralization did not allow to reflect many of their essential properties, including important in practical terms. Therefore, the main attention began to be paid to the composition of mineral salts, primarily to the content of ions in the water. It should be noted that when they talk about the content of ions in water, they mean primarily the way of expressing the results of research, since in natural waters, as a rule, there are no elements in the free state - only inert gases - helium, neon, argon, krypton, xenon, radon, and also partially oxygen and nitrogen are in water in free form.

The ionic composition of natural waters determines the features of their use both in the national economy and in medicine. At the same time, the features of the ionic composition of natural waters are of great importance when using water for drinking purposes. Thus, the content of ions in water of such elements as fluorine, potassium, calcium, etc., is of great importance for human health. At the same time, depending on the climatic conditions of a particular area, the content of ions of these elements may vary, which is reflected in GOST for drinking water.

It should be noted that the ionic composition of natural waters, with all its great scientific and practical significance, does not determine the entire diversity of waters. In many cases, its role is clearly receding into the background. This is due to the fact that in natural waters, some elements are present in both ionic and non-ionic form. In this regard, it is not possible to carry out a universal classification of natural waters in terms of the ionic composition content.

Dissolved organic substances (ROV) and gases have a huge impact on the geochemical features of most waters. In the biosphere, the main process of formation of ROV is the microbiological decomposition of plant and animal residues, while the synthesis of new specific high-molecular compounds of dark color - humus substances - also occurs. In composition and properties, they differ sharply from organic compounds of living organisms, for example, proteins.

In addition to humus compounds, many natural waters contain BOCs of the petroleum series - various hydrocarbons, phenols, etc. Found in the waters and organic compounds characteristic of living organisms - proteins, amino acids, carbohydrates, acetic, butyric and other acids, fats, esters, aldehydes, etc.

Along with humus substances for some groundwater, the ROV of the oil series are also known. In deep hot groundwater, where the activity of microorganisms is impossible, the formation of ROV is associated with the thermal decomposition of organic compounds of rocks and other related processes.

Organic substances are also dissolved in thermal waters. For example, in hot chloride-sulfate waters, copper, zinc, gold and other metals migrate as part of organic complexes. In hydrothermal solutions, this form of element transfer is very important.

All the data presented significantly change the theoretical ideas about the laws of water migration. Being part of an organic compound, the element seems to lose its individual chemical properties, and a variety of elements migrate at the same rate, determined by the intensity of migration of organic compounds. The properties of the ions lose their significance. Operating with parameters such as ionic radius, valence, etc. does not make sense. Thus, it becomes clear why the ionic composition of waters cannot claim to be the main geochemical parameter of waters. For example, the properties of ultrapresic waters are largely determined by the dissolved organic substances present in them.

In all natural waters, gases are dissolved, the content of which, as a rule, is small, but their geochemical role is not proportional to the mass. Of great importance is the high chemical activity and migration capacity of gases.

V.I. Vernadsky emphasized the geochemical role of gases. According to the gas composition, the scientist released oxygen, carbon dioxide, nitrogen, methane, hydrogen sulfide and hydrogen waters. The ideas of V.I. Vernadsky were further developed by A.M. Ovchinnikov, who divided all the waters into three types:

1) water with gases of an oxidizing environment (N_2, O_2, CO_2 , etc.);

2) water with gases of the restorative situation (CH_4, H_2S, CO_2, N_2, etc.);

3) waters with gases of metamorphic environment (CO_2 , etc.).

Dissolved O_2 contained in water comes from atmospheric air, and is also formed as a result of photosynthesis by algae, organic substances (carbohydrates) from inorganic. The oxygen content in water decreases due to the course of oxidation of organic substances and its consumption by living organisms during respiration.

A noticeable decrease in the oxygen content in the water indicates its pollution. This leads to a slowdown in the microbiological processes of self-purification in water. Another example of pollution: rainwater, previously considered pure today, contains an increased concentration of carbon dioxide due to pollution by human waste products. This is extremely undesirable for the microflora of water. It is known, for example, that fish can exist in the water in the pH range from 5 to 9, and the desired pH value should be in the range of 6 to 8.

In the water cycle, the following main links are distinguished: atmospheric, oceanic, continental, soil, river, lake, glacial and biological. It is known that the primary source of water on our planet is the ocean. When evaporating under the influence of sunlight from the surface of the globe annually passes into the atmosphere about 500 thousand^{km3} of water. About 2/3 of this amount returns in the form of atmospheric precipitation to the ocean. This is a small water cycle on our planet. The remaining 1/3 of evaporation is carried away by winds from the surface of the ocean to the land and joins the water vapor rising into the atmosphere from the vegetation cover, from the soil and water bodies of the land.

On land, about 100,000^{km3} of water falls annually in the form of precipitation. Part of this water evaporates and returns to the atmosphere, and the other part of the water that has fallen on the ground seeps into the ground, forming storehouses of groundwater. Sometimes groundwater finds its way out on the surface of the earth in the form of a spring

(spring). Next, the water flow rushes into the stream, which flows into the river and eventually this water flow replenishes the reserves of the seas and oceans. This closes the large cycle of water in the form of a spring (spring). nature: ocean - clouds - groundwater - springs - river - sea and ocean.

The duration of a complete change in the mass of water in water bodies, according to scientists, is very different. For example, the waters of the World Ocean are renewed every 2500 years, lakes - on average in 17 years, riverbeds - in 12 days, and water in living organisms - in a few hours.

Everywhere on earth, water flows from top to bottom and only in a gaseous state in the form of water vapor does water rise from the bottom up. In the general water cycle on our planet, it is this part of its path that provides water supply to the land, but largely unevenly and irregularly.

The biological link of the water cycle is very complex and diverse. The most important biological link that ensures the existence of the entire organic world on earth is photosynthesis with the participation of water. It also includes transpiration of plants. In the process of absorption of soil moisture by the roots, substances dissolved in water also enter the plant. With the help of transpiration, significant amounts of water consumed by plants are returned to the atmosphere (see Fig. 1.1).

When passing through the hydrological cycle, water is polluted with two types of waste. Common ones include organic residues, in particular, human and animal excrement, as well as plant fibers left after harvesting. Another type includes industrial waste of various industries and obsolete industrial products and equipment.

Although organic waste undergoes complete biological degradation, it is a significant problem and accumulates in large quantities in some places. Decay and decomposition of organic residues can cause a decrease in the oxygen content of lakes and rivers. At the same time, human excrement contains some of the most dangerous pollutants, including pathogens that can be carriers of diseases such as cholera, dysentery, etc.

Industrial waste can contain heavy metals and significant amounts of synthetic chemicals such as pesticides. These substances are very toxic and stable, they do not break down for a long time in natural conditions. Waste can enter water bodies both from faulty sewage devices and in various other ways, for example, when water flows through contaminated soil and then enters a river or lake. Hazardous sources of pollution of surface and groundwater are spontaneous landfills of various materials and substances.

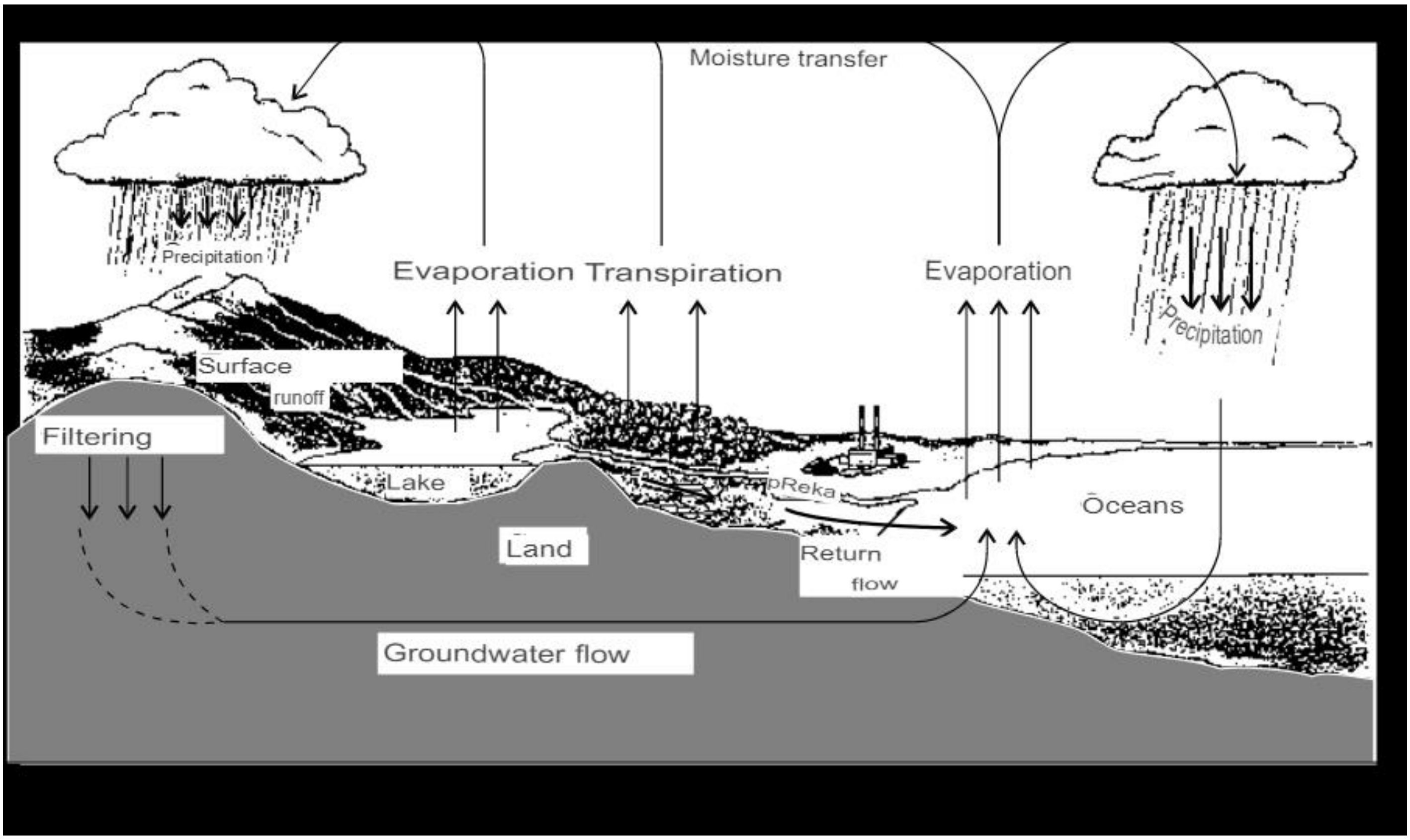


Fig. 1.1. Scheme of the water cycle in nature

Of particular note are the pollutants entering the water from the atmosphere, one of the most common of which is acid, which is formed during the release of nitrogen oxides and sulfur dioxide by industrial enterprises. Falling acid rain washes out positively charged ions from the soil, which then, getting into water bodies, can cause the death of fish and microorganisms.

Organic substances that have fallen into water bodies both with surface water flows and due to the death of aquatic vegetation do not remain unchanged and, as a result of the biological processes taking place, decompose into simpler substances. At the same time, organic substances are involved in the metabolic process of living organisms, the food of which they are, as a result, biodegradable substances with a smaller molecular weight are formed from large molecules of proteins, fats.

It is known that all substances of biological origin can be oxidized under aerobic conditions, regardless of the complexity of the composition of the parent substance. In natural conditions, there are always microorganisms that can fully or partially oxidize organic substances of biological origin. In this case, the substances formed in the process of decomposition of the starting material can be used by other microorganisms during the continuation of the chain of decomposition of the initial substances of complex composition to obtain water and carbon dioxide.

A convincing confirmation of the above is the absence of a "natural landfill" of organic substances of biological origin. In this regard, the biological oxidation of domestic wastewater pollutants is naturally included in the chain of the general biological cycle of the biosphere. Consequently, the main task of biological treatment of domestic wastewater is the intensification of those oxidative processes that occur in natural conditions, although in reality in the process of biological treatment of domestic wastewater it is necessary to face many different problems associated with the need to adapt certain strains of microorganisms to oxidize various chemicals synthesized by man in artificial conditions. It should be noted that the adaptive (adaptive) properties of microorganisms have naturally boundary possibilities, so certain classes of substances cannot be oxidized biologically both in natural and artificial conditions. In this regard, other methods are used to neutralize such substances, for example, chemical, physico-chemical, physical, etc.

1.1.2.On **the effect of weak electromagnetic fields on water systems**

One of the ways of physical effects on water and water systems is the use of electromagnetic fields. In the twentieth century, or rather in its second half, many works were published in the scientific and popular science literature on the properties of water and the preservation by water of individual properties acquired after external, including electromagnetic, effects. At the same time, along with such works, there were publications that rejected such allegations. In the end, it seemed that the truth had triumphed and the water had no memory from external influences. However, with the onset of the so-called perestroika in society, everything turned out to be wrong. Again, there were works with the old statement that water has a memory from external influences, even from the human voice and at the same time from the social significance of human thought.

Some films about water shown on television claim that the structure of water changes under the influence of the human voice and retains these changes after this impact. At the same time, it is argued that when voicing kind words, water becomes more tasty and pleasant, and in the case of voicing bad words, for example, the word "Hitler", the water becomes very bad. What can I say? A complete fantasy and there are no references to the results of any serious research.

Magnetic treatment in fields up to 3000 oersteds does not have any noticeable effect on changing the physicochemical properties of water and aqueous solutions. By the way, such processing, as a rule, is carried out with the pronunciation of various words of both optimistic and pessimistic mood, which does not affect the accuracy of the experiment. And, indeed, the effect of a magnetic field of such intensity with magnetic field sources in the form of permanent magnets or electromagnets (Fig. 1.2) on changing the properties of high-purity water has not yet been experimentally proven by anyone.

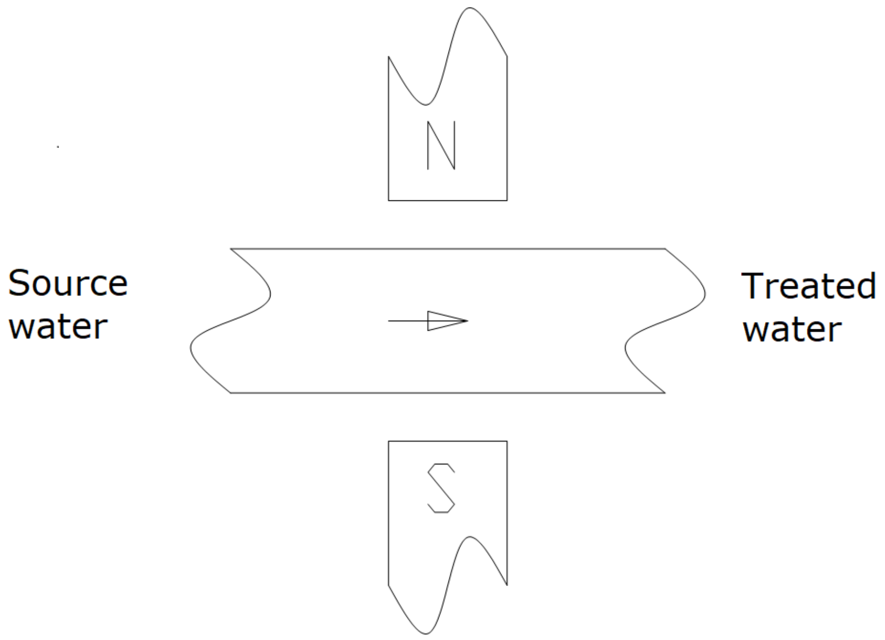


Fig. 1.2. Scheme of magnetic water treatment

However, there are a large number of works in which it is argued that on distillate and bidistillate, the action of magnetic fields with a strength of the order of thousands, hundreds and even tens of ørsteds affects so much that it can be detected by changes in electrical conductivity, viscosity, diamagnetic susceptibility, dielectric constant, light absorption and other physical properties of water. Unfortunately, these experiments are not reproduced. The reasons for non-reproducibility, as a rule, according to the authors of such works, remain not entirely clear. However, in almost all cases when we had to check the results of such work, the reason was one that the claimed effect was large within the errors of the method in question.

At the same time, we were faced with the task of using at least one method for determining the degree of "magnetization" of water to determine the effect of various parameters of magnetic treatment on the efficiency of this process and, on the basis of these experiments, to give recommendations for their practical use.

We tested several methods for indicating the degree of "magnetization" of water, but positive results were achieved only when using protein electrophoresis on a supporting medium, which was used as a polyacrylamide gel.

The final results of this effect were that the magnetic treatment of the water, on which the polyacrylamide gel was subsequently prepared, adversely affected the structure of the gel, namely, led to an increase in the heterogeneity of the medium. Later it was shown that the reason for the increase in the heterogeneity of the structure of the polyacrylamide gel was the agglomerates of ferromagnetic iron particles formed in the magnetic field that acted on this water containing such iron particles. Such aggregates in the case of obtaining a polyacrylamide gel degrade its structure, and in the case of using magnetic treatment to reduce scale formation on heat exchange surfaces play a positive role, being centers of crystallization of calcium and magnesium salts (Fig. 1.3).

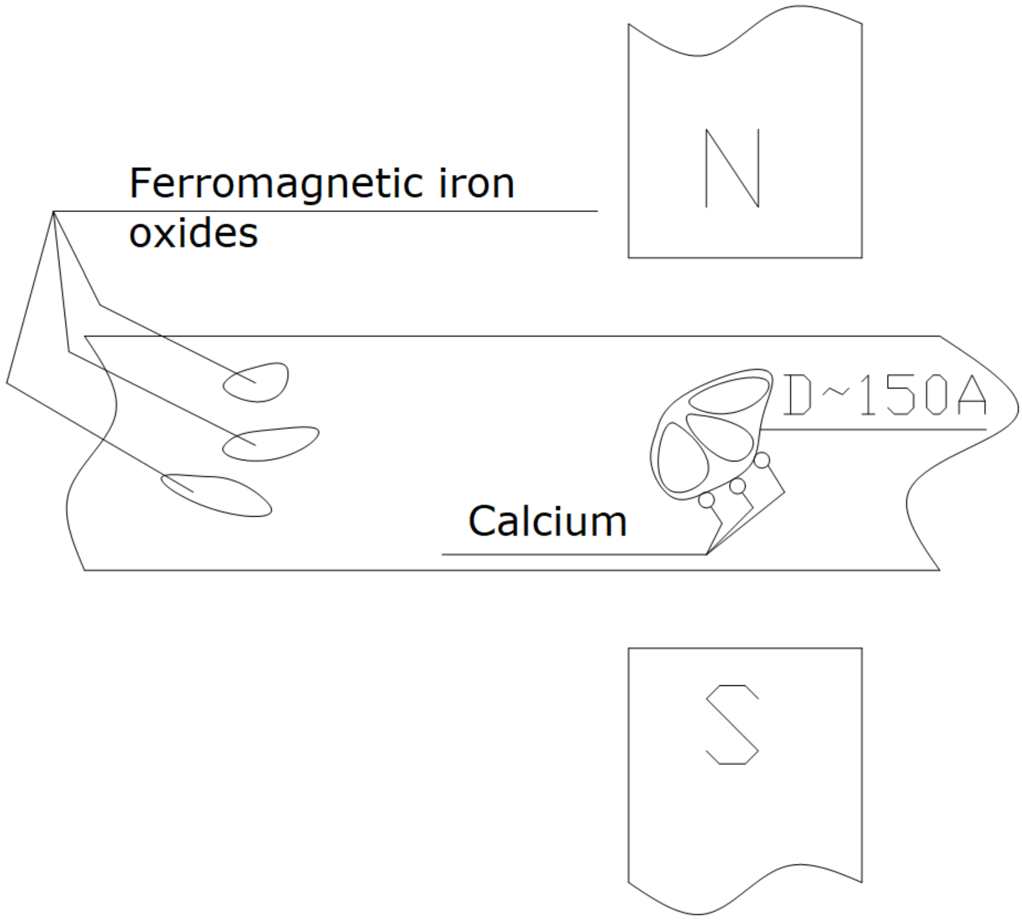


Fig. 1.3. Scheme of formation of aggregates from ferromagnetic particles of iron

This effect was manifested when using tap water, which almost always contains ferromagnetic iron oxides.

The minimum content of ferromagnetic oxides in water should be at least, as the results of our experiments showed, 0.3-0.4 mg / l.

The effect of the magnetic field when using bidilled water could not be detected.

In this regard, it was concluded that the effect of magnetic water treatment is associated with the presence of ferromagnetic iron oxides in the water. Additional studies on the effect of the magnetic field on iron in a dissolved state with paramagnetic properties did not lead to the above effect.

Another possible manifestation of the effect of exposure to an electromagnetic field is the mixing of a multicomponent non-equilibrium water system containing necessarily ionic components. This mixing effect at the so-called micro level, that is, the level of ions and molecules, was established by us when preparing the reaction medium for the production of polyacrylamide gel. The essence of the installed effect is as follows. When a magnetic or electromagnetic field is applied to a moving non-equilibrium water system containing an electrically conductive component, such as an electrolyte solution, the ions are affected by the force of the induced electric field in a liquid medium, intensifying diffusion processes. This leads to the mixing of the water system at the "micro level" almost immediately after the imposition of an electromagnetic field on the water system.

It is known that the effectiveness of the use of coagulants and flocculants in the processes of natural and wastewater treatment depends both on the properties of these reagents and on the conditions of their contact with water. Rapid mixing of reagents with water, as a rule, increases the efficiency of their use. The use for these purposes of devices with agitators, as the most effective technical means, leads in some cases to the destruction of the units formed in this case, which in this regard requires strict observance of the time interval of mixing. The use of various whirlpool and vortex mixers, although they have become very widespread in domestic practice, is less effective than devices with agitators.

The electromagnetic mixers developed by us do not have the above disadvantages and are highly efficient. The principle of operation of these mixers is based on the mixing or "absorbing" effect of the electromagnetic field described above when it is applied to a non-equilibrium reagent system - water. This effect was established by us in 1974 in the study of the properties and effectiveness of the use of polyacrylamide gels (Ksenofontov B.S. et al. Doklady as USSR, 1974, v. 215, No. 4; 1976, v. 227, No. 1).

The force that occurs when exposed to an electromagnetic field moves ions in small local regions commensurate with the scale of turbulent pulsations that are formed during the movement of the considered non-equilibrium water system. In this case, mixing occurs at the micro level, i.e. at the level of ions and molecules. Mixing any mixture at the micro level makes it homogeneous at the molecular level, which leads to a more complete use of reagents involved in subsequent chemical reactions and physical processes.

The mechanism of the absorbable effect of the electromagnetic field described above makes it possible to create various magneto- and electric mixers, including in the form of a mixer made in the form of one or more pairs of permanent magnets or electromagnets fixed on the surface of the pipe through which natural or wastewater flows. At the same time, a branch pipe is installed in front of the system of magnets or electromagnets, through which a solution of coagulant is supplied, usually in the form of aluminum or iron salts. The coagulant thus introduced is almost instantaneously (within a fraction of a second) mixed at the micro level with the treated water. This leads to a more complete use of coagulants and a reduction in their consumption by up to 10 - 20%.

In the case of adding flocculants to natural or wastewater, it is possible to use electromagnetic mixers of a more complex design, made in the form of a linear induction rotator with a load of cylindrical or any other form of elements that rotate intensively under the action of a rotating electromagnetic field. Some of the simplest analogues can serve in this case as a magnetic stirrer, but only as a first approximation. Rotating under the action of an alternating electromagnetic field, ferromagnetic elements stir the flocculant-water mixture, bringing it to a homogeneous state for 0.5 - 1.0 minutes or less.

The use of small-sized electromagnetic mixers allows not only to reduce the consumption of reagents, but also to perform components for mixing reagents with natural and wastewater in the form of compact automated devices.

It should also be noted that magnetic treatment to reduce scale formation is carried out at relatively small field strengths, not exceeding, as a rule, 2500 - 3000 ørsteds. In industrial settings, both permanent magnets and electromagnets are sometimes used. Magnetic devices with permanent magnets are easier to operate. However, permanent magnet machines are more difficult to adjust, and the field strength is practically limited to 1000-2500 ørsteds in a small gap.

Electromagnets must be placed in a dry place, they are more bulky than permanent magnets, consume electricity, but are convenient when it is necessary to change the field strength and allow you to create fields up to 2000 - 3000 ørsted and more (provided that the solenoids are cooled).

In some cases, electromagnets operating on alternating current without rectifiers are used. The effectiveness of these magnetic devices has not been subjected to detailed research. The productivity of such devices is small (up to 10 - 15 cubic meters / h).

Using the data of the practice of magnetic processing, it is possible to recommend devices with permanent magnets for installations of small capacity, not exceeding, as a rule, several tens of cubic meters / h, and in installations of greater capacity electromagnets should be used.

The speed of water flow is essential. Most authors working in the field of magnetic processing recommend a speed of about 1 m / s, however, there are cases of increasing the flow rate to 2 - 4 m / s without a noticeable deterioration in the effect of magnetic processing. When designing, it is necessary to focus on the speed of 1 m / s, and during operation the value of this parameter can be clarified.

The technical solutions developed and described above were used in the domestic practice of water treatment for both drinking and industrial purposes.

1.1.3. Water Quality Requirements

Depending on the purpose of use, certain requirements are imposed on water quality. Consider first of all the requirements for the quality of drinking water.

The quality of drinking water has a great impact on human health. In this regard, the preparation of drinking water is important, especially in large cities, where in most cases water is taken from surface water bodies experiencing high anthropogenic load. In addition, there is a constant tightening of drinking water quality standards. All this leads to the need for continuous improvement of equipment for water treatment. Water treatment technologies include the use of various methods and devices. In most cases, a two-stage water treatment technology is used, which includes the following stages: water intake, reagent water treatment, its subsequent settling and filtration.

The problem of the content of various toxicants in drinking water attracts the attention not only of researchers of various fields of science and water treatment specialists, but also of consumers. The concentrations of pollutants in surface waters vary widely, and depend on many factors. The dominant of them is human economic activity, as a result of which surface runoff and precipitation are polluted with a variety of substances and compounds, including organic ones. The quality of drinking water is largely determined by the stage of water treatment. Depending on what methods and reagents are used for this, the quality of drinking water entering the centralized water supply network is formed.

The complexity of the problem lies in the fact that the set of organic pollutants contained in microquantities, both in surface waters and drinking water, is very wide and specific. Some substances, such as pesticides, polycyclic aromatic hydrocarbons (PAH), organochlorine compounds (HOC), including dioxins, heavy metals (HM), even in microdoses, are extremely dangerous to human health, so almost every year there is a tightening of environmental requirements for purified water, especially for the MPC of organochlorine compounds, inevitably formed during chlorination.

The requirements for water used in industry in most cases do not exceed the value of the standards characterizing the quality of drinking water. However, there are industries that use water whose quality is noticeably higher than the quality of drinking water. These may include certain industries of electronic, instrument-making, food and other industries. A number of modern industrial consumers place such high demands on the quality of water used that no natural source of water supply can satisfy them. These requirements can only be met as a result of artificial water treatment. Such consumers include, for example, high-pressure steam boilers, the semiconductor industry and others. It should also be noted that there are many different industries for which the quality indicators of the water used are much less stringent than the indicators of the quality of drinking water (see, for example, Annex 1, Section 2, Table P-1.6).

The most striking examples of individual requirements for the quality of water used are recycling water management systems. In these cases, the specific water quality requirements are determined by the local technological service of the enterprise.

Thus, the requirements for the quality of the water used depend on the purpose of its use and, depending on this, specific water treatment technologies are applied.

1.1.4. Environmental regulation and monitoring of water bodies

Problems in the use of water resources depend on the quality of the natural environment. In general, it should be noted that the regulation of the quality of the natural environment should begin with the definition of environmentally acceptable effects, the development of norms for such exposure at each point in the environment for each organism and system, for example, the norms of maximum permissible concentrations (MPC) and maximum permissible environmental loads (MPEL). Accordingly, criteria should be developed aimed at limiting the sources of exposure, for example, the norms of maximum permissible emissions (MPE) of pollutants into the environment. The development of norms requires taking into account a large number of factors, and the priority of factors and effects of influence is of great importance. In the case of limited material resources, the identification of priorities for action is particularly important. It is necessary to take into account all possible types of damage - environmental, economic, social, political.

Let us consider successively the issues of standardizing the quality of wastewater treatment, discharged both into the city sewerage system for their subsequent complete treatment at urban treatment facilities, and treated wastewater into an open reservoir (lake, river).

Industrial wastewater can be accepted into the city sewerage if the content of harmful substances in it does not exceed the values given in the Decrees of the Government of the

Russian Federation dated July 29, 2013 No. 644 and Dated November 3, 2016 No. 1134 (see Annex 1, Section 3, Tables P-1.7 and P-2.7).

When treated wastewater is discharged into a body of water, the quality of the water in it undergoes changes. Up to a certain limit characterized as an acceptable ecological shift, the quality changes so slightly that the water remains virtually harmless to the relevant water uses, as well as in the complete absence of pollutants. The concentration of substances entering the reservoir does not remain constant. It changes primarily due to the dilution of wastewater and due to various chemical, physicochemical and biochemical processes in water.

Protection of water bodies from pollution is carried out in accordance with the "Sanitary Rules and Norms for the Protection of Surface Water from Pollution". The rules include general requirements for water users in terms of wastewater discharge into water bodies. The rules establish two categories of water bodies:

I - water bodies for drinking and cultural purposes;

II - water bodies for fishery purposes.

The composition and properties of water in type II water bodies must comply with the standards at the place of wastewater release with a dissipation release (if there are currents), and in the absence of a scattering outlet - no further than 500 m from the place of release.

The rules establish standardized values for the following water parameters of water bodies: the content of floating impurities and suspended particles, odor, taste, color and temperature of water, pH value, composition and concentration of mineral impurities and oxygen dissolved in water, biological water demand for oxygen, composition and maximum permissible concentration (MPC) of toxic and harmful substances and pathogenic bacteria.

The maximum permissible concentration is the concentration of a harmful (poisonous) substance in the water of the reservoir, which, with daily exposure for a long time to the human body, does not cause any pathological changes and diseases, including in subsequent generations detected by modern methods of research and diagnosis, and also does not violate the biological optimum in the reservoir.

Harmful and poisonous substances are diverse in their composition, and therefore they are standardized according to the principle of a limiting indicator of harmfulness (LIH), which is understood as the most likely adverse effects of this substance.

For water bodies of the first type, three types of HDL are used: sanitary-toxicological, general sanitary and organoleptic, for water bodies of the second type - in addition, two more types: toxicological and fishery.

The MPC has been established for more than 400 harmful basic substances in drinking and cultural water bodies, as well as more than 100 harmful basic substances in fishery reservoirs (see Annex 1, Section 4, Table P-1.8-9.

Compliance with the above requirements is possible when implementing the recommendations of existing regulatory documents (see Annex 1, Section 5, Table P-1.10), as well as the recently developed best available technologies (BAT) in various areas of water treatment and sanitation (see Annex 1, Section 6).

In 2015, the information and technical reference book "Wastewater Treatment Using Centralized Wastewater Disposal Systems of Settlements, Urban Districts" was approved.

In the development of this reference was used

Federal Law of 21.07.2014 No. 219-FZ "On Amendments to the Federal Law "On Environmental Protection" and Certain Legislative Acts of the Russian Federation", which laid the legislative foundations for the transition of rationing in the field of wastewater treatment based on the best available technologies (BAT). The most important documents in the new system will be the Information and Technology Handbooks on Best Available Technologies.

The implementation of the recommendations set out in the above-mentioned normative documents and handbooks predetermines the successful implementation of problems in the efficient use of water resources.

1.2. Sources of water supply

Water supply sources are divided into surface, which include a fence from a river or lake, and underground. The latter are more reliable in sanitary and hygienic terms. Indeed, in the event of possible accidents, the water of these sources is practically not subject to pollution.

Groundwater, depending on the level of location, is divided into soil, groundwater and interlayer. Figure 1.4 shows the simplest scheme of groundwater occurrence.

Groundwater non-pressurized (Fig. 1, 4 Pos.1) is located in the first aquifer from the earth's surface. Their composition and consumption are stable, they are widely used as sources of water supply in rural areas. Interlayer waters are located in aquifers located between two watertight layers. The composition of these waters is characterized by great constancy. They are well protected from direct contamination by surface runoff and the water of such sources is used, as a rule, without treatment and disinfection of groundwater. However, in some cases, when water is taken from an underground source, it is purified and disinfected (Fig. 1.5).

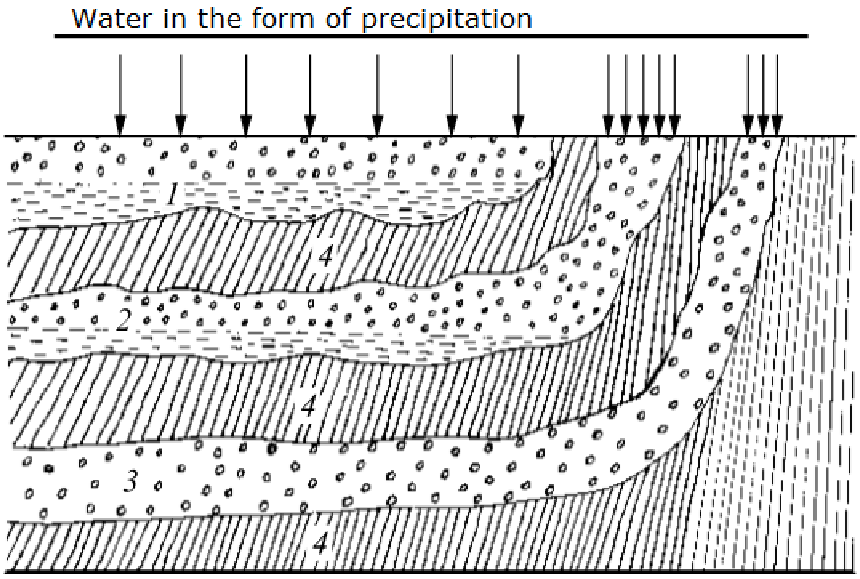


Fig.1.4. Scheme of groundwater occurrence: 1 - groundwater aquifer; 2 - an aquifer of inter-reservoir non-pressure waters; 3 - aquifer of artesian waters; 4 - water-resistant aquifers

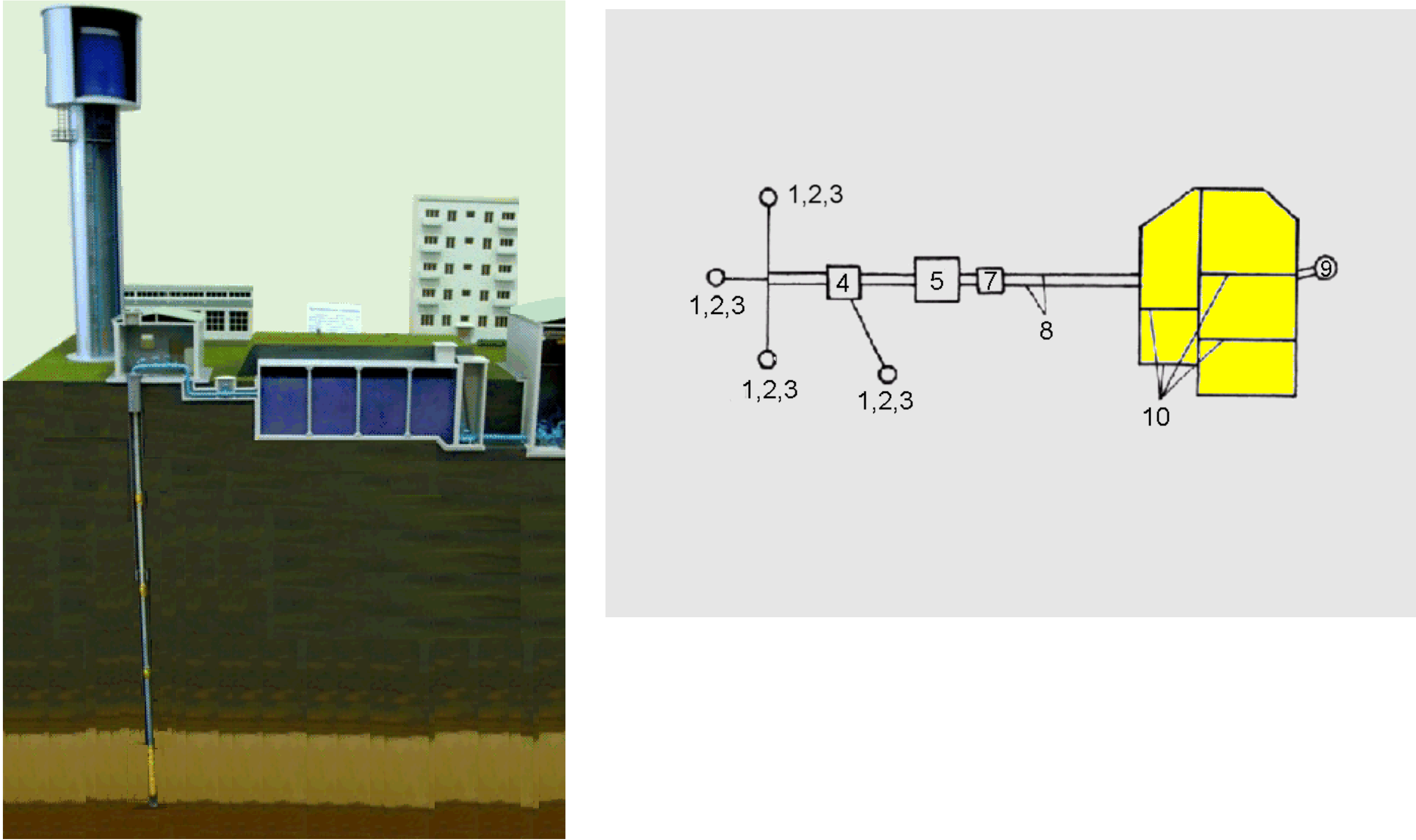


Fig. 1.5. Scheme of water supply from an underground source

1 - water source; 2,3 - water intake construction-

; 4 - treatment plants; 5 - clean water tanks; 6 – water treatment with ultraviolet; 7 - pumping station of the second lift; 8 - water pipelines; 9 - water tower; 10 - main water distribution networks.

In the case when a large flow of water is necessary, rivers, reservoirs, lakes are used as water sources. The water of such sources contains many suspended particles, for example, sand, the smallest residues of various plants and organisms, as well as many microorganisms unsafe for human health. Therefore, water from open sources is used for drinking purposes, as a rule, with preliminary treatment, including disinfection.

Consider the simplest scheme of water intake from a river or lake (Fig. 1.6).

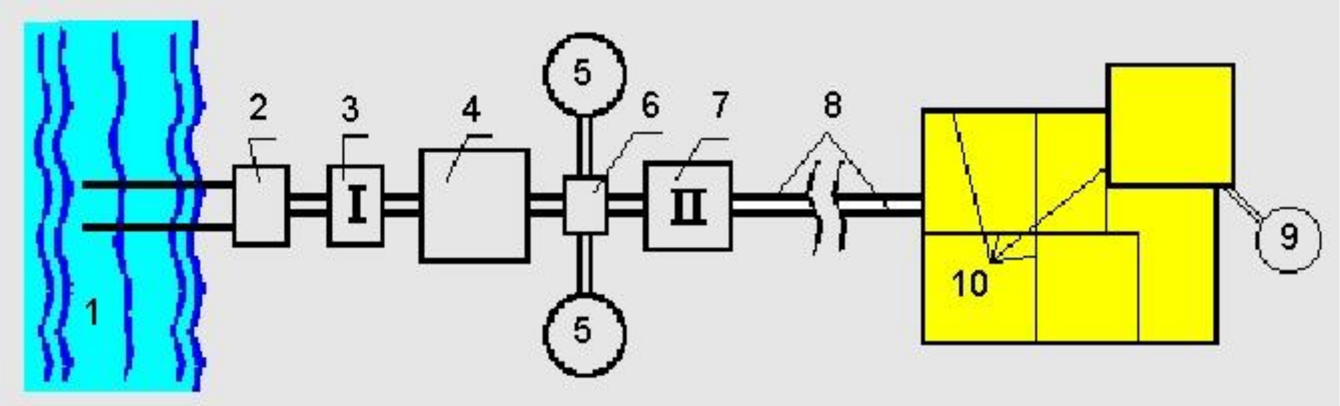


Fig. 1.6. Scheme of water supply from a surface source

1 - water source; 2 - water intake facility; 3 - pumping station of the first lift;4 - treatment facilities; 5 - clean water tanks; 6 – switching camera; 7 - pumping station of the second lift; 8 - water pipelines; 9 - water tower; 10 - main distribution water supply networks

The source water is first supplied by the pumps of the first station to the sedimentation tanks, where the suspended particles precipitate. To speed up this process, special chemicals are added - coagulants, which contribute to the adhesion of suspended particles into larger aggregates. After that, the water is filtered and sent for disinfection, which is carried out by chlorination, ozonation or ultraviolet irradiation. Further, the purified water enters the distribution network to consumers.

The actual scheme of water intake, purification and disinfection of water, as a rule, is more complicated. Nevertheless, the scheme discussed above gives a general idea of the sequence of technological operations that have to be carried out in order to obtain clean and disinfected water.

Water intake devices from surface sources should ensure the intake of the calculated water consumption from the water source and supply it to the consumer, protect the water supply system from biological fouling, from the ingress of sediments, litter, plankton, etc. In addition, on fishery water bodies, water intake devices must meet the requirements of the fish stocks protection authorities, including protecting young fish from entering the water intake. There are many different types of water intake devices, the use of which is advisable under different conditions.

For the abstraction of water from surface sources, the removal of phytoplankton is essential. The development of phytoplankton depends on a number of factors, the main of which are the warming and illumination of water masses, as well as the presence of sufficient nutrients - biogenic elements (mainly nitrogen and phosphorus). Of great importance are the morphometric features of reservoirs and their hydrological regime. The number of phytoplankton varies markedly from year to year. High concentrations of algae in some periods contribute to the deterioration of organoleptic indicators of water quality, which complicates the process of water treatment. For example, the analysis of long-term data (according to MOSVODOKANAL PJSC) shows that of all the reservoirs that are sources of water supply in Moscow, the most intensive flowering is exposed to Moskvoretsky, especially Ozerninskoye and Istranskoye. In the Mozhaisk reservoir, the process of algae development is less noticeable, in the Ruza reservoir - even less.

There are many ways to remove phytoplankton, for example, drum sieves, rotating tape sieves, disk sieves, etc. In particular, the engineering and technological center of JSC "Mosvodokanal" offers the use of microfiltration on disk filters (Figure 1.7).

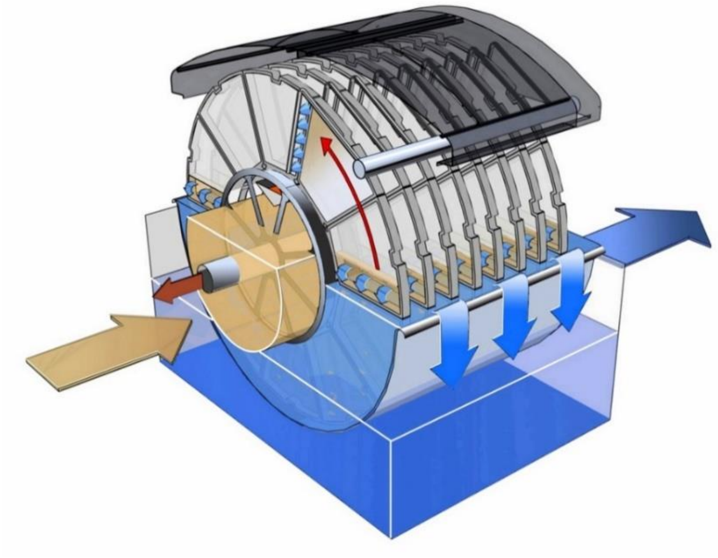
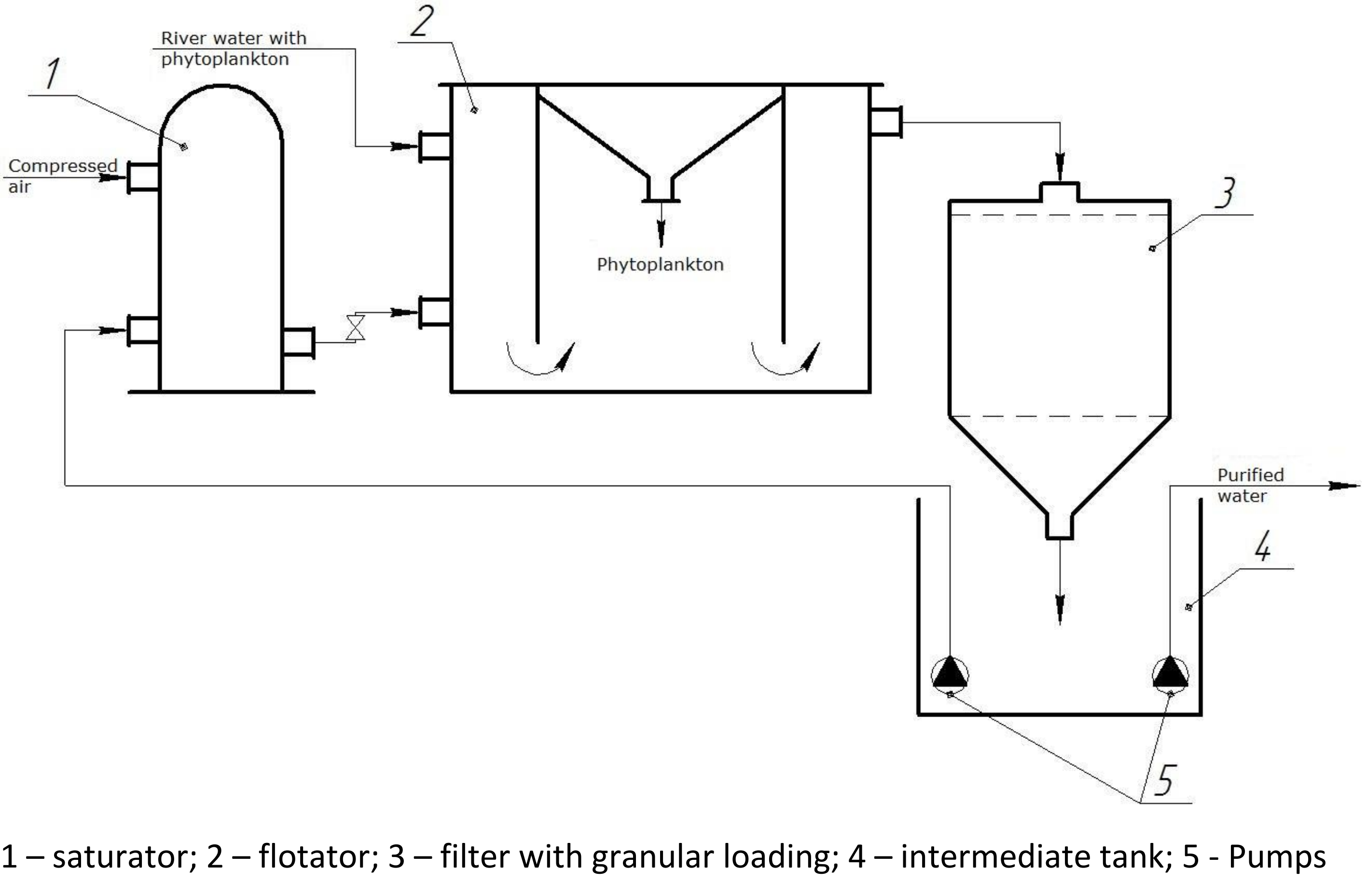


Fig. 1.7 – Disk filter diagram.

A promising method for removing phytoplankton is the technology using flotation (Fig. 1.8).



1 – saturator; 2 – flotator; 3 – filter with granular loading; 4 – intermediate tank; 5 - Pumps

Fig. 1.8 – Scheme of flotation removal of phytoplankton

River water is fed into the flotator, which is also supplied with working fluid from the saturator. In the chambers of the flotation plant, phytoplankton particles stick together with air bubbles and form flotation complexes that float into the foam layer, which is periodically removed. For cleaning from smaller particles, water after the flotation plant is fed to the filter with a granular load and then to the intermediate tank. This scheme is simple and highly efficient.

After collection, the source water is subjected to reagent treatment. Basically, the processing is carried out in mixers consisting of several chambers (dosing, mixing and flaking). For disinfection, a chlorine-containing reagent is added to the source water. Until recently, liquid chlorine was widely used to disinfect drinking water, but it is a highly toxic substance. In this regard, many water treatment plants have replaced liquid chlorine with sodium hypochlorite, which has a wider spectrum of biocidal action on various types of microorganisms, while being less toxic compared to liquid chlorine.

1.3. Processes and devices of water treatment

The choice and justification of technological processes and equipment for water purification is recommended to be carried out taking into account the regulatory documents and regulations in force in the Russian Federation. In this regard, updated versions of individual regulatory documents should be considered.

Since January 1, 2013, a number of updated SNiP (Building Codes and Regulations) have come into force, including the main norms governing design solutions in the field of water supply and sanitation: SNiP 2.04.01–85* "Internal water supply and sewerage of buildings", SNiP 2.04.02–84* "Water supply. External networks and structures" and SNiP 2.04.03–85 "Sewerage. External networks and structures" (Sanitary Engineering, 2013, No.2, pp.56-57).

The main laws, in the light of which the SNiP is updated, are:

Federal Law No. 384-FZ "Technical Regulations on the Safety of Buildings and Structures" dated 30.12.2009;

Federal Law No. 261-FZ "On Energy Saving and On Improving Energy Efficiency and on Amendments to Certain Legislative Acts of the Russian Federation" dated 23.11.2009;

Order of the Ministry of Regional Development of the Russian Federation No. 262 "On the requirements of energy efficiency of buildings, structures, structures" dated 28.05.2010.

In the updated SNiP, items have been added that meet the requirements of the above laws. For example, in SP 30.13330.2012 of the updated edition of SNiP 2.04.01–85* such sections as "Energy and Resource Saving" and "Ensuring Reliability and Safety during Operation. Durability and maintainability".

Of course, the updated SNiPs could not solve all the tasks set, which in the future, apparently, will be clarified and will find a certain solution.

Without considering the variety of technological schemes for the preparation of water for drinking and economic purposes, we will dwell on a typical scheme for the treatment of water taken from surface sources. The complex of typical treatment facilities includes, as a rule, the following main elements: mixers, flaking chambers, settling tanks or clarifiers, filters - with a two-stage purification scheme, contact clarifiers or contact filters - with a single-stage water purification technology (Fig. 1.9)

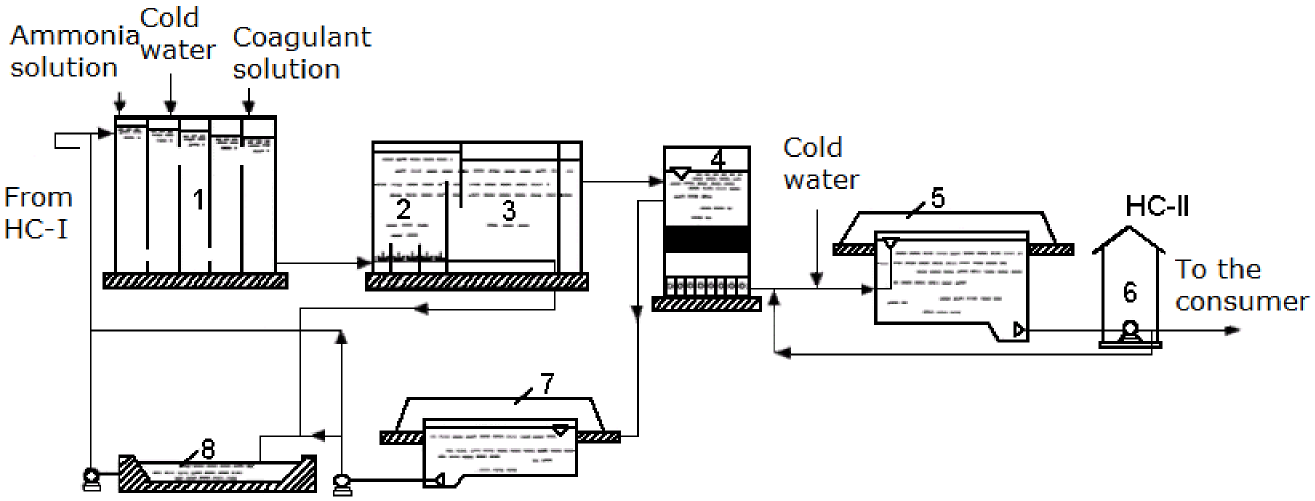


Fig. 1.9 Typical scheme for the preparation of drinking water

1 - mixer; 2 - flaking chamber; 3 - horizontal settling tank;

4 - fast filter; 5 - pure water tank; 6 - pumping station of the second lift (NS-II); 7 - facilities for the treatment of washing water;

8 - storage tank

Such structures were widely used in domestic practice in the twentieth century. In recent decades, more advanced technologies with the use of highly efficient equipment have been used.

Consider the most commonly used processes and apparatus in water treatment, as well as modern schemes of water treatment plants.

1.3.1. Water treatment with coagulants and flocculants.

Natural waters are polydisperse systems, they can contain simultaneously particles, the size of which corresponds to the size of colloidal and coarse particles.

Purification of water from coarse impurities is carried out mainly during settling. Colloidal impurities are not removed when settling water.

Depending on the nature of the dispersed particles contained in the water, turbid and colored waters are distinguished. In turbid waters, colloidal particles of aluminosilicates (clay) of silicic acid and soil organomineral complexes predominate. Colloidal particles of impurities of natural waters, as a rule, have a negative charge.

The method of water treatment, aimed at removing particles of contaminants that are in a colloidal state with the help of chemical reagents, by enlarging the particles due to their interaction, is called coagulation.

The chemicals used for this purpose are called coagulants, which can cause not only coagulation of contaminant particles, but also form, hydrated, poorly soluble products that can combine into large flakes.

Water coagulation is used to clarify turbid and discolor colored waters. Along with colloidal impurities, coagulation removes coarse particles from the water, as well as plankton, bacteria and viruses. For water purification, the following coagulants are often used: aluminum sulfate $Al_2(SO_4)_3 \cdot 18H_2O$, ferrous sulfate (II) $FeSO_4 \cdot 7H_2O$ (iron sulfate), iron (III) chloride $FeCl_3 \cdot 6H_2O$, aluminum hydroxochloride $Al_2(OH)_5Cl$, sodium metal aluminate $NaAlO_2$, etc.

The main factor determining the rate of coagulation of water is the stage of flaking. The growth of flakes is as a result of sorption by sconagulated particles of aluminum or iron hydroxides of colloidal particles, water impurities, enlargement of the formed flakes by connecting them to each other. Enlarged flakes settle under the influence of gravity, dragging suspended particles with them. The faster the flakes grow, the greater their mass and size, the more intensive the sedimentation process is, the higher the degree of clarification of water.

In water discoloration, when humus compounds having the properties of hydrophilic colloids are removed from water, the main role is given to the specific adsorption of multi-charged aluminum cations by the surface of complex high-molecular humic acids. As a result, insoluble aluminum complexes are formed. Coagulation of humus compounds by aluminum coagulant is irreversible. The optimal pH values of the treated water with discoloration are

4.5 – 5.5. The coagulation process is quite fast, vigorous mixing of water is necessary after the intake of coagulant. The coagulation process is also affected by the temperature of the treated water. As the temperature decreases, the rate of thermal motion decreases and the number of effective collisions of colloidal particles decreases, so the stability of the system increases.

The amount of coagulant introduced into the water (mg / l, mg-eq / l, g / m^3 or g-eq / m^3) is called the dose of coagulant. The minimum concentration of the coagulant that meets the best clarification or discoloration of water is called the optimal dose. It is determined experimentally and depends on the salt composition, hardness, alkalinity of water, etc. The optimal dose of the coagulant is its minimum amount, which during trial coagulation gives large flakes and the maximum transparency of water after 15-30 minutes.The effectiveness of the reagents is checked under identical conditions and, based on the data obtained, a conclusion is made about the advisability of further use of the selected coagulant or flocculant.

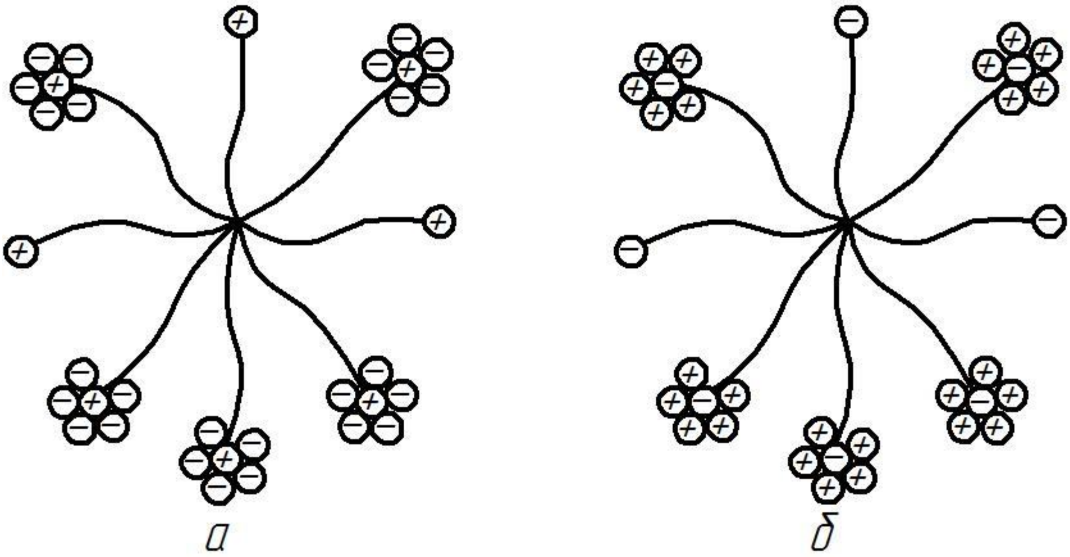
It should be noted that the coagulation of colloidal particles of metal hydroxides occurs under the influence of anions in the water, so soft waters (during flooding) have poor coagulation. Coagulation of impurities in soft waters, for example, under the action of aluminum sulfate occurs better at a pH of 5.7 - 6.6, in waters of medium hardness - at a pH of 6.6 - 7.2, hard - at a pH of 7.2 - 7.6. The process of water coagulation does not differ in the constancy of the parameters of the treatment facilities due to the continuous change in such indicators of water quality as temperature, chemical composition, concentration of impurities, the degree of their dispersion.

To intensify water purification by coagulation, additional flocculant reagents are used to accelerate the processes of flaking and precipitation. The use of flocculants contributes to the formation of strong, quickly settling flakes, which speeds up the water treatment process.

Currently, the following classes of flocculants are used for water purification: 1) inorganic (activated silicic acid); 2) organic high-molecular compounds (HMC) obtained by processing natural products [sodium alginate, starch, carboxymethylcellulose (CMC)]; 3) synthetic high-molecular compounds (polyacrylamide, polyethyleneimine, praestol, etc.).

According to the charge of the terminal groups of macromolecules, flocculants are divided into cationic (positive charge), anionic (negative charge) and neonogenic (zero charge). Examples of the interaction of flocculants of cationic and anionic types are presented in Fig. 1.11. As a result of such interaction, colloidal particles of contaminants are collected into aggregates. Depending on the nature of the destabilized particles contained in the water, the type of flocculant is chosen. Macromolecules of flocculants combine destabilized particles by means of a polymer chain most often with charged terminal groups (Fig. 1.10).

As a result, at this stage there is a significant increase in the size of the particle aggregates, which is expressed in the formation, as a rule, of large flakes.



a – cationic flocculant; b – anionic flocculant

Fig. 1.10 – Approximate scheme of interaction of flocculants with particles of contaminants

The optimal dose of flocculant is determined similarly as in the case of a coagulant. The main indicators are the minimum dose of flocculant with the achievement in this case of the maximum effect of water purification.

The most commonly used flocculants in domestic practice are proto-estol type (joint production of the Russian Federation and the Federal Republic of Germany, Perm). In addition, flocculants are also used, supplied by other various foreign and domestic firms - developers.

The effectiveness of the joint action of the aluminum-containing coagulant (aluminum sulfate) flocculant protostol 655 is shown in Fig. 11a and 11b)

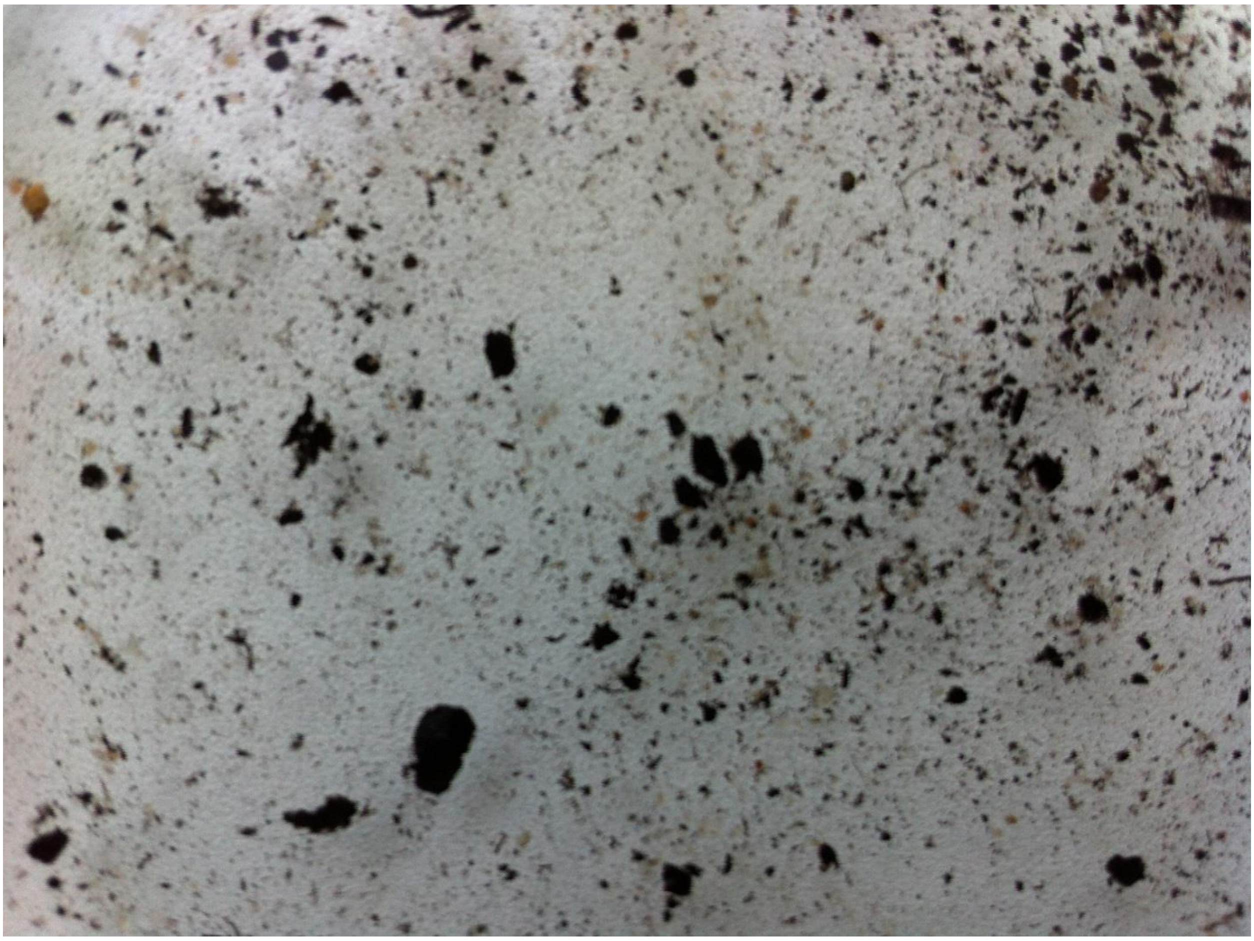


Fig. 11a – photo of particles of contaminants in water without treatment with reagents.

Fig. 11b – photo of pollution particles in the form of large aggregates after adding aluminum sulfate and flocculant praestol 655 to water

A comparison of the sizes of the initial particles of pollution (Fig. 11a) and in the form of large aggregates (Fig. 11b) shows their significant difference. The resulting large aggregates are easily separated from the water, for example, by settling.

1.3.2. Mixers and flaking chambers

Of great importance in the reagent treatment of water is not only the selection of the dose of reagents, but also the process of mixing reagents, in particular coagulants, with water. The coagulation process is quite fast and, in this regard, it is important to distribute the reagent in water as evenly and quickly as possible. The intensity of mixing of reactants with water is characterized by the magnitude of the velocity gradient G ($^{c-1}$), as well as camp's criterion:

$$K = G \cdot \tau$$

where τ is the mixing time, c.

For devices with a stirrer, the velocity gradient can be found by the formula:

$$G = 10\sqrt{\frac{W}{\mu}}$$

where W is the power expended on stirring water, related to a unit volume of water in the flaking chamber, μ is the dynamic viscosity. The mixing time is determined by the formula:

$$T = \frac{V}{Q}$$

where Q is the wastewater flow rate, m^3/s; V – working volume of the mixer, m^3.

Mixing can mainly be carried out by hydraulic and mechanical methods. In the case of the use of mechanical stirrers, the mixing intensity in the mixer should be approximately from 130 to 360 $^{s-1}$. For example, in the mixer of the Central Water Supply Station of Yaroslavl, a mechanical submersible propeller stirrer with a capacity of 0.75 kW and a rotational speed of 1365 s-1 is installed, the scheme of which is presented in Figure 1.12.

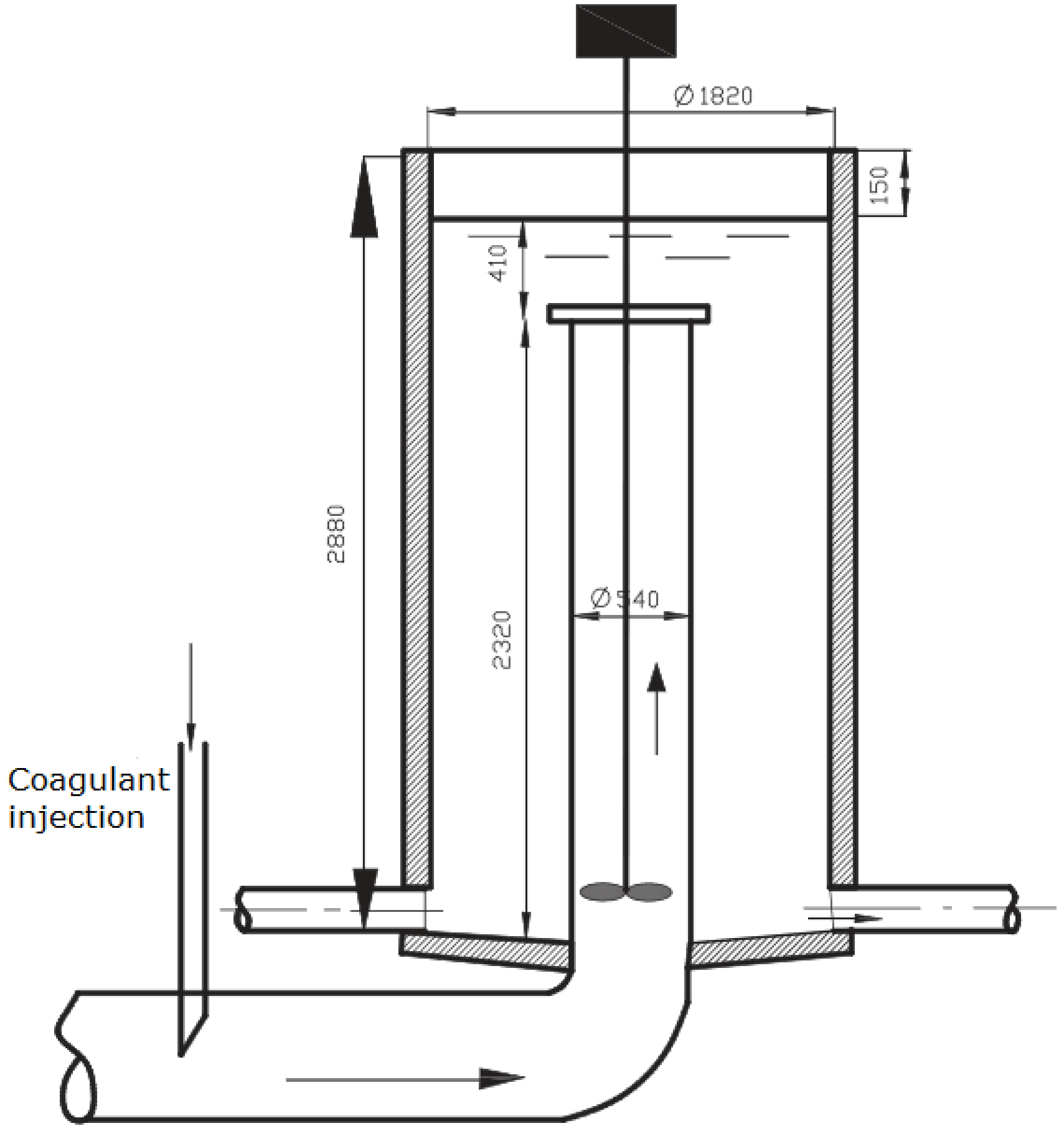


Fig. 1.12 – Scheme of the paddle agitator installed in the mixer of the Central Water Supply Station of Yaroslavl.

In the domestic practice of water treatment, depending on the productivity of the water treatment plant and other parameters, the following types of mixers are mainly used: washer, vertical (vortex), cloisonne and perforated.

For example, a vertical (vortex) mixer is used at water supply stations of medium and large capacity, and the water consumption per mixer should not exceed 1200 - 1500^{m3} / h. A photo of the vortex mixer developed by the author is presented in Fig. 1.13. The central angle between the inclined walls of the mixer is approximately 40^{0}. The treated water is supplied to the lower part of the mixer at a speed of 1 - 1.2 m / s.

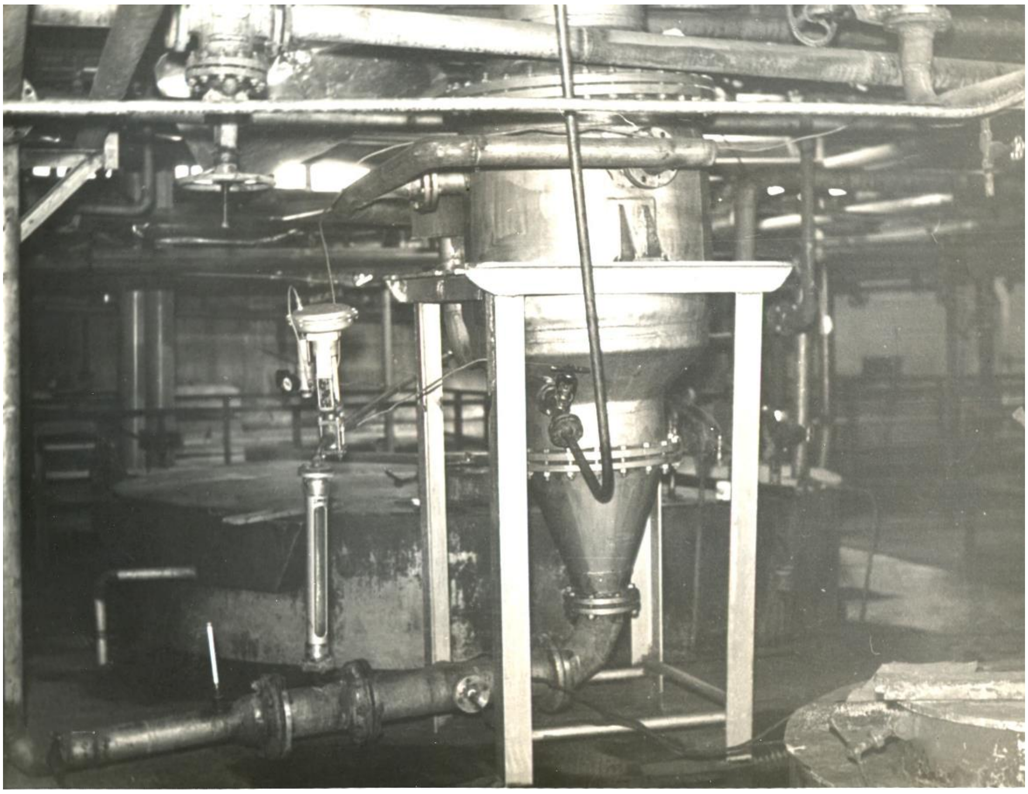


Fig. 1.13 – Vortex type mixer with fluidized nozzle (author's development)

Rapid mixing of reagents with water, as a rule, increases the efficiency of their use. Nevertheless, the use of devices with agitators for these purposes, as the most effective technical means, leads in some cases to the destruction of the units formed in this case, which in this regard requires strict adherence to the time interval of mixing.

To mix coagulants with water, in some cases it is possible to use special magnetic and electric mixers to obtain homogeneous mixtures after adding coagulants to water (Fig. 1.14). Such mixers are characterized by very small dimensions.

The principle of operation of these mixers is based on the use of the mixing or "absorbing" effect of the electromagnetic field when superimposing it on the non-equilibrium coagulant-water system. 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).

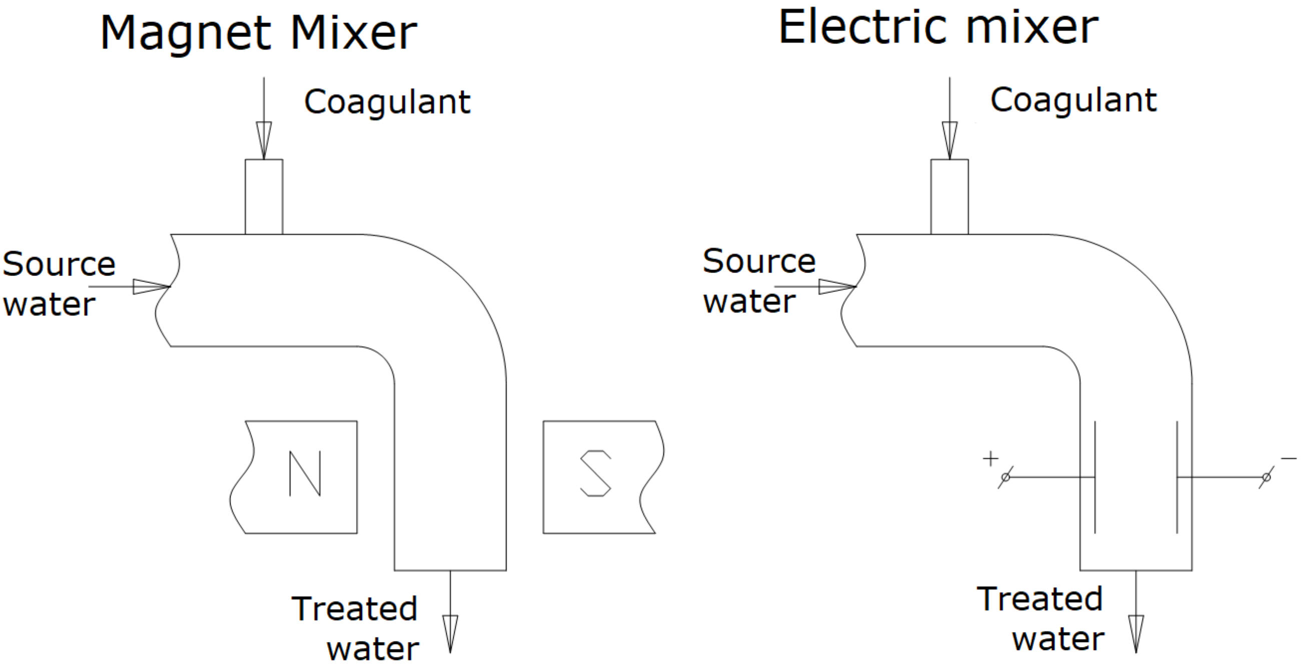


Fig. 1.14. Schemes of magneto- and electric mixers

In the practice of water treatment, hydraulic mixers are often used, in which turbulence of the treated water flow is created by changing the direction of movement of this flow or creating a large gradient of its speed (Fig. 1.15).

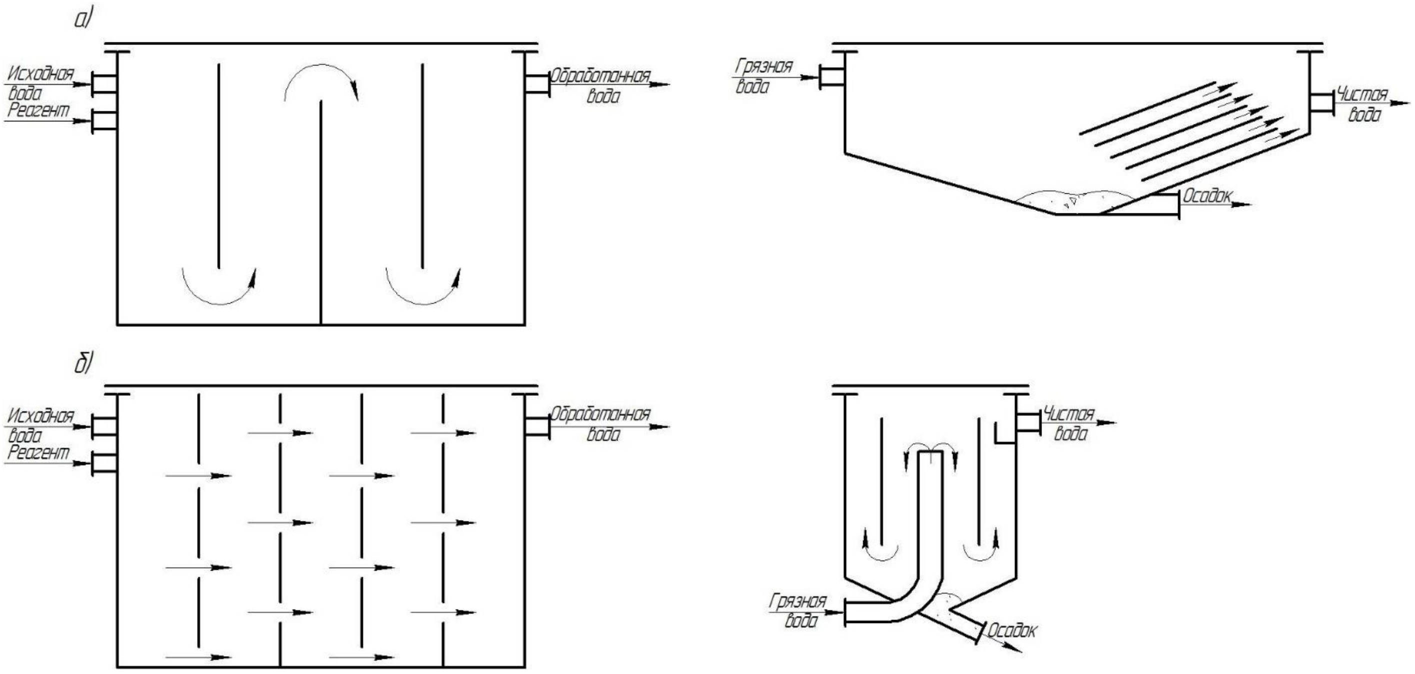


Fig. 1.15. Scheme of hydraulic mixers: a) cloisonne; b) perforated

After the mixer, water enters the flaking chamber, which serve to additionally mix the water and provide a more complete agglomeration of small coagulant flakes into large flakes. The location of the flaking chambers in the process diagram may be in front of the settling tanks or they are built directly into the settling tanks. If, instead of settling tanks, a clarifier with a suspended sediment is provided in the technological scheme, then the device of flaking chambers is not required.

In front of horizontal sedimentation tanks, cloisonné, built-in suspended sediment and lobed flaking chambers are often installed; in front of vertical sedimentation tanks - separate or built-in whirlpool chambers of flaking formation.

The residence time of water in the vortex chamber of flaking is 6 – 10 minutes instead of 15 – 30 minutes for other types of chambers.

Calmer conditions are needed in the flaking chambers than in the mixers, and therefore the velocity gradient in them should vary from about 25 to 65 $^{s-1}$. At the same time, the following modes are recommended in the flaking chambers: a velocity gradient of 25 - 50 $^{s-1}$, and the Camp criterion is in the range of about 15,000 - 25,000.

1.3. 3. Sumps

Sedimentation ponds are mainly used to deposit the resulting flakes of contaminants, and depending on the turbidity of the source water and the productivity of the water treatment plant, various types of sedimentation tanks are recommended: vertical, horizontal, radial and others, for example, of the combined type. In Fig. diagrams of sedimentation tanks of horizontal type with a block of thin-layer module (Fig. 1.16) and vertical type (Fig. 1.17) are presented.

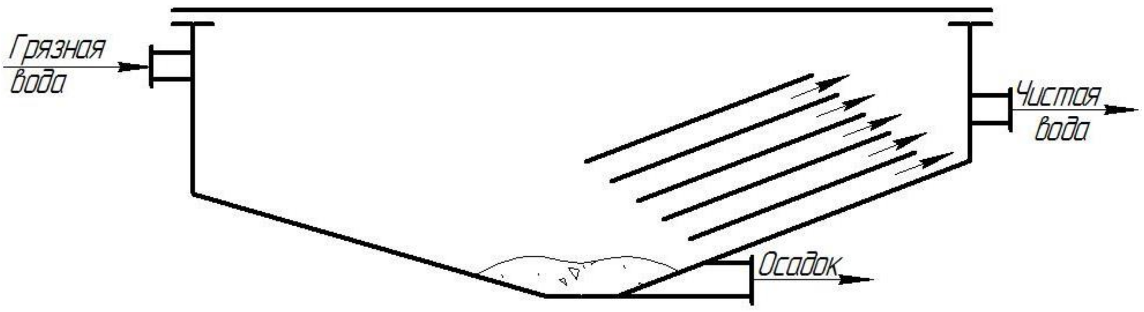


Fig. 1.16 - Scheme of the sedimentation tank of horizontal type

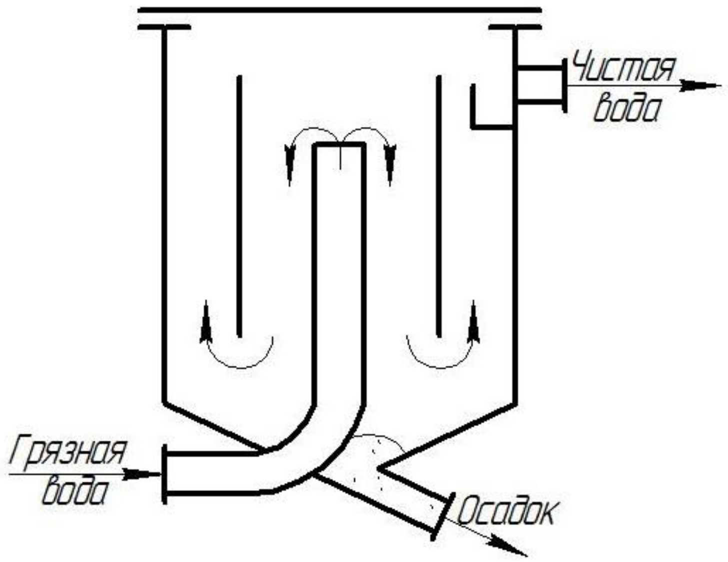


Fig. 1.17 - Scheme of the vertical settling tank

As an example of sedimentation tanks of a combined type, we present the schemes of flotation settling tanks developed by us and used in the practice of water purification (Figures 1.18 - 1.20).

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, sewage sludge 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.

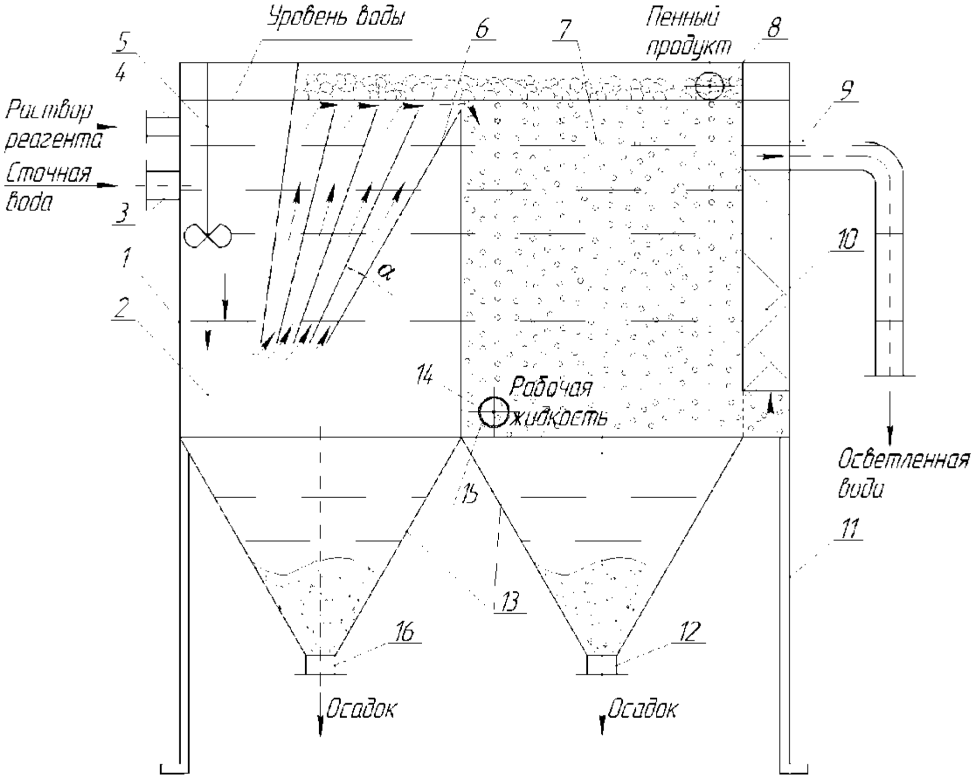


Fig.1.18. Flotation settling tank with sequentially arranged settling and flotation chambers

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.

Возможно исполнение флотоотстойника, в котором вода поступает сначала во флотационную, а затем в отстойную камеры (рис. 1.19).

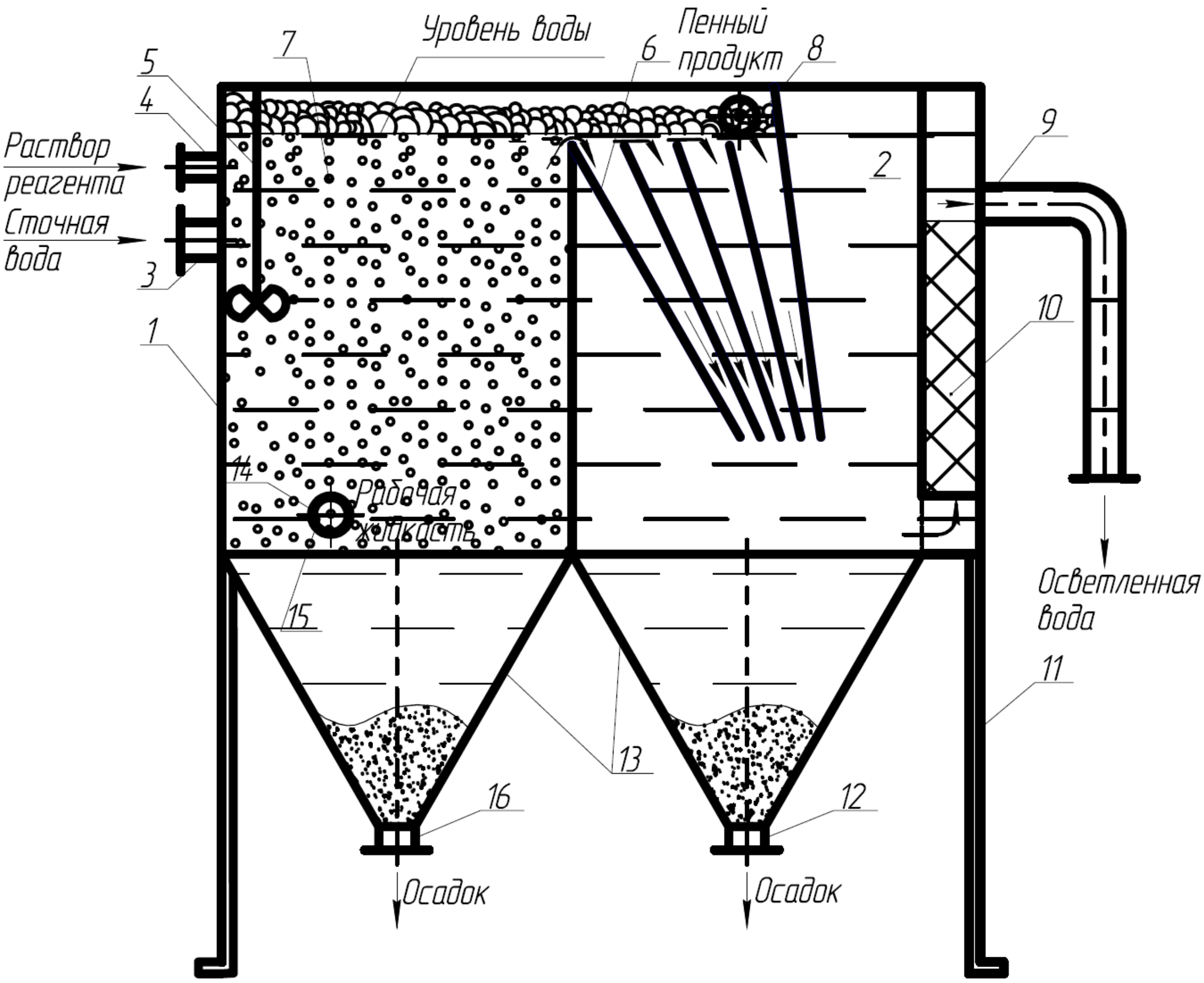


Fig. 1.19. Flotation settling tank with sequentially arranged flotation and settling chambers

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.

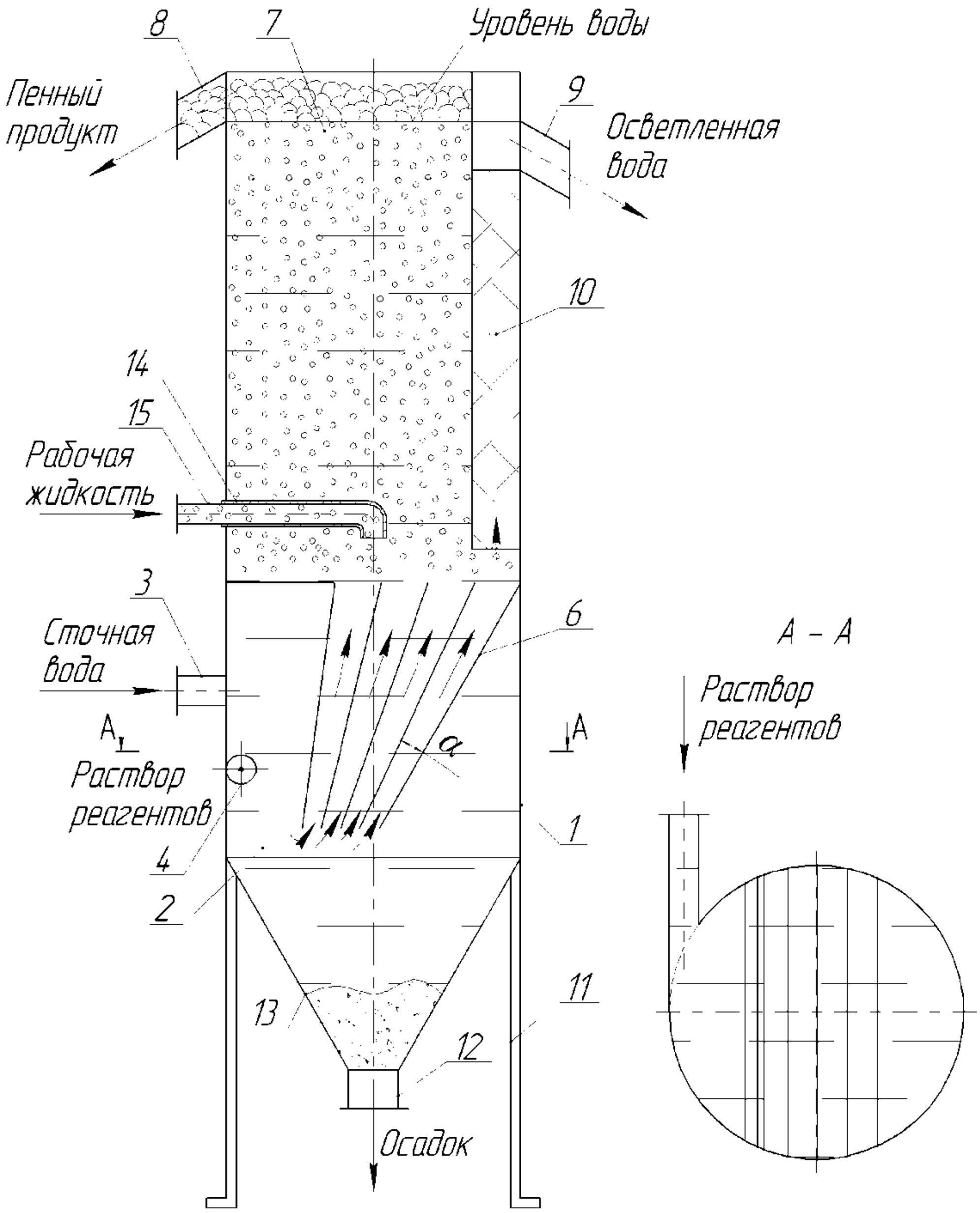


Fig.1.20. Column-type flotation settling tank

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.

Particular attention should be paid to the consideration of the effect of clarification of water supplied to the settling tank, if it is passed through the previously fallen precipitate. This process is carried out in clarifiers with suspended sediment. Very detailed studies of this method of water purification in our country were carried out by Professor E.F. Kurgaev. As an example, consider the clarifier of the VNII VODGEO design with a vertical sedimenter and water distribution by lowering pipes, which is presented in Figure 1.21. Such clarifiers can be used for the productivity of treatment facilities from 3 to 50 thousand m^3 / day.

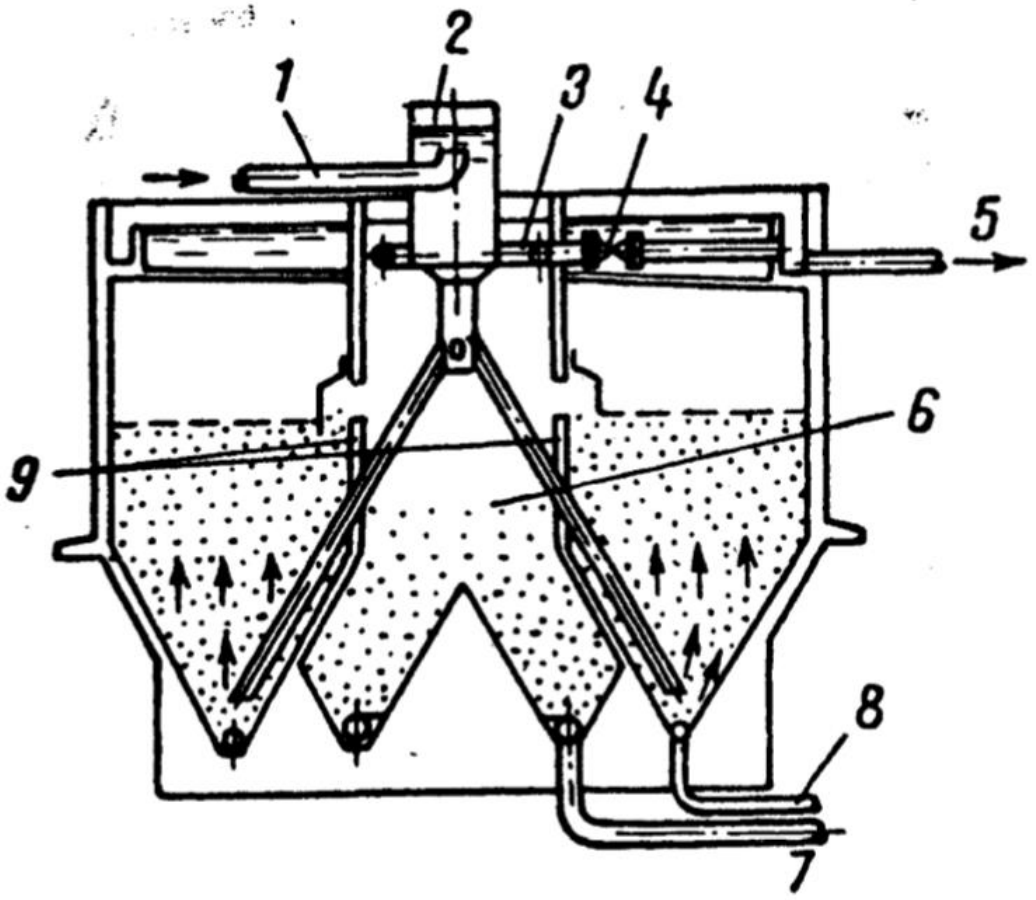


Fig. 1.21 – Clarifier of the VNII VODGEO structure with vertical sedimentation compactor and water distribution by lowering pipes

A clarifier with a vertical draught compactor and water distribution by lowering pipes works as follows. Water from the mixer flows through a horizontal pipe 1 to the air separator 2, where it is released from air bubbles. The air separator is placed in the central part of the clarifier. The bottom of the air separator shall be located 0.5 m below the water level in the clarifier. The water released from air bubbles enters the junction box, from where it is supplied to the grooved bottom through four lowering inclined pipes. Next, the water passes through a 2 – 2.5 m layer of suspended sediment with an upward velocity of 0.5 – 1.2 mm / s, depending on the suspension content and the time of year. Above the layer of suspended sediment there is a zone of clarification, which is a water cushion with a height of 1.5 - 2 m.

Clarified water that has passed through the suspended sediment layer and the clarification zone rises to the annular collection chute and is diverted to the filters through pipe 5.

Particles of suspension when passing through the layer of suspended sediment are retained in it, increasing its volume, and, consequently, the height of the layer. To prevent this, the excess sediment is continuously retracted from the suspended layer into the sediment compactor 6 through the sediment receiving windows 9. To ensure the forced removal of excess sediment, an annular hole pipeline 3 placed in the upper central part of the clarifier is used, which continuously sucks out the clarified water. Released when compacting the excess sediment to be removed. From this pipeline, clarified water also enters the collection annular chute and is diverted to the filters through pipe 5.

To regulate the amount of excess sludge discharged into the sedimenter 6, a gate valve 4 on the pipeline 5 is used. By changing the degree of opening of this gate valve, it is possible to reduce or increase the suction of clarified water through the ring pipe 3, which immediately changes the amount of sediment discharged through the sediment receiving windows 9.

In a clarifier of this type, a vertical sedimenter 6 is arranged, occupying the lower central part. The sediment entering it accumulates, compacts and is periodically or continuously removed from the clarifier through the discharge pipe 7. A pipe 8 is used to empty the clarifier.

1.3.4. Filtration equipment

After settling, the water is fed to the filtration stage, which is mainly carried out in granular filters. According to a number of basic features, such filters are classified:

– by filtration speed:

slow (0.1–0.3 m/h); ambulance (5-12 m / h); ultra-high-speed (36–100 m/h);

– the pressure under which they work:

non-pressure and pressure;

– by the number of filter layers:

single-layer; two-layer; multilayer.

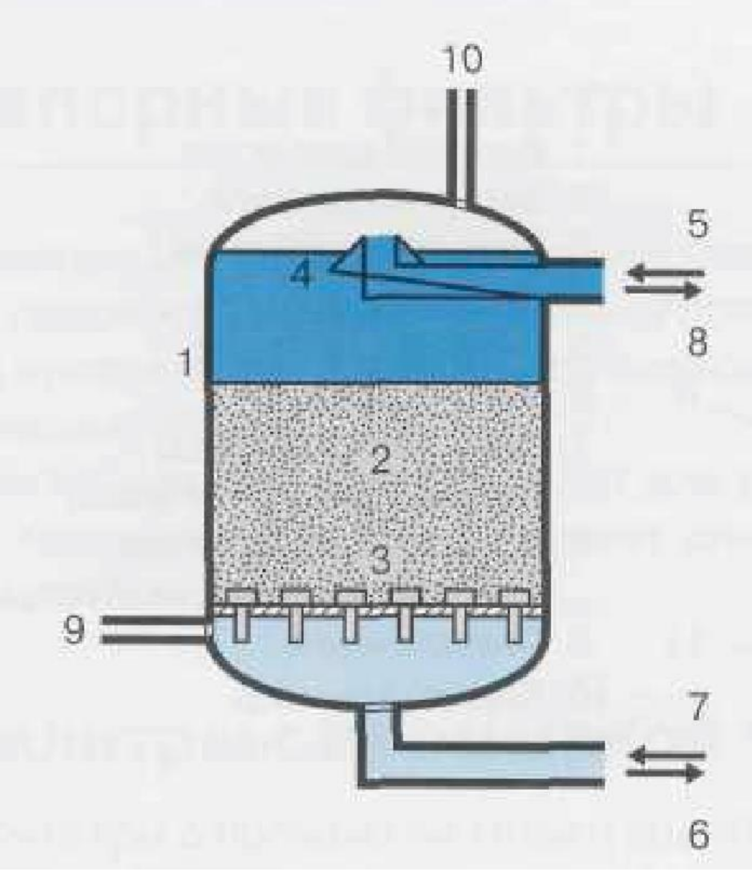
The most effective and economical are multilayer filters, in which, in order to increase dirt capacity and filtration efficiency, the loading is carried out from materials with different density and particle size: large light particles are on top of the layer, and small heavy particles are on the bottom. With the downward direction of filtration, large contaminants are retained in the upper load layer, and the remaining small ones in the lower one. This is how the entire download volume works. Clarifier filters are effective at trapping particles larger than 10 µm.

The process of cleaning by filtration is carried out as follows. Water containing various impurities, moving through a granular load is purified. The efficiency of the process depends on the physicochemical properties of impurities, filter loading and hydrodynamic factors. In the thickness of the load, contaminants accumulate, the free volume of pores decreases and the hydraulic resistance of the load increases, which leads to an increase in head losses in the load. In general, the filtration process can be conditionally divided into several stages: the transfer of particles from the water stream to the surface of the filter material; fixation of particles on grains and in the pores between them; separation of fixed particles with their transition back into the flow of water. Extraction of impurities from water and fixing them on the loading grains occurs under the influence of adhesion forces. The precipitate formed on the loading particles has an often fragile structure, which, under the influence of hydrodynamic forces, can be destroyed. Some of the previously adhered particles break away from the loading grains in the form of small flakes and are transferred to subsequent loading layers, where they again linger in the pores.

When the limit of head loss is reached, the clarifier filter must be switched to the loosening mode, when the load is washed with a reverse current of water, and contaminants are discharged into the drainage. The possibility of catching coarse suspension with a filter depends mainly on its mass; fine suspension and colloidal particles, depending on the magnitude of the surface forces.

Of particular interest is the volumetric filtration, which is observed in double-layer filters and in contact clarifiers. The filter is filled with the lower layer of quartz sand with a grain size of 0.65-0.75 mm and the upper layer of anthracite with a grain size of 1.0-1.25 mm. On the upper surface of the layer of large anthracite grains, a film is not formed, suspended impurities penetrate deep into the layer - into the pores and are deposited on the surface of the grains. Suspended substances that have passed the anthracite layer are retained by a layer of sand.

Depending on the operating conditions, multilayer filters with different types of loading, number of layers, washing method, etc. For example, In Figure 1.22, as an example, a diagram of the FV2B filter with one homogeneous loading layer and with washing with both water and air is presented as an example.



1 – filter housing; 2 – filter loading; 3 – load-bearing floor with drainage caps; 4 – water supply zone; 5 – input of the source water; 6 – filtered water outlet; 7 – flushing water inlet; 8 – flushing water outlet; 9 – flushing air inlet; 10 – Air Outlet

Fig. 1.22 – FV2B filter scheme

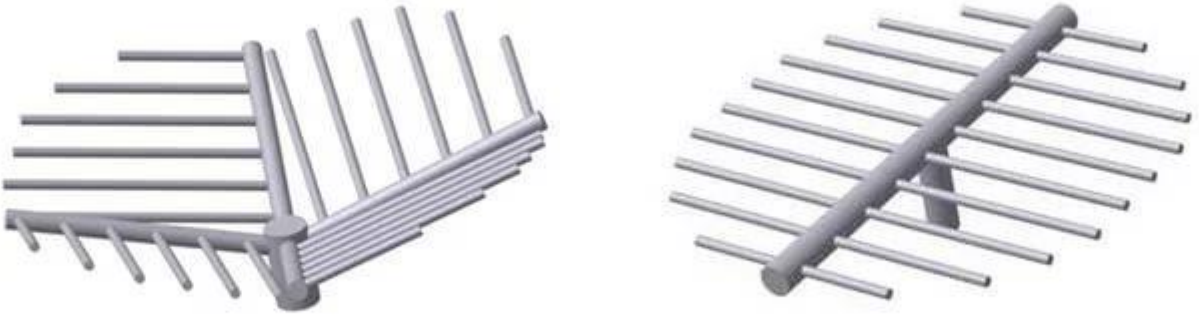
Multilayer pressure filters with two loading layers have been widely used in the field of drinking water treatment: the lower layer is sand; the top layer is anthracite. Filtration rates for filters of this type are maintained, as a rule, in the range from 7 to 20 m / h. Washing of filters is carried out most often with water and air. Figure 1.23 shows a possible drainage device for such a filter.

1 – water supply for clarification; 2 – flushing of washing water; 3 – output of clarified water; 4 – descent of the first filter; 5 – compressed air supply; 6 – flushing water supply; 7 – round manhole; 8 – elliptical manhole; 9 – upper switchgear; 10 – filter layer (sand, anthracite); 11 – fitting for hydraulic unloading and loading of filters.

Multilayer pressure filters with two loading layers have been widely used in the field of drinking water treatment: the lower layer is sand; the top layer is anthracite. Filtration rates for filters of this type are maintained, as a rule, in the range from 7 to 20 m / h. Washing of filters is carried out most often with water and air.

Drainage systems play an important role in the operation of filters. In modern practice, many types of various drainage systems are used.

Figure 1.23 shows, as an example, separate drainage systems for filters offered on the domestic market.



(a) B)

Fig. 1.23 (A, B) – Examples of drainage systems for filters offered on the domestic market

It should be noted that the composition of water and the ever-increasing requirements for its quality of water purification lead to the need to improve filter technology.

1.3.5. Ion exchange

The essence of ion exchange is to use the ability of special materials called ion exchange materials or ion exchangers to change the ionic composition of water in the desired direction.

The ability of ionites to ion exchange is explained by their specific structure. Ionite consists of a solid water-insoluble molecular grid, to individual places of which chemically active functional groups of ionite atoms are attached on the surface and inside its mass.

From an electrochemical point of view, each molecule is a kind of solid electrolyte. As a result of the electrolytic dissociation of ionite around the insoluble in water nucleus, an ionic atmosphere is formed, which is a limited space around the ionite molecule, in which there are mobile and exchangeable ions. If these mobile ions have a positive charge, the ionite is called a cationite if the negative is an anionite.

Ion exchange reactions obey the rules applicable to the reaction of ordinary electrolytes: equivalence of ion exchange, reversibility of this process, selectivity. The equivalence lies in the fact that the exchange of ions between the solution and the ionite occurs in equivalent ratios so that the principle of electroneutrality of the solution is observed. However, it should be noted that the total amount of ions in the solution may change after ionization due to secondary reactions.

The ability of ionite to preferential sorption of some types of ions over others is called selectivity. The reason causing selectivity is the difference in the attractive energies of different ions by the solid phase, due to the values of the radii of the sorbed ions and their charges. With an increase in the charge of an ion (i.e., with an increase in its valence), the energy of attraction of it increases according to Coulomb's law by the oppositely charged solid phase. Therefore, with an increase in the valence of ions, the selectivity of their sorption by ionite increases. Accordingly: divalent ions are sorbed better than monovalent ions, and trivalent ions are absorbed better than divalent ones.

Selectivity series for cations and anions have been established, in which each subsequent ion is sorbed better than the previous one. For example, for the highly acidic cationite KU-2, the following series was obtained:
H+<Na+<NH4+<Mg2+<Zn2+<Cu2+<Ca2+<Al3+...

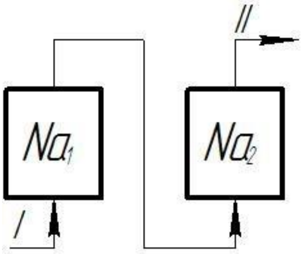
The main cations of natural waters can be distinguished into the following series of selectivity:

H+<Na+<Mg2+<Ca2+.

The choice of schemes for the preparation of additional and make-up water is determined by the quality of the source water and the required quality of the treated water, as well as the conditions of economy, reliability and minimal discharge of impurities formed during the operation of water treatment plants.

Various schemes of softening water preparation for low and medium pressure boilers are used, for example, by two-stage Na - cationization.

Двухступенчатое Na-катионирование (рис.1.24)



I – water inlet; II – water outlet.

Fig. 1.24 – Scheme of two-stage Na - cationation

It is used to soften natural waters with low carbonate hardness. The applicability of this scheme is limited by the size of the purge on the alkalis. In the first stage, the main number of ions Ca2 + and Mg2 + is removed. The remaining stiffness ions are absorbed in the second stage filter. A weakly acidic cationite is used.

Along with the simplest scheme considered above, other more complex and quite effective ones are also used.

1.3.6. Membrane methods

In recent decades, baromembrane methods have been widely used in the field of water treatment, which include microfiltration, ultrafiltration, nanofiltration and reverse osmosis. All membrane separation processes are characterized by the presence of a special selectively permeable barrier between the two phases, which is the membrane (Fig. 1.25).

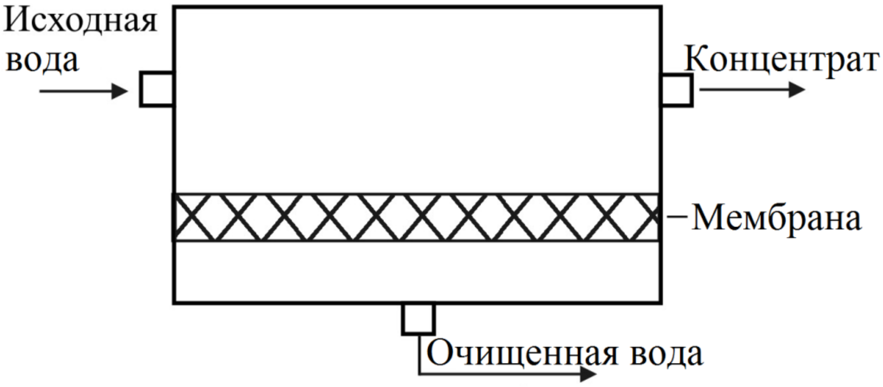


Fig. 1.25 - Scheme of the membrane process of water clarification

In the simplest representation, a membrane is a porous septum that has pores similar in size. The filtration process traps particles with dimensions larger than the pore size, while permeate, containing smaller particles, including solvent molecules, is able to pass through the pores.

The classification of membrane methods is presented in Table 1.1.

Table 1.1 – Classification of membrane methods of water purification

Pore size, µm	Types of pollution	Molecular weight of contaminants	Water purification method
1 – 100	Mechanical suspensions, oxidized contaminants	–	Mechanical water purification, macrofiltration
0,1 – 1	Bacteria, colloids, suspensions	< 500 000	Microfiltration
0,002 – 0,1	Colloids, bacteria, viruses.	10 000 – 500 000	Ultrafiltration
0,002 – 0,001	Multi-charging ions, molecules, viruses	300 – 10 000	Nanofiltration
< 0,0001	Ions	< 300	Reverse osmosis, osmosis

Microfiltration is the mechanical filtration of fine and colloidal impurities with a size usually above 0.1 µm. Usually, microfiltration elements are installed as a safety net at the last stages of purification in water treatment complexes. Microfiltration is used in medicine, the food industry at enterprises producing alcoholic and non-alcoholic beverages, wine, beer, vegetable oil, other products, for water purification in water treatment systems, for filtration semi-finished products, ingredients, various process media, finished product before bottling, for air and gas purification, etc.

Ultrafiltration - according to the rating of water filtration occupies an intermediate position between nanofiltration and microfiltration. Ultrafiltration membranes have a pore size from 20 to 1000 A^0 (or 0.002-0.1 µm) and allow you to retain finely dispersed and colloidal impurities, macromolecules (the lower molecular weight limit is several thousand), algae, unicellular microorganisms, cysts, bacteria and viruses, etc.

The process of ultrafiltration proceeds due to the pressure difference before and after the membrane. Water under pressure is "pushed" through the membrane (semi-permeable partition). The pore size lies in the range of 0.03 – 0.1 µm. The main difference between membrane filtration and conventional volumetric filtration is that most of all detained substances accumulate on the surface of the membranes, forming an additional filter layer of sediment, which has its resistance.

Ultrafiltration, unlike nanofiltration and reverse osmosis, allows you to preserve the natural salt composition of water, which is an important circumstance for maintaining its physiological usefulness, guaranteed to remove bacteria and viruses at a stable level with high technological and sanitary reliability. Thus, high quality of drinking water is ensured, regardless of the state of the water source.

Figure 1.26 shows a membrane installation of a typical design.

GRUNDFOS
H1
E2
K16
ROSheile

Fig. 1.26 – Membrane installation of standard design

Micro- and ultrafiltration plants are widely represented in the Russian market. Their cost depends on many parameters, the main of which is performance.

Nanofiltration - is used to obtain especially pure water, purified from bacteria, viruses, microorganisms, colloidal particles of organic compounds (including pesticides), molecules of salts of heavy metals, nitrates, nitrites and other harmful impurities. A great advantage of nanofiltration over reverse osmosis in the production of drinking water is the preservation of salts and trace elements vital for human health.

Reverse osmosis is often used to demineralize water. Reverse osmosis - used for the production of ultra-pure water, the size of the pores in reverse osmosis membranes is comparable to the size of the water molecule. Thus, water is purified from all soluble and insoluble impurities. The principle of operation of reverse osmosis plants is based on the unilateral flow of water through a semi-permeable membrane. It serves as a separator between solutions with different salt concentrations. The installation of the reverse osmosis system is based on the basis of baromembrane process, the principle of thermodynamic equilibrium. Water is artificially distilled through the membrane - from a highly concentrated solution to a solution of a lower concentration. This process is facilitated by the pressure applied from the concentrated water. Pure water passes to the other side of the membrane, thereby forming a filtrate flow (Figure 1.27).

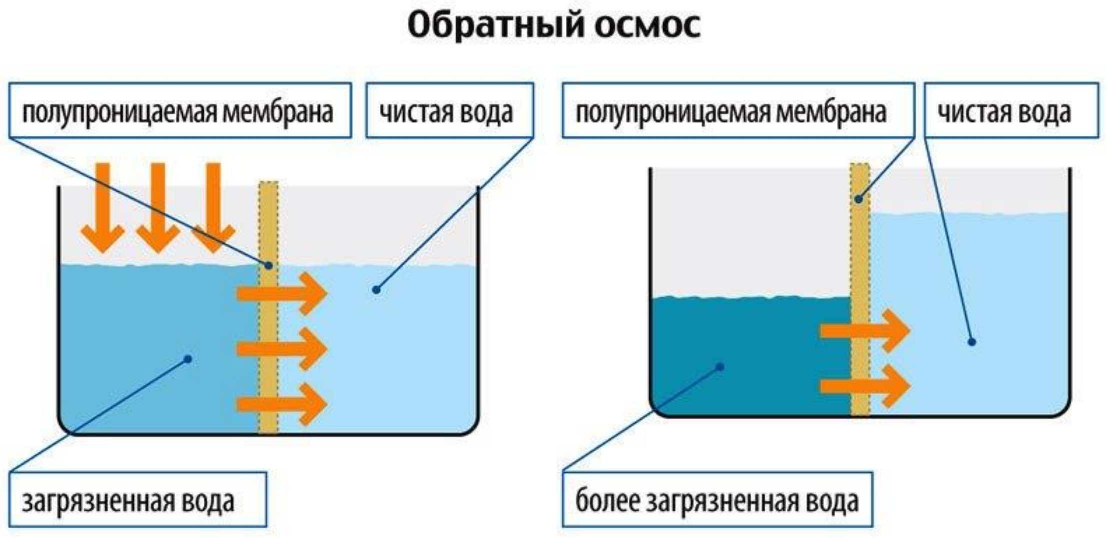
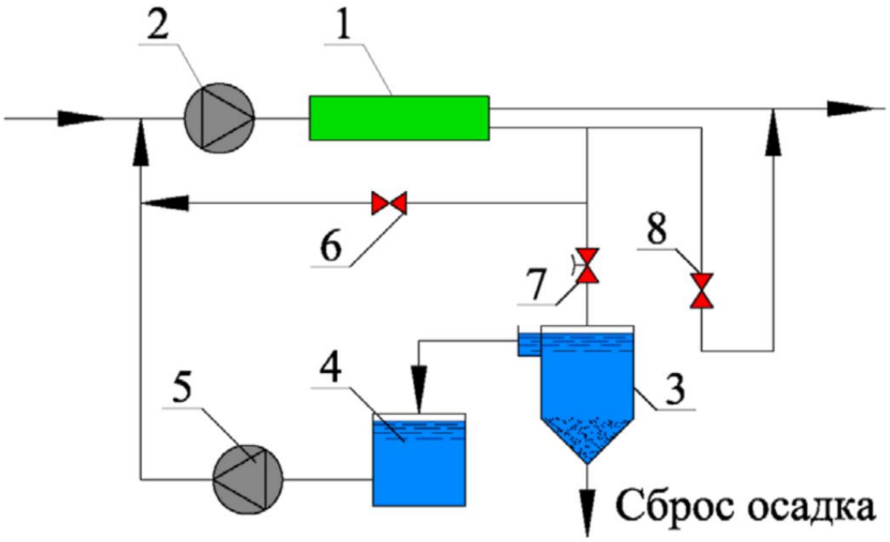


Fig. 1.27 – Reverse Osmosis Process Diagram [**Ошибка! Источник ссылки не найден.**]

The advantages of reverse osmosis include low energy costs, simplicity of design of devices and installations, small dimensions of installations, as well as ease of operation.

When using membrane technologies, the source water is divided into two streams - "pure water" permeate and "dirty" water - concentrate, so an important characteristic of the membrane is the degree of extraction of permeate or the yield of permeate. Since the volume of the resulting concentrate depends on the salinity of the purified water, it is recommended to supply water to a low-salinity unit to reduce the volume. In some cases, the salt content in the concentrate allows it to be discharged into the sewer, but still reducing the consumption of the concentrate of reverse osmosis plants still remains an important unsolved problem.

For example, a reduction in concentrate consumption can be achieved by repeated concentration - an increase in the yield of leachate. Figure 1.29 shows a process diagram for the treatment of surface water to reduce turbidity, chromaticity and oxidizability. The membrane unit operates in circulation mode, so that the filtrate yield can be up to 90...95%. Water containing a precipitate of suspended solids after hydraulic washing of membrane devices is collected in a special sedimentation tank. After settling, the wash water is mixed with the original water. The sludge is removed for dehydration, the silt water that is produced can also mix with the original water.



1 – membrane apparatus; 2 – high-pressure pump; 3 – sedimentation tank for collecting washing water; 4 – water collection tank; 5 – pump; 6 – valve; 7 – solenoid valve; 8 – pressure control valve

Fig. 1.28 – Technological scheme of preparation of drinking water from surface sources using the reverse osmosis method

A distinctive feature of the new proposed technology is the use of membrane transport as a "driving force" of the calcium carbonate deposition process. A similar process occurs in the stagnant zones of reverse osmosis apparatuses, where the source water is concentrated tenfold, and the resulting high values of the solution's supersaturation by calcium carbonate cause "spontaneous" homogeneous nucleation and further growth of crystals. The alkaline solution of NaOH, therefore, in the new technology is used not to create conditions for the precipitation of calcium carbonate from water, but to initiate homogeneous nucleation. High values of supersaturation are thus achieved with constant concentration of the source water. The amount of lime or caustic soda used to operate the described technological scheme is 20-30 times less than the stoichiometric amount required to remove stiffness by reactant methods.

There are also schemes in which it is planned to reduce the volume of concentrate due to evaporation plants, but this is a rather energy-consuming and expensive method.

The most promising, in our opinion, is the reagent softening of water, which can be carried out, for example, in vortex reactors.

Figure 1.29 shows a vortex reactor for reagent softening of water of the design of the Research Institute of VODGEO. It is designed to soften natural waters with a suspended solids content of less than 10 mg / l, permanganate oxidizability of less than 8 mg / l and a chromaticity of less than 50 degrees. The softening process is carried out in the presence of a special seed loaded into the vortex reactor.

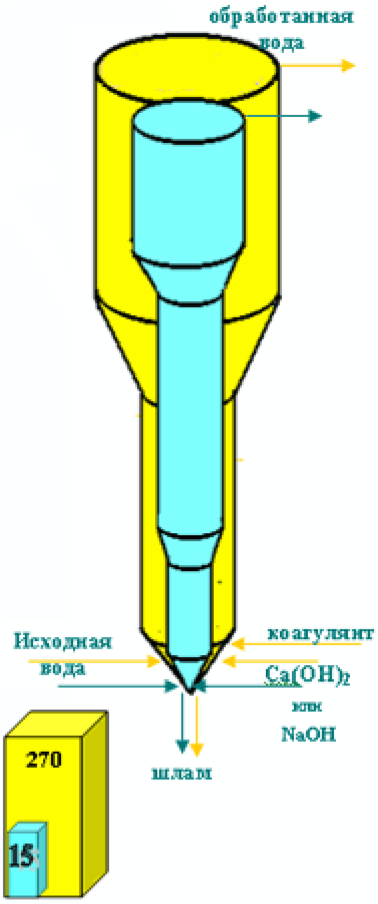


Fig. 1.29 – Vortex reactor designed by RESEARCH INSTITUTE VODGEO

1.3.7. Water disinfection

In the technology of water preparation, there are many different methods of disinfection, which can be divided into four main groups: thermal, using strong oxidants, oligodynamia (exposure to heavy metal ions), physical (using ultrasound, radioactive radiation, ultraviolet rays). Among these methods, the most widespread is the use of strong oxidizing agents, for example, chlorine, sodium hypochlorite, ozone, as well as the physical method - ultraviolet treatment.

For water disinfection by chlorination at water treatment complexes, various chlorine-containing reagents are mainly used, including chlorine and its derivatives, chlorine lime, etc., under the influence of which bacteria in the water die as a result of oxidation of substances that make up the protoplasm of cells. Chlorine acts on organic substances, oxidizing them.

For high-quality chlorination, good mixing is necessary, and then at least 30 minutes of contact of chlorine with water before it reaches the consumer. The contact may occur in a filtered water tank or, in the case of sufficient length of the pipeline without water intake, in the water supply pipeline to the consumer.

Previously, liquid chlorine was quite widespread, but being a highly toxic substance, it posed a danger to residential areas that are getting closer to the territories of water treatment plants. Unlike chlorine, sodium hypochlorite is not flammable and not explosive, it belongs to low-toxic substances, so recently water treatment plants have been transferred to the use of sodium hypochlorite. When using it, the risk of emergencies and their consequences is incommensurably lower than when using liquid chlorine. Both chlorine and sodium hypochlorite, when ingested into water, form hypochlorous acid, which is directly involved in the inactivation of microbiological contaminants. This explains the similar disinfecting effect of the two reagents. Since the new disinfectant is used in the form of a diluted solution, fewer by-products are formed in drinking water than when using liquid chlorine. According to studies, the amount of organochlorine compounds either does not increase after treatment with sodium hypochlorite compared to the background content, or they appear in negligible quantities that do not exceed the norms of the MPC.

It is known that the sources of by-products of water chlorination are natural impurities and various anthropogenic pollutants. The diversity of chlorination by-products is associated with the formation of the chemical composition of the water source and the conditions of water treatment. At the same time, the main share falls on volatile organohalogen compounds - trihalomethanes (TGM), the total concentration of which often reaches 100 - 200 μg / dm3. The results of numerous studies prove that the formation of TGM is associated with the presence in water, including humus substances. It is also known that algae have a great influence on the quality of natural waters, in the process of vital activity of which and after the death of their cells, a large number of substances of various chemical nature enter the aquatic environment. Some of these substances are characteristic of almost all algae, the other part is characterized by significant specificity and is found only in certain representatives of certain departments, classes and genera of algae.

The introduction of chlorine into the water causes the appearance of specific chlorine odors and tastes in it. They are already felt at the content of chlorine in the water in an amount of 0.3-0.4 mg / l. In addition, if the source water contains some substances, for example, phenols, the introduction of chlorine into it causes the appearance of strong unpleasant odors and tastes in it. To combat these odors and tastes, ammoniation of water is used, that is, ammonia or its salts are introduced into the water simultaneously with chlorine.

With ammoniation, the chlorination process proceeds somewhat differently. When an aqueous solution of NH_4OH reacts with the hypochlorous acid NOSl formed during the chlorination of water, chloramines are obtained that

change the nature of the interaction of chlorine with phenols and prevent the formation of chlorophenol odors. At the same time, they weaken the bactericidal effect of chlorine, but prolong the period of this action. The ratio of doses of ammonia and chlorine depends on the physicochemical properties of water and is established in each case empirically.

For the administration and dosing of ammonia, ammoniizer dispensers are used, similar to chlorinators, but made of materials resistant to ammonia, and having some design features. Gaseous ammonia is delivered to the station in cylinders. In addition to ammonia, ammonium sulfate $(NH_4)_2SO_4$ is also used for ammoniation.

The use of ammonized chlorination is also an effective means of combating the development of bacterial life in the pipes of the water supply network and, in particular, with iron bacteria that cause overgrowth of pipes.

Ozonation has been widely used in the field of water treatment. It is used both as a preliminary stage of cleaning and in the final stages. A photo of the laboratory ozonizing unit is shown in Figure 1.30.

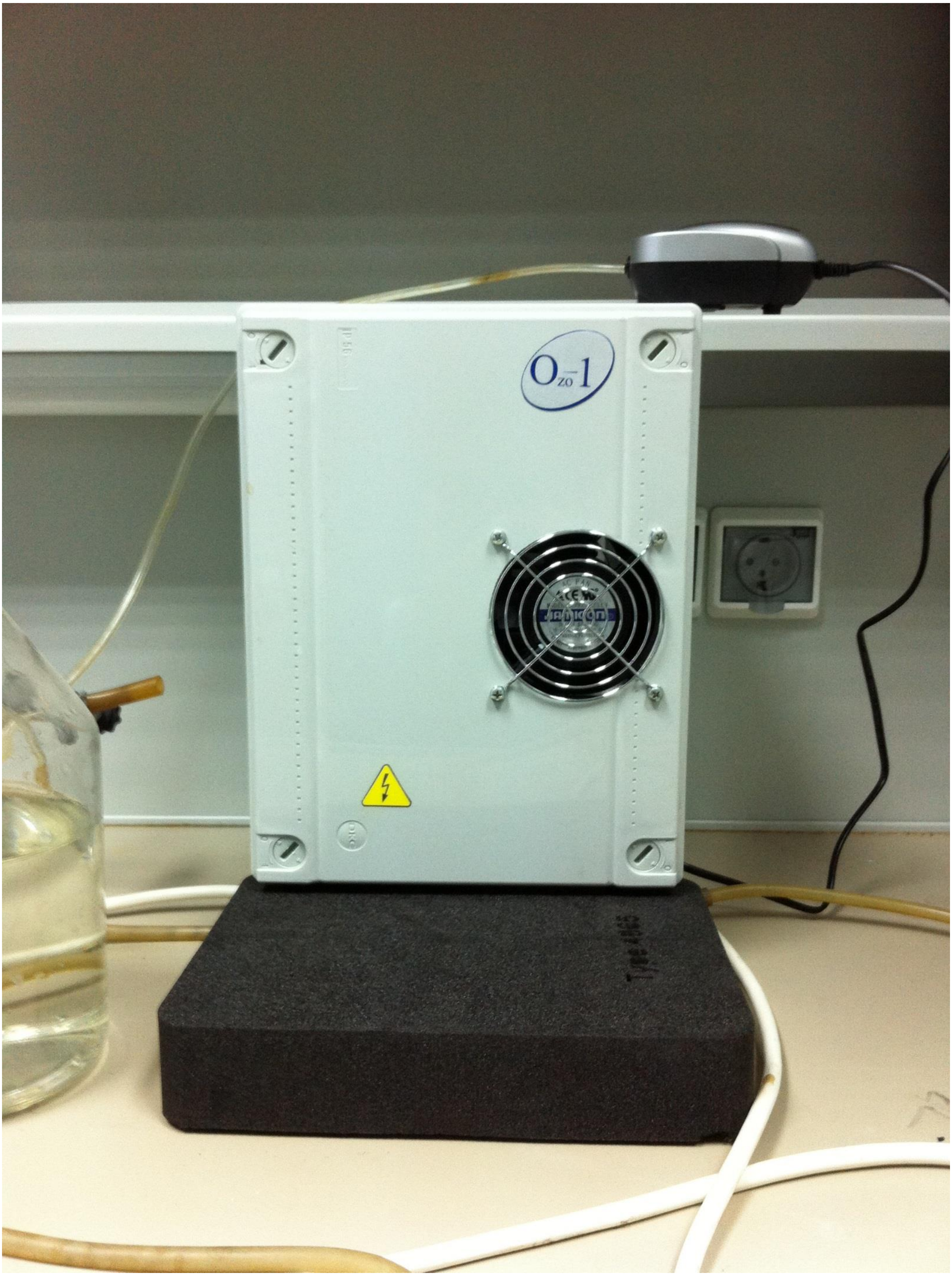

Ozo-1

Fig. 1.30 – Photo of the laboratory ozonizer unit

The principle of operation of most installations for ozonation of water is as follows. Atmospheric air is passed through a filter to clean the dust, after which the air compressor is pumped onto the cooling devices, from where it enters the air drying devices. The cooler is water supplied, for example, to the coil. The cooled and dehumidified air is sent to the ozone generators. Under the influence of an electric discharge, ozone is obtained, but not in its pure form, but in a mixture with air.

The final stage of the technological process is the rapid and complete mixing of water with ozonized air in a special tank. The dose of ozone for water treatment usually ranges from 0.6 to 3.5 mg / l, depending on the indicators of the source water.

Another effective way to disinfect water is ultraviolet treatment. The scheme of ultraviolet water treatment is presented in Figure 1.31.

This method of disinfection consists in the passage of a thin layer of water along the ultraviolet lamp, since irradiation passes only a few centimeters into the depth of the water. The ultraviolet lamp is protected by a quartz tube. In this case, the lamp can be installed directly in the water, but the quartz tube during its service life is covered with particles that limit the flow of ultraviolet rays from the lamp. In this regard, all types of lamps are equipped with purifiers. Each UV chamber is designed for some maximum volume that should not be exceeded. Consequently, most chambers are equipped with a control valve, which limits the flow of water coming from the pump at a high consumption.

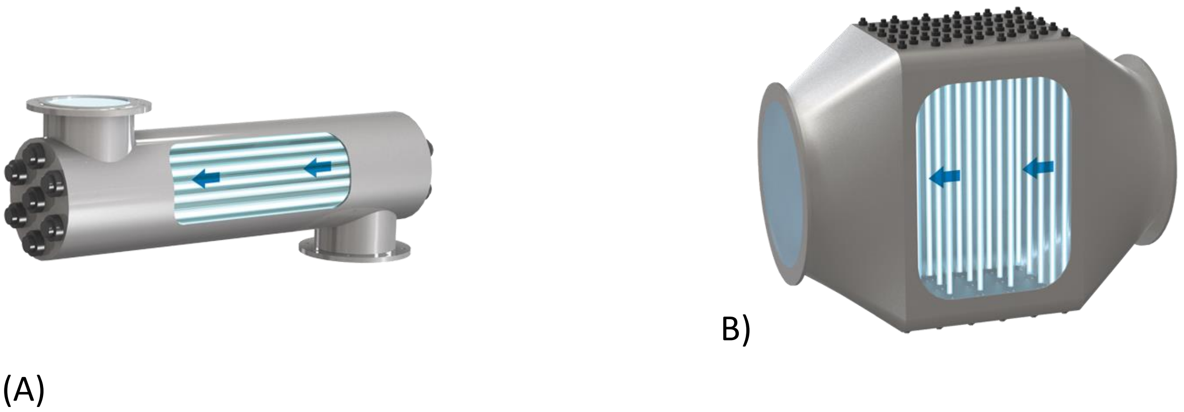
On the domestic market, many different types of installations for the treatment of water with ultraviolet (UV) are offered. For example, a company

LIT (Moscow, Russia) offers a wide range of UV natural water treatment systems of different capacities depending on the water quality, the required degree of disinfection and operating conditions.

The entire production line of serial UV systems of this company undergoes mandatory certification, including equipment certified according to international standards: ÖVGW (Austria), DVGW (Germany), USEPA (USA). In Fig. Figure 1.31 presents the different types of NPO LIT installations.

UDV is a group of housing (pressure) equipment, where the lamps are located along the treated water flow (Fig. 1.31 A).

UDV Pro is a group of housing (pressure) equipment, where the lamps are located across the treated water flow (Fig. 1.31 B).



MLP is a group of channel (tray) equipment, where cassettes with lamps (modules) are located in a channel along the stream of treated water (Fig. 1.31 V).

MLV is a group of channel (tray) equipment, where cassettes with lamps (modules) are located vertically across the stream of treated water (Fig. 1.31 G).

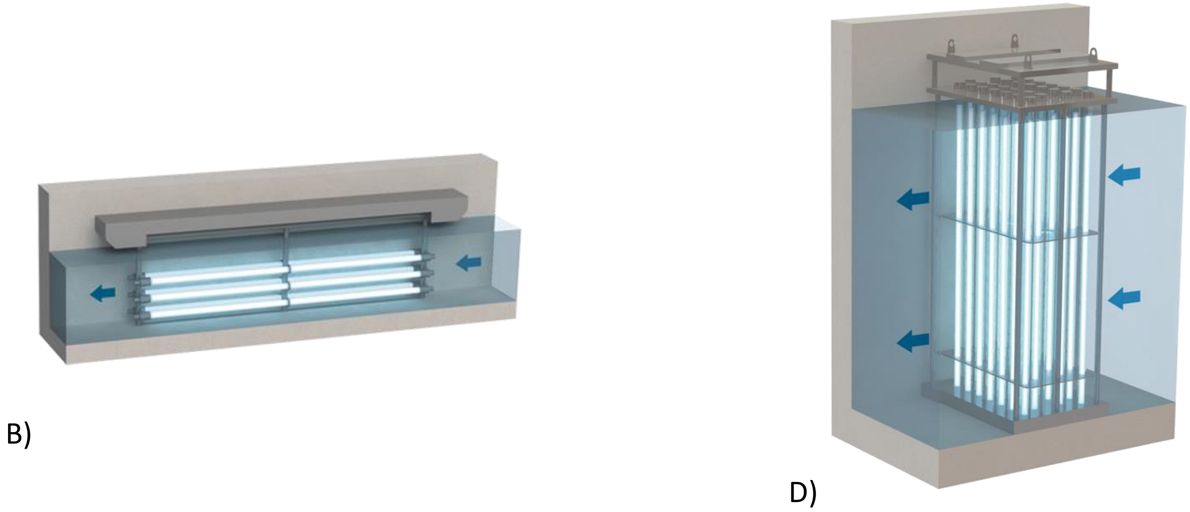


Fig. 1.31 A, B, C, D – UV water treatment plants of NPO LIT

The advantages of ultraviolet treatment include:

- versatility and effectiveness of the defeat of various microorganisms - UV rays destroy not only vegetative, but also spore-forming bacteria, which, when chlorinated with conventional regulatory doses of chlorine, remain viable;

- during processing, the physicochemical composition of water is preserved;

- no limit on the upper dose limit; there is no need to organize a special safety system, as in chlorination and ozonation;

- there are no secondary products;

- there is no need to create a reagent economy;

- the equipment works without special maintenance personnel;

- In the ratio "quality of disinfection price" the method is better than others.

The disadvantages of the method include:

- a drop in efficiency in the treatment of poorly purified water (turbid, colored water);

- periodic washing of lamps from precipitation deposits required for the treatment of turbid and hard water;

- there is no aftereffect effect;

Comparing the methods of disinfection (chlorination, ultraviolet treatment and ozonation), it can be said that each of the three technologies, if applied in accordance with the norms, can provide the necessary degree of inactivation of bacteria, in particular, for the indicator bacteria of the E. coli group and the total microbial number. It is also worth noting that it is recommended to combine these methods of disinfection with the phenomena of reducing turbidity.

Ozone and ultraviolet have a fairly high disinfecting effect at real doses for practice, and chlorination is less effective against viruses, but the technological simplicity of the chlorination process and the availability of chlorine cause the widespread use of this method of disinfection.

As for the economics of decontamination, the method of ozonation is the most technically complex and expensive compared to chlorination and ultraviolet disinfection.

In addition, ultraviolet radiation does not change the chemical composition of water, even at doses much higher than practically necessary.

Chlorination provides water preservation in doses of 0.3-0.5 mg / l, that is, it has the necessary long-term effect. It should be noted that chlorination can lead to the formation of undesirable organochlorine compounds with high toxicity and carcinogenicity.

During ozonation, the formation of by-products classified by standards as toxic - aldehydes, ketones and other aliphatic aromatic compounds - is also possible.

1.3.8. Examples of the use of water treatment technologies

As an example of the use of classical water treatment technology, consider the technological scheme of drinking water treatment of the Metelevskaya water treatment plant (Tyumen), which is presented in Fig. 1.32. Water intake for purification is carried out from a surface source - the Tura River. The technology of river water purification is based on a two-stage reagent scheme: horizontal settling tanks and rapid filters. The station includes a channel-type water receiver, a shore well combined with NS-1, a water treatment plant that includes two blocks of facilities, three clean water tanks (RFV), a pumping station of the 2nd rise (NS-2), a reagent farm, a chlorinator with a chlorine warehouse. Each stage of treatment facilities includes: a section of three drum nets, a cloisonné type mixer, four horizontal settling tanks with built-in flaking chambers, four fast filters.

Fig. 1.32 – Technological scheme of the Metelevskaya water treatment plant

Water intake from the river is carried out using a recessed reinforced concrete head, the entrance holes of which are equipped with lattices (Fig. 1.33).

Fig. 1.33 – Scheme of the pumping station of the I rise of the Metelevskaya water treatment plant

Water treatment at the Metelevskaya water treatment plant includes several stages: rough cleaning in front of the mixers, where large river debris is retained, after which the reagents necessary for purification are added to the water on the cloisonné mixers of the horizontal type. The reagent facilities of the treatment facilities can be used for water purification and disinfection: oxidizing disinfecting reagent - chlorine, coagulants - aluminum sulfate and aluminum oxychloride, flocculant - polyacrylamide (PAA) AK-631 and ammonium sulfate for water ammoniation. Next, the water enters the flaking chambers, where, under the action of chemical reagents, the impurities contained in the water begin to form into flakes. The water prepared in this way enters the horizontal sedimentation tanks, where the resulting flakes settle. In this case, the water is clarified and enters the filter room for further purification. In the filtration hall of the Metelyovskaya water treatment plant there are 8 fast filters loaded with a two-meter layer of quartz sand of a special fraction. The scheme of the high-speed filter of the Metelevskaya water treatment plant is presented in Fig. 1.34. After that, the purified water is chlorinated and enters the tanks of clean water.

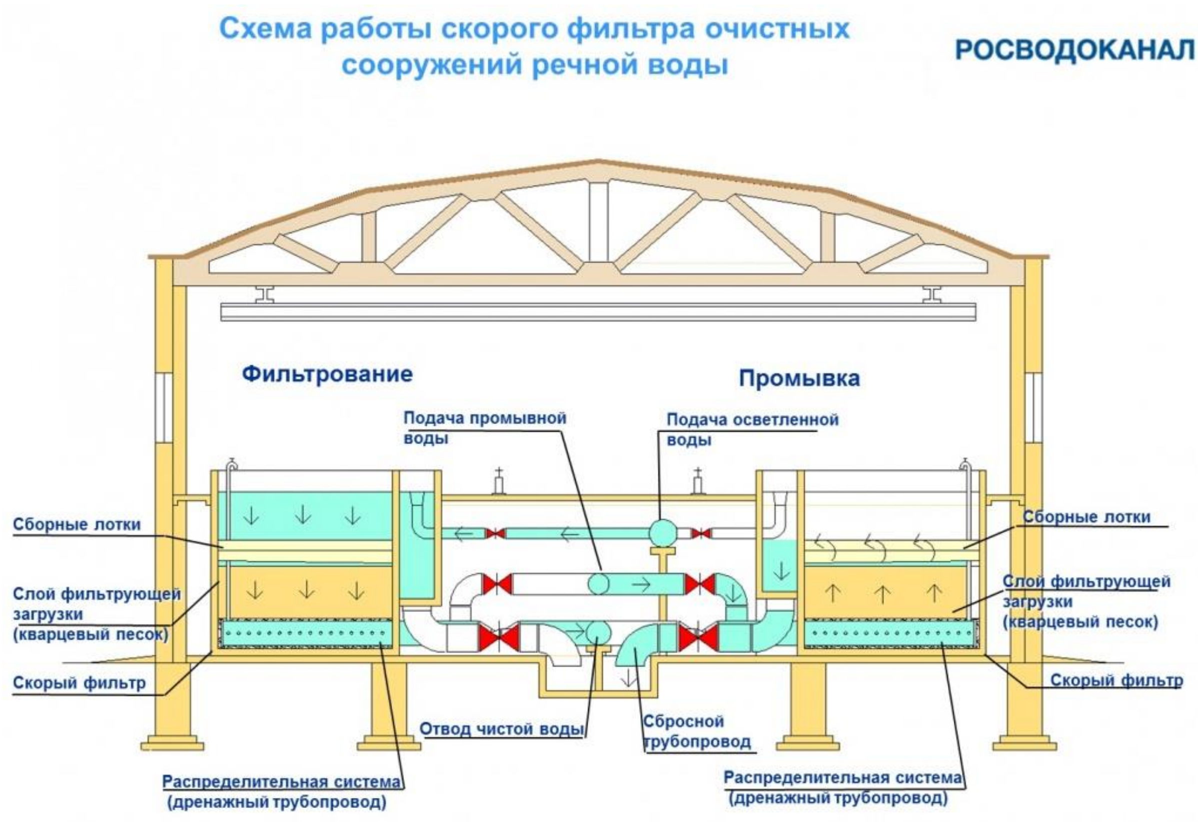


Fig. 1.34 – Scheme of the high-speed filter of the Metelevskaya water treatment plant

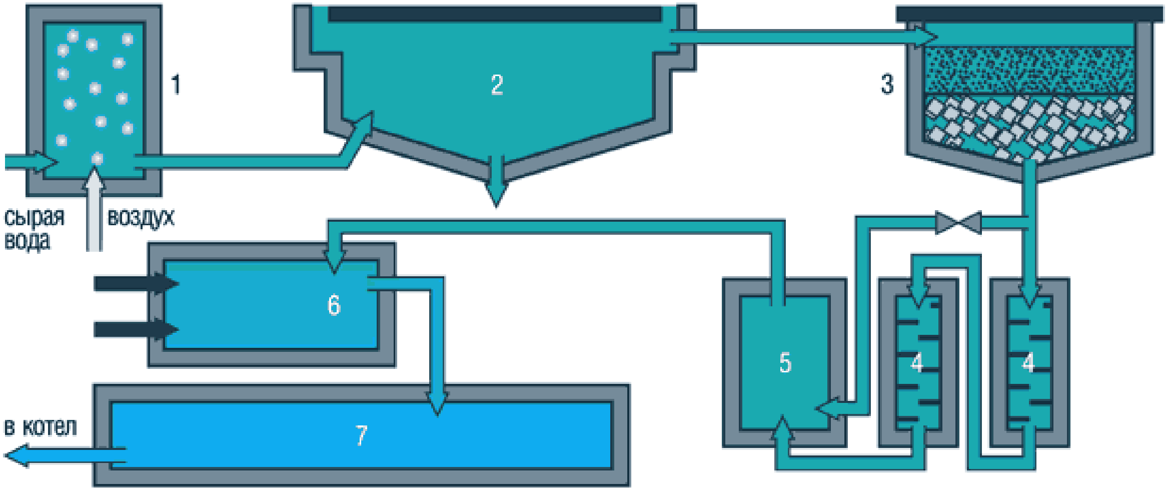
The same classical water treatment technology is used at the Velizhanskaya water treatment plant (Tyumen), the water purification scheme of which is presented in Fig. 1.35. Unlike the Metelevskaya water treatment plant, water intake at the Velizhanskaya station is carried out from underground sources.

Fig. 1.35 – Technological scheme of Velizhanskaya water treatment plant

The original water is supplied to the deironing station. Water treatment is carried out at treatment plants using aeration with the subsequent supply to filters loaded with quartz sand and opoka.

Regeneration of the filtering capacity of loading in all filters of the water treatment plant is carried out by washing with a reverse flow of water, which is supplied from a reservoir of clean water.

The removal of iron and manganese from groundwater is important for water treatment. As an example, consider the technological scheme of water treatment in Athens (Ohio, USA), which is presented in Fig. 1.36.



1 – aerator; 2 – sump; 3 - sand filter; 4 – cascade of ion exchange filters; 5 – water hardness mixer-conditioner; 6 – pH rationing and water disinfection tank; 7 – end well of clean water

Fig. 1.36 – Scheme of the technological process of preparation of drinking water with standardized hardness

Water purification is carried out as follows. Water is pumped into aerator 1 (water consumption - 670^{m3} / h) for forced aeration of water with air. Oxygen of the air oxidizes iron and manganese, and the air itself removes gases that may be contained in the water. Then the water enters the sedimentation pool 2, with a volume of 350 m3, where suspended solid particles settle in about 30 minutes. Water from sedimentation pool 2 flows by gravity through a series of fast sand filters 3. This makes it possible to further remove suspended substances, in particular, iron and manganese oxides. The filters 3 consist of a layer of sand 0.6 m thick and layers of gravel of various sizes serving as the basis of the sand filter. The filtered water enters the ion exchange softening step 4. For this purpose, mineral adsorbents are used - zeolites, in which calcium and magnesium ions are extracted from water due to exchange adsorption. Then water with conditionally zero hardness is mixed with filtered water (total hardness of 15 geq / l) in a drinking water conditioner mixer 5 in order to obtain a final hardness of 7.5 mgeq / l. Water with a normalized total hardness is stabilized at a pH of 50% by caustic, which is added at the rate of 3.0 mg / l. Water is disinfected with chlorine gas in the tank 6, bringing the chlorine content in the water to 0.8 mg / l. Drinking water prepared in this way is stored in the end wells of clean water 7. End wells are tanks with a total volume of 4500 m3. From these wells, water is pumped using two pumps with a capacity of 600 m3 / h and one with a capacity of 950 m3 / h in tanks and reservoirs located throughout the city. The total capacity of the tanks is 26,000^{m3}.

Of particular interest are the water treatment systems of JSC Mosvodokanal.

According to JSC Mosvodokanal, the main structures of the Moscow water supply system include:

1. 9 hydraulic engineering units,
2. 4 water treatment plants,
3. water supply and distribution systems:
    1. city pumping stations (due to the different altitude position and distance from water treatment plants to ensure the required water pressure in the city, there are 6 pumping stations).
    2. urban regulatory units, which have in their composition, in addition to pumps, also drinking water tanks, which make it possible to smooth out irregularities in the city's water consumption. There are 11 regulating units in Moscow.

At the stations, water is prepared to drinking quality on the basis of a classic two-step purification scheme with coagulation, clarification in settling tanks and on sand filters, followed by disinfection with chlorine-containing reagents. If necessary, water treatment with ozone, activated carbon is introduced.

Disinfection is carried out with sodium hypochlorite with the addition of an ammonia-containing reagent to ensure the sanitary condition of the long distribution network, regardless of the presence of water in the technological scheme of ozonation. This practice is typical not only for Moscow, but also for other large cities of the world (Paris, London, Tokyo, etc.), which have a long water supply network, which is due to the long action of the bactericidal properties of chlorine. Ozone is an unstable compound that decomposes rapidly in water, which explains its limited use for final disinfection only in small towns and wider use in the intermediate stages of water treatment.

In order to meet the requirements of constantly tightening standards for water quality and increase the barrier role of water treatment plants, especially in case of accidental contamination of water supply sources, the existing classic two-step technological scheme is supplemented by other progressive methods, for example, such as ozonation with sorption on activated carbon and membrane filtration.

The work of the centralized water supply system in Moscow allows us to reliably provide residents of the capital with drinking water, the quality of which meets state regulatory requirements.

Special consideration should be given to the preparation of drinking water at the Rublevskaya water treatment plant (Moscow), the scheme of which is presented in Fig. 1.37. Water is taken from the river, where it is cleaned of large debris, fish, etc. and pumps of the first ascent are pumped to the station. Then the water enters the mixer, where various reagents are added to it - coagulants and flocculants, which contribute to the precipitation of contaminants. Then the water is sent to the sedimentation tank, where, under the influence of gravity, the resulting flakes precipitate. Next, water is fed to sand filters, where smaller contaminants are retained. Next, the water undergoes ozonation. A large amount of ozone is fed into the water, which contributes well to water purification, destroying various impurities. Next, the purified water is purified through carbon filters. After that, sodium hypochlorite is added to the water for disinfection. Water accumulates in tanks, from where pumps of the second lift are fed into the city.

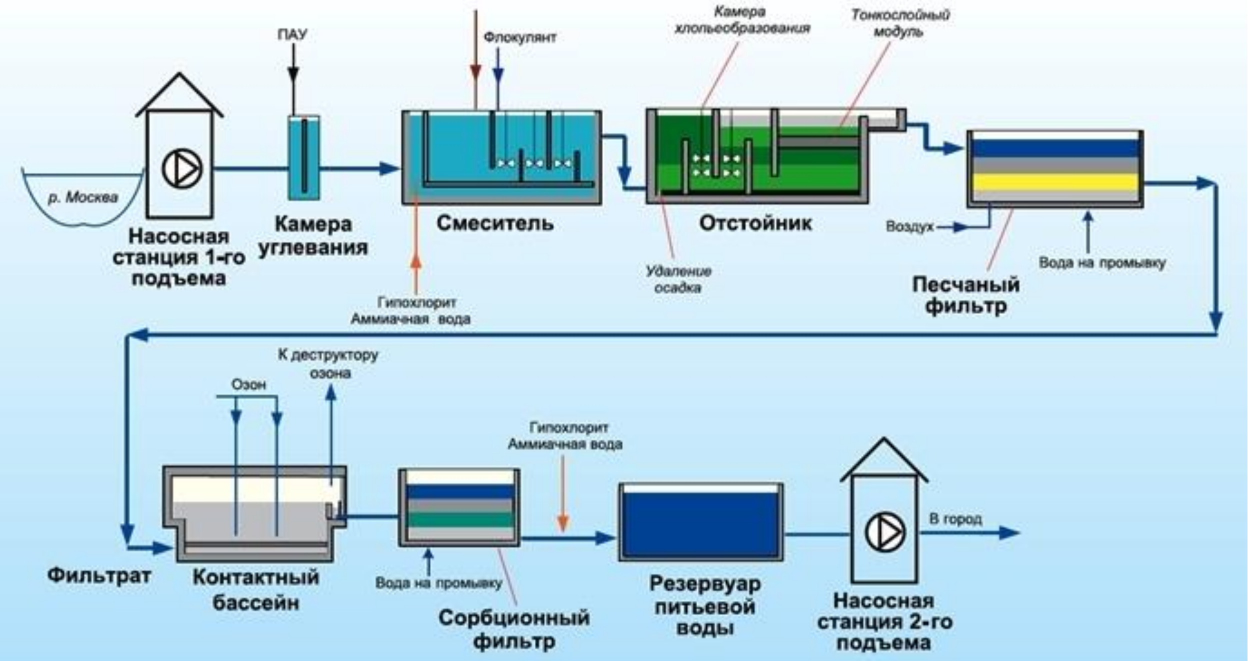


Fig. 1.37 – Scheme of water treatment of the Rublevskaya water treatment plant (Moscow)

The advantage of the technological scheme proposed and implemented at the Rublevskaya water treatment plant is the removal of organochlorine compounds from the purified water.

A serious improvement in the technology of water treatment from surface sources was the creation of a new process for the purification of natural water at the South-Western Station (Moscow). Consider the technological scheme of water treatment of the South-Western water supply station, which is presented in Fig. 1.38. This scheme is a modernization of the classical technology of drinking water purification.

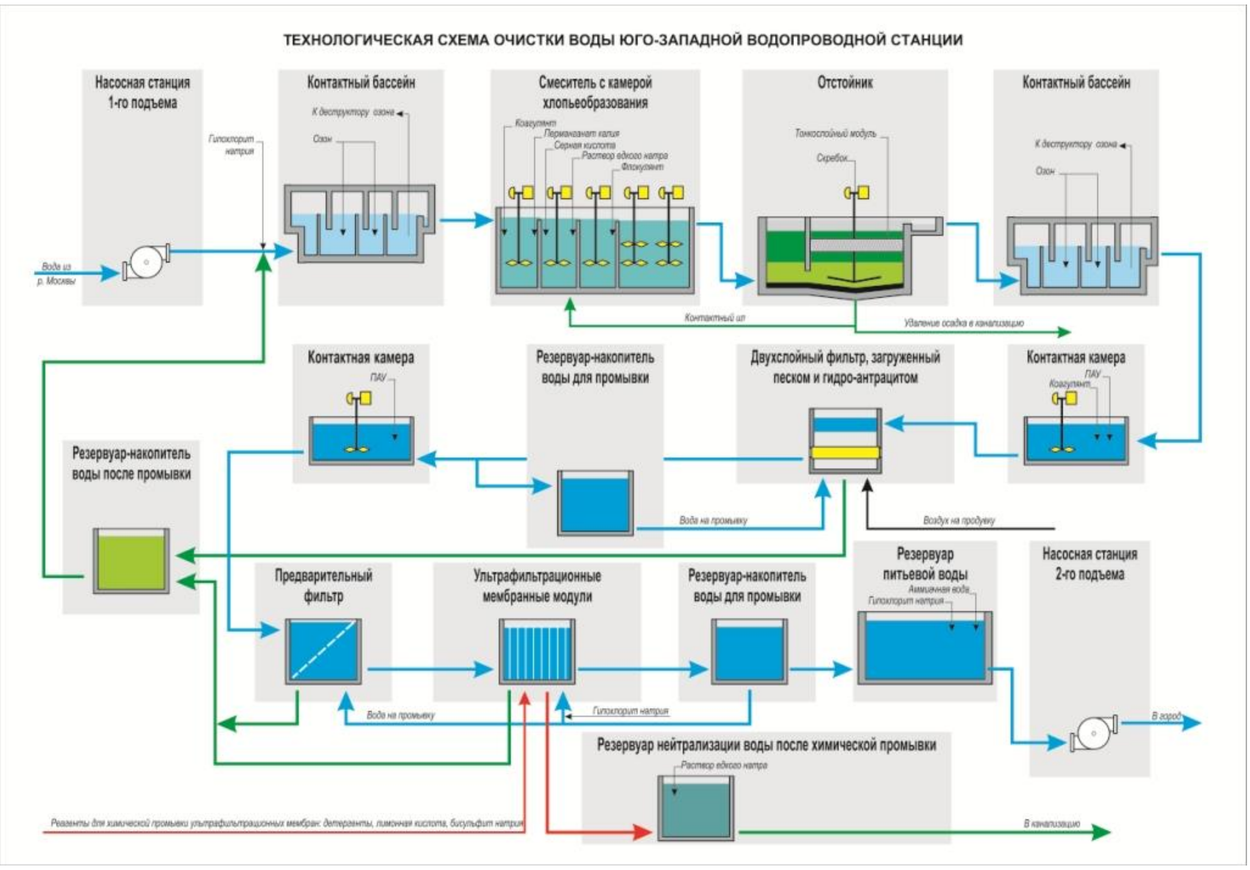


Fig. 1.38 – Technological scheme of water purification of the South-West water supply station

This scheme includes preliminary ozonation of the source water, as a result of which the oxidation of iron, manganese and other substances is carried out. In addition, as a result of preliminary ozonation, bleaching of water occurs, and the organoleptic properties of water are also improved. It should also be noted that this allows you to reduce the consumption of reagents.

To purify water from colloidal contaminants, a coagulant (aluminum polyoxychloride) is added to it. Flocculant is used to enlarge the resulting flakes and improve deposition. It is also possible to dose contact sludge, which is taken from the settling tank. The addition of reagents is carried out in sequential chambers equipped with stirrers to improve the contact of reagents with water. In the last chamber, a stirrer with a low speed is installed, thanks to which flaking occurs in the chamber.

Precipitation of the resulting flakes of contaminants takes place in settling tanks equipped with thin-layer clarification units. The sludge formed in the settling tank can be used as contact sludge, which is fed into the mixer.

Further, water is supplied for secondary ozonation, which is carried out similarly to preliminary ozonation.

To remove traces of organic matter that were not removed in the previous stages of water treatment, a suspension of powdered activated carbon is added to the water. As a result of processing, organic substances are adsorbed with activated carbon. Then particles of coal at the stage of multilayer filtration, and to increase the efficiency of filtration, a coagulant is added to the water.

Loading of multilayer filters consists of sand and anthracite laid in layers. Regeneration of multilayer filters is carried out by combined water-air washing.

Further, to remove residual contaminants of bacteria and viruses, ultrafiltration is used in membrane modules. Ultrafiltration, in contrast to nanofiltration and reverse osmosis, allows you to preserve the natural salt composition of water, which is an important circumstance for preserving its physiological usefulness. At the same time, bacteria and viruses are guaranteed to be removed. Thus, high quality of drinking water is ensured, regardless of the state of the water source.

Ultra-filtered water is collected in a channel of clean water, where sodium hypochlorite and ammonia water are dosed, providing a long-lasting disinfectant effect for drinking water.

It should be noted that the water supply stations of St. Petersburg also use a two-stage technology of complex water disinfection, which includes a chemical method of disinfection - treatment with sodium hypochlorite and a physical method of ultraviolet exposure. In the future, as it seems to us, it is necessary to abandon disinfection with chlorine-containing reagents that contribute in one way or another to the formation of organochlorine compounds. In this regard, it seems more appropriate to disinfect water both at the water treatment plant and at the places of its consumption. Of course, this requires additional feasibility studies.

1.3.9. Treatment of water sludge

Along with the preparation of water for various purposes, an important task is the treatment of the resulting sediments. A feature of tap sediments is that the composition of such sediments contains a significant part of minerals. This makes it possible to use standard approaches for the treatment of sediments such as thickening using centrifuges and filter presses. In some cases, such precipitation is mixed with sewage waste and then the resulting mixture is thickened. At the same time, in most cases, this improves the efficiency of condensation of such mixed sediments by increasing the mineral fraction of the solid phase and the presence, as a rule, in a sufficiently large number of various reagents added in water purification processes.

For example, in Moscow, the sediment of the Northern, Rublevskaya and Western water treatment plants is sent to the city sewerage for subsequent treatment together with the sediment of sewage treatment plants. The sludge of the Eastern Station was treated at mechanical dewatering facilities directly at the station and taken to landfills for the preparation of fertile soil.

Part II: Wastewater disposal and Wastewater Treatment

2.1. Characteristics, approximate composition and classification of wastewater.

Wastewater disposal systems of cities and industrial enterprises.

Water discharged after use in domestic and industrial activities of a person is called sewage. At the same time, in the vast majority of cases, such water contains more pollution than, for example, river water. In this regard, wastewater treatment is necessary to prevent pollution of water bodies, in which, under heavy pollution loads, there will be practically no self-cleaning process, which ultimately can lead to unpredictable and difficult to fix consequences. Wastewater treatment refers to wastewatertreatment for the purpose of breaking down or removing certain substances from it.

Pollution of the hydrosphere is mainly associated with economic activities and is due to inefficient treatment facilities. According to state reports (State Report "On the State and Use of Water Resources of the Russian Federation in 2014" – Moscow: NIA-Priroda, 2015. – 270 p.), in 2000, a total of 20.3 billion^{m3} of polluted wastewater (36.5% of the total volume of water disposal in water bodies) were discharged into the country's water bodies, in 2005 - 17.7 (almost 35%), in 2007 - about 17.2 (33.5%), in 2008 - 17.1 billion m3 (about 33%). In 2009, the volume in question fell significantly and simultaneously to 15.9 billion m3 (the corresponding share was slightly more than 33%), and in 2010 it increased again to 16.5 billion m3 (an increase to 33.5%).

In 2014, the total discharge of polluted wastewater was at the level of 14.8 billion m3, including 0.07 billion^{m3} in the Crimean Federal District. Compared to the previous year, this value decreased by about 3%. The share of dirty wastewater in the total volume of water disposal was almost 34%. At the same time, the volume of dirty effluents that have not undergone any treatment increased from 2.96 to 3.23 billion^{m3}, or by 9% (amendments to the Crimean Federal District in this case are insignificant).

In general, in 2001-2014 it was possible to reduce by almost 30% the discharge of polluted wastewater into water bodies that has not undergone any treatment. At the same time, the reduction of insufficiently treated effluents occurred only by 22%.

As for regulatory and treated wastewater, i.e. such waters, the discharge of which after treatment into water bodies does not lead to a violation of water quality standards in the controlled alignment or water use point, thenover the past fourteen years there has been a decrease in the discharge of regulatory and treated wastewater - from 2.40 billion^{m3} in 2000 to 1.84 billion^{m3} in 2014, or 24%.

Among all areas of activity, the largest volume (according to estimates of about 55-60% of the total value) of polluted wastewater falls on housing and communal services. In other words, the wastewater in question is overwhelmingly related to the wastewater of municipal sewers of cities and other settlements.

Based on the results of the analysis of Russian data in recent years, it is necessary to draw another conclusion. One of the tangible factors influencing the objectivity and correctness of the analyzed information is the systematic reduction in the number of reporting water users. For example, in 2007, compared to the previous year, their number decreased by 3.2%, and in 2008 - by 3.3%. In 2009, more than 1,000 water users "fell out" of the consolidated report (a decrease of 3.4%).

2.1.1. Characteristics of contaminants

Wastewater, as you know, is diverse in its composition. The contaminants present in them are in various aggregate states. By their nature, wastewater pollution is divided into organic, mineral, biological. Organic contaminants are impurities of plant and animal origin. Mineral pollution is, for example, quartz sand, clay, alkalis, mineral acids and their salts, mineral oils, etc. Biological and bacterial contamination are various microorganisms: yeast and mold fungi, algae and bacteria, including pathogens - pathogens of typhoid, paratyphoid, dysentery, etc.

All impurities of wastewater, regardless of their origin, are conditionally divided into four groups in accordance with the size of the particles.

The first group of impurities includes coarse impurities insoluble in water. Impurities of an organic or inorganic nature can be insoluble. This group also includes protozoa, algae, microscopic fungi, bacteria and helminth eggs. These impurities form unstable systems with water. Under certain conditions, they can precipitate or float to the surface of the water. A significant part of the contaminants of this group can be released from the water as a result of gravitational deposition.

The second group of impurities are substances of colloidal dispersion with a particle size of less than 10-6 cm. Hydrophilic and hydrophobic colloidal impurities of this group form systems with water with special molecular-kinetic properties. This group also includes high-molecular compounds, since their properties are similar to colloidal systems. Depending on physical conditions, impurities of this group are able to change their aggregate state. Small size their particles are difficult to deposit under the influence of gravity. When the aggregate stability is destroyed, impurities precipitate.

The third group includes impurities with a particle size of less than 10-7 cm. They have a molecular degree of dispersion. When they interact with water, solutions are formed. Biological and physicochemical methods are used to purify wastewater from impurities of the third group.

Impurities of the fourth group have a particle size of less than $^{10-8}$ cm, which corresponds to the ionic degree of dispersion. These are solutions of acids, salts and bases. Some of them, in particular, ammonium salts and phosphates are partially removed from the water during biological treatment. However, the technology of biological wastewater treatment does not allow to change the salinity of water. To reduce the concentration of salts, physicochemical purification methods are used, for example, ion exchange, electrodialysis, pH change, etc.

2.1.2. Classification and composition of wastewater

There are three main categories of wastewater depending on its origin:

domestic;

Industrial;

Atmospheric.

Household wastewater enters the drainage network from residential areas and industrial enterprises, public catering plants and medical institutions. In the composition of such waters, fecal wastewater and household wastewater are distinguished, polluted with various household waste, detergents. Household wastewater always contains a large number of microorganisms, which are products of human vital activity. Among them may be pathogenic. A feature of domestic wastewater is the relative constancy of their composition. The main part of the organic pollution of such waters is represented by proteins, fats, carbohydrates and products of their decomposition. Inorganic impurities, as a rule, make up particles of sand, clay, as well as salts formed in the process of human life. The latter include phosphates, bicarbonates, ammonium salts, etc. Of the total mass of pollution of domestic wastewater, the share of organic substances accounts for 45-58%.

Industrial wastewater is formed as a result of technological processes. The quality of wastewater and the concentration of pollutants are determined by the following factors: the type of industrial production and raw materials, modes of technological processes. In enterprises, for example, metalworking industrial wastewater is contaminated with mineral substances. The food industry is largely a source of organic pollution. Wastewater from many enterprises contains both mineral and organic contaminants in various ratios. The concentration of wastewater pollution from different industries is not the same. It varies very widely, depending on the water consumption per unit of production, the specifics and perfection of the technological process and production equipment. The concentration of contaminants in industrial wastewater can vary greatly in time and depends on the course of the technological process in individual shops or in the enterprise as a whole. The uneven flow of wastewater and its concentration in all cases worsens the work of treatment facilities and complicates their operation.

Atmospheric wastewater is formed as a result of precipitation. This category of wastewater includes meltwater, as well as water from watering the streets. In atmospheric waters, there is a high concentration of quartz sand, clay particles, garbage and petroleum products washed off the streets of the city. Pollution of the territory of industrial enterprises leads to the appearance in storm water of impurities characteristic of this production. A distinctive feature of stormwater runoff is its episodic nature and pronounced unevenness in the flow rate and concentrations of pollution.

Depending on the hydrogeological conditions of the area, the nature of production processes in a given region, the consumption of water for household and industrial purposes, a particular wastewater disposal system and, accordingly, the scheme of the drainage network are selected. Pollution of household and industrial effluents affects the technology of water purification and the environmental situation in the area.

The composition of wastewater and its properties are evaluated by the results of sanitary-chemical analysis, which includes, along with standard chemical tests, a number of physical, physico-chemical and sanitary-bacteriological definitions.

The complexity of the composition of wastewater and the impossibility of determining each of the pollutants leads to the need to choose such indicators that would characterize certain properties of water without identifying individual substances. Such indicators are called group or total. For example, the determination of organoleptic parameters (smell, color) avoids the quantification in water of each of the substances that have an odor or give the water color.

A complete sanitary and chemical analysis involves the determination of the following indicators: temperature, color, odor, transparency, pH value, dry residue, dense residue and losses during calcination, suspended substances, sedimentation by volume and by weight, permanganate oxidizability, chemical oxygen demand (COD), biochemical oxygen demand (BOD), nitrogen (general, ammonium, nitrite, nitrate), phosphates, chlorides, sulfates, heavy metals and other toxic elements, surfactants, petroleum products, dissolved oxygen, microbial number, bacteria of the Escherichia coli group (BGCP), helminth eggs. In addition to the listed indicators, the number of mandatory tests of complete sanitary and chemical analysis at urban treatment plants may include the determination of specific impurities entering the drainage network of settlements of industrial enterprises.

Temperature is one of the important technological indicators. The function of temperature is the viscosity of the liquid and therefore the resistance force of the settling particles. Therefore, temperature is one of the determining factors of the sedimentation process. Temperature is of the utmost importance for biological purification processes, since the rates of biochemical reactions and the solubility of oxygen in water depend on it.

Coloring is one of the organoleptic indicators of wastewater quality. Household-fecal wastewater is usually weakly colored and has yellowish-brownish or gray shades. The presence of intense coloring of various shades is evidence of the presence of industrial wastewater. For stained wastewater, the intensity of the color is determined by dilution to colorless.

Smell is an organoleptic indicator characterizing the presence of odorous volatile substances in the water. Usually, the smell is determined qualitatively at a sample temperature of 20 ° C and described as fecal, putrefactive, kerosene, phenolic, etc. With an indistinct odor, the definition is repeated, heating the sample to 65 ° C. Sometimes it is necessary to know the threshold number - the smallest dilution at which the smell disappears.

The concentration of hydrogen ions is expressed by the pH value. This indicator is extremely important for biochemical processes, the speed of which can decrease significantly with a sharp change in the reaction of the medium. It is established that the wastewater supplied to biological treatment plants should have a pH value in the range of 6.5 - 8.5. Industrial wastewater should be neutralized before discharge into the drainage network to prevent its destruction. Urban wastewater usually has slightly alkaline reaction of the medium with a pH of approximately 7.5 - 8.0.

Transparency characterizes the total contamination of wastewater with undissolved and colloidal impurities, without identifying the type of pollution. The transparency of municipal wastewater is usually 1-3 cm, and after treatment increases to 15 cm.

The dry residue characterizes the total contamination of wastewater with organic and mineral impurities. This indicator is determined after evaporation and further drying at t = 105° C of the wastewater sample. After calcination (at t = 600° C), the ash content of the dry residue is determined. These two indicators can be used to judge the ratio of organic and mineral (ash) parts of the contaminants in the dry residue.

The dense residue *is* the total amount of organic and mineral substances in the filtered wastewater sample. It is determined under the same conditions as the dry residue. After calcination of the dense residue at t = 600 ° C, it is possible to roughly estimate the ratio of the organic and mineral parts of the soluble wastewater contaminants. When comparing the calcined dry and dense residues of municipal wastewater, it is determined that most of the organic pollution is in an undissolved state. At the same time, mineral impurities are more in dissolved form.

Suspended solids are an indicator of the amount of impurities that are retained on the paper filter when filtering a sample. This is one of the most important technological indicators of water quality, allowing you to estimate the amount of precipitation formed during wastewater treatment. In addition, this indicator is used as a design parameter in the design of primary sedimentation tanks.

Losses during the calcination of suspended solids are determined in the same way as for dry and dense residues, but are usually expressed not in mg / l, but as a percentage of the mineral part of the suspended substances to their total dry matter quantity. This indicator is called ash content. The concentration of suspended solids in municipal wastewater is usually between 100 and 500 mg/l.

Sedimentation is the part of the suspended solids that settle to the bottom of the settling cylinder for 2 hours of settling at rest. This indicator characterizes the ability of suspended particles to settle, allows you to assess the maximum effect of settling and the maximum possible amount of sludge that can be obtained at rest. In urban wastewater, settling substances on average make up 50-75% of the total concentration of suspended solids.

Ooxidizability - the total content of reducing agents of organic and inorganic nature in water. In urban wastewater, the vast majority of reducing fluids are organic substances, so it is believed that the amount of oxidizability almost entirely refers to organic pollution. Depending on the nature of the oxidant used, a distinction is made between chemical oxidizability, if a chemical oxidizing agent is used in the determination, and biochemical, when the role of the oxidizing agent is distinguished. agents perform aerobic bacteria - this indicator - biochemical oxygen demand - BOD. In turn, chemical oxidizability can be permanganate (oxidizing agent $KMnO_4$), bichromate (oxidizer $K_2Cr_2O_7$) and iodatic (oxidizer KJO_3). Bichromate and iodine oxidation is called chemical oxygen demand or COD.

Permanganate oxidizability is the oxygen equivalent of easily oxidized impurities. The main value of this indicator is the speed and simplicity of determination. Permanganate oxidizability is used to obtain comparative data. However, there are substances that are not oxidized by $KMnO_4$. Determining COD, it is possible to sufficiently fully assess the degree of water pollution with organic substances.

BOD is the oxygen equivalent of the degree of contamination of wastewater with biochemically oxidized organic substances. BOD determines the amount of oxygen necessary for the vital activity of microorganisms involved in the oxidation of organic compounds. BOD characterizes the biochemically oxidizable part of organic wastewater contaminants that are in dissolved and colloidal states, as well as in the form of suspension.

Nitrogen is found in wastewater in the form of organic and inorganic compounds. In urban wastewater, the bulk of organic nitrogenous compounds are substances of a protein nature - feces, food waste. Inorganic nitrogen compounds are represented by reduced - NH_4^+ and NH_3 oxidized forms NO_2^- and NO_3^- . Ammonium nitrogen in large quantities is formed during the hydrolysis of urea - a product of human vital activity. In addition, the process of ammoniation of protein compounds also leads to the formation of ammonium compounds.

In municipal wastewater, nitrogen in oxidized forms (in the form of nitrites and nitrates) is usually absent before it is purified. Nitrites and nitrates are reduced by a group of denitrifying bacteria to molecular nitrogen. Oxidized forms of nitrogen can appear in wastewater only after biological treatment.

The source of *phosphorus* compounds in wastewater is the physiological secretions of people, waste products of human economic activity, including detergents in the form of synthetic surfactants (SS) and some types of industrial wastewater.

Approximately 75% of the total amount of spav produced is accounted for by anionactive substances, the second place in terms of release and use is occupied by non-ionic compounds. In urban wastewater, these two types of SS are determined.

Concentrations of nitrogen and phosphorus in wastewater are the most important indicators of sanitary and chemical analysis that are important for biological treatment. Nitrogen and phosphorus are essential components of the composition of bacterial cells. They are called biogenic elements. In the absence of nitrogen and phosphorus, the process of biological purification is impossible.

Chlorides and sulfates are indicators whose concentration affects the total salinity. At very large values, the salinity significantly affects the process of biological wastewater treatment.

The group of heavy metals and other toxic elements includes a large number of elements, which with the accumulation of knowledge about the purification processes is increasing. Toxic heavy metals include iron, nickel, copper, lead, zinc, cobalt, cadmium, chromium, mercury; toxic elements that are not heavy metals are arsenic, antimony, boron, aluminum, etc.

The source of heavy metals is industrial wastewater of machine-building plants, enterprises of electronic, instrument-making and other industries. In wastewater, heavy metals are contained in the form of ions and complexes with inorganic and organic substances.

Petroleum products are non-polar and low-polar compounds extracted by hexane. The concentration of petroleum products in water bodies is strictly standardized, and since the degree of their detention at urban treatment plants does not exceed 85%, the content of petroleum products in the wastewater entering the station is also limited.

There is no dissolved oxygen in the wastewater entering the treatment plant. In aerobic processes, the oxygen concentration should be at least 2 mg / l.

Sanitary and bacteriological indicators include: determination of the total number of aerobic saprophytes (microbial number), bacteria of the Escherichia coli group and analysis of helminth eggs.

The microbial number estimates the total contamination of wastewater with microorganisms and indirectly characterizes the degree of water pollution with organic substances - food sources of aerobic saprophytes. This indicator for urban wastewater ranges from 10^6 - 10^8.

The variety of quantity and quality of wastewater, both industrial and domestic, determines the choice of the wastewater disposal system and the scheme of drainage networks, and, accordingly, the methods of treatment.

2.2. Wastewater disposal systems of cities and industrial enterprises

The wastewater disposal system and the scheme of the drainage network are selected depending on the hydrogeological, topographic conditions of the area, the nature of production processes in the region, water consumption for household and industrial purposes. Depending on how individual types of wastewater are diverted - jointly or separately, wastewater disposal systems are divided into all-alloy, separate (complete or incomplete), semi-separate and combined.

1) With a general alloy drainage system, all types of wastewater are discharged through a single drainage network. During heavy rains, due to the insignificant concentration of pollution, it is envisaged to discharge part of the wastewater mixture into the water body without treatment through special devices - storm drains, usually placed on the main collector near the reservoir. The use of all-alloy drainage systems is advisable if there is a powerful reservoir near the serviced facility, into which it is permissible to discharge significant volumes of untreated wastewater. Currently, all-alloy systems are not designed, because they do not meet modern rules for the protection of surface water, or arrange all-

alloy systems without storm drains, that is, all types of wastewater are diverted for treatment. The disadvantage of such systems is that in dry weather, the hydraulic conditions of the collectors are worse due to their low filling.

2) With a separate system, certain types of wastewater are discharged through independent networks. A complete separate system has at least two networks (usually domestic and rainwater), while industrial wastewater is purified together with domestic wastewater. An incomplete separate system has only one drainage network for the drainage of domestic and industrial wastewater. Drainage of rainwater into the reservoir is carried out through open trays, ditches and ditches. The device of an incomplete separate system is possible only for small objects. Usually this system is an intermediate stage in the construction of a complete separate system.

3) The semi-separate system has two drainage networks – industrial and domestic and rain networks. At the intersection of these networks, separation chambers are arranged. The principle of operation of the separation chamber is based on taking into account the varying degrees of departure of the water jet from the ledge at different speeds of water movement in the collector at small and large fillings. With relatively low water flows in the rain network, the chambers pass the entire flow of rainwater into the main collector, with high flows, they pass into it only a part of the water flowing through the pipes in the bottom part. Thus, the most polluted rainwater flowing in the initial period of rain, when the bulk of the contaminants are washed off the surface of the catchment area, and the bottom streams of water, the most saturated with pollution, are diverted for treatment. With high water flows (during heavy rains), less polluted rainwater is discharged into the reservoir without treatment. From a sanitary point of view, this system is the most progressive, but due to the high construction and operational cost, it is not widely used. The term "urban wastewater" often appears in the specialized literature. Municipal wastewater is understood as a mixture of all three types of water with a general alloy drainage system or domestic and industrial with a separate system. In the whole country, industrial wastewater accounts for about 30-40% of the total volume of wastewater disposal of urban sewerage systems. According to the chemical nature, urban wastewater pollution is divided into mineral (sand, clay, dissolved mineral salts, acids and alkalis) and organic, which in turn can be of vegetable and animal origin. Urban wastewater has extremely high microbial contamination. To solve the issue of the discharge of urban wastewater into a water body, it is not necessary to study its composition, since it is quite constant, and the differences can only be in the concentration, which depends on the rate of wastewater disposal. Industrial wastewater is accepted into the city sewerage system with restrictions. Nevertheless, the presence of industrial wastewater in the urban runoff informs it of a variety of composition, uneven volume and concentration. At city treatment plants, water sequentially passes through mechanical, biological treatment facilities and is disinfected. To ensure the normal operation of these

biological structures, a number of requirements are imposed on urban wastewater, the fulfillment of which is ensured by constant monitoring of the quality of wastewater of industrial enterprises connected to the city's drainage network. The conditions for the formation of wastewater at different enterprises can vary greatly. Sewerage of industrial enterprises, as a rule, is carried out according to a complete separate system. Industrial wastewater, depending on the type of pollutants and their concentrations, as well as on the amount of wastewater and the places of its formation, is discharged by several independent streams. For better local treatment of various types of pollution, several industrial sewerage networks are organized, for example, for highly mineralized waters that do not contain highly toxic substances, acidic and alkaline wastewater, highly toxic wastewater, wastewater from cooling units, usually not carrying pollution. The separation of industrial wastewater can be dictated by sanitary reasons, fire and explosion hazards, the possibility of overgrowth and destruction of sewage pipelines, etc. For preliminary wastewater treatment, local treatment facilities are included in the sewerage system of industrial enterprises, which are located, as a rule, in the territories of canalized enterprises. Uncontaminated wastewater is usually combined into a separate stream. Domestic wastewater generated in an industrial enterprise is discharged and treated separately if the industrial wastewater does not require biological treatment in its composition. Joint disposal of domestic and industrial wastewater is also possible, if the latter are contaminated with organic substances, the destruction of which is possible by biological means, while the concentrations of toxic impurities should not exceed the maximum permissible. Rainwater flowing from unpolluted enterprises is diverted by a separate sewage system or combined with unpolluted industrial wastewater and discharged into the reservoir without treatment. Contaminated rainwater is discharged together with polluted industrial wastewater and is subject to joint treatment before release into the reservoir. For some enterprises, during a feasibility study, a total alloy sewerage system can be designed that collects household, fecal and industrial waters (for example, when the enterprise is located in the city and there is an urban all-alloy sewerage). At enterprises where industrial wastewater is close in composition to domestic wastewater, wastewater disposal can be carried out through two networks: industrial and domestic and rainwater.

As examples of the use of separate and all-alloy water disposal systems, consider the sewerage of wastewater from Moscow and St. Petersburg.

The sewerage system of Moscow, according to MOSVODOKANAL JSC, in its historical development has developed as a separate one. It receives only household, municipal and industrial wastewater. Surface wastewater is discharged through an independent drainage system. All household and industrial wastewater entering the city sewerage system of Moscow through a network of pipelines, canals and collectors with a diameter of 125 mm to 4.5 m undergoes a full treatment cycle at treatment facilities with a total design capacity of

6.345 million m3 / day. The total length of the city's sewerage network is more than 8178.4 km.

The main direction of sewage pipelines is oriented to the south and south-east of the city, in the direction of the flow of the Moskva River, which is due to the terrain. The city's water disposal is carried out at the Lyuberetsky (LOS) and Kuryanovsk (KOS) treatment facilities, as well as at the treatment facilities in South Butovo. Sewerage of the Zelenograd Administrative District of Moscow is carried out on separate treatment facilities. Treated wastewater is discharged into the Moskva River and its tributaries - Pekhorka, Desna, Skhodnya.

St. Petersburg is canalized according to the data of SUE "Vodokanal of St. Petersburg" according to a combined scheme: 70% of the entire territory has a total alloy sewerage system, which receives household, industrial, as well as surface (rain, melt) effluents; the rest of the territory - these are mainly areas of new buildings and suburbs - are canalized according to a separate scheme (rainwater and meltwater are collected separately from the rest of the effluents).

The sewerage system is divided into sewerage basins. The effluents of each basin are directed to certain sewage treatment plants. In turn, the sewerage basins are divided into canalization areas with an area limited by the catchment of large tunnel collectors.

Sewerage areas are divided into sections of local catchments of street sewer networks.

Sewerage sectors are formed similarly to water supply sectors.

The sewerage system of St. Petersburg includes:

sewerage network – 8603 km

tunnel collectors – 270,7 km

sewage pumping stations (SPS) – 176

treatment plants of various capacities – 16

sludge incineration plants – 3

stationary snow-melting points - 10

stationary engineering-equipped snow receiving points - 6

The diameters of the pipelines of the city drainage network of St. Petersburg are from 150 mm (yard networks) to 4.7 m (tunnel collectors).

Tunnel collectors are the main highways for transporting wastewater to treatment plants. The construction of tunnel sewer collectors in Leningrad began in 1947. The inner diameter of tunnel collectors is from 2 to 4.7 m, the depth of laying is from 15 to 80 m.

The design capacity of sewage pumping stations ranges from 0.3 thousand m3 / day to 1000 thousand m3 / day. SUE "Vodokanal of St. Petersburg" carries out modernization and reconstruction of the KNS, using modern submersible pumping units and complex sewage pumping stations. In addition to the replacement of pumping and electrical equipment, other auxiliary mechanisms are being modernized.

The largest sewage treatment plants in St. Petersburg are:

Central aeration station

North aeration station

Southwest Wastewater Treatment Plant

St. Petersburg is the first metropolis in the world where the problem of wastewater sludge disposal has been solved.

There are three sludge incineration plants in the city - at the Central Aeration Station, at the Northern Aeration Station and at the South-West Treatment Facilities. Combustion is carried out in furnaces with a fluidized bed at a temperature of 870 º C. The heat obtained from the combustion of precipitation is used for technological needs, heating buildings and generating electricity, which allows Vodokanal to save energy resources. Flue gases undergo a three-stage purification.

It should be noted that in most cities of the Russian Federation a separate wastewater disposal system is used.

After wastewater treatment, the release of treated water into the reservoir should take into account the category of the water body. Of great importance in this case is the characteristic of water bodies - receivers of treated wastewater.

The sanitary characteristics of the reservoir are compiled on the basis of a sanitary and topographic survey. This also takes into account the sanitary conditions of water supply to populated areas. On the basis of such surveys, indicators of water quality of water use sources have been compiled. They are divided into three classes (Table 2.1).

The division of water sources into classes shows their great variation in the quality and quantity of water. Water quality indicators vary depending on the hydrogeological conditions of the object, its geographical location, as well as on the presence of industrial enterprises (they can discharge wastewater into the reservoir). According to their purpose, water sources are divided into fishery, household and cultural sources.

Fishery facilities, in turn, are divided into two categories. The first includes objects used during the conservation and reproduction of valuable fish species with high sensitivity to oxygen. To the second - all water bodies used for other fishery purposes.

When releasing treated wastewater into a reservoir, it is necessary to take into account the category of the water body and the MPC of harmful pollution. The conditions for the discharge of wastewater into water bodies are regulated by the "Rules for the Protection of Surface Water from Pollution by Wastewater". These rules establish water quality standards: for water bodies of economic, drinking and cultural water use; for water bodies used for fishery purposes.

In accordance with the rules, it is forbidden to discharge wastewater into water bodies, which can be eliminated by switching to anhydrous production or by reuse and recycling.

The rules establish water quality standards for water bodies by categories of water use: the first category includes areas of water bodies used as sources for centralized or non-centralized drinking water supply, as well as water supply for food industry enterprises. To the second - areas of water bodies used for sports and recreation of the population.

The water quality standards in water bodies given in the rules refer to alignments located on flowing sections 1 km above the nearest water use point, on non-flowing sections and reservoirs - to alignments 1 km in both directions from the water use point.

Clarification of the categories of water bodies or their sections is carried out by the bodies of the sanitary and epidemiological service and fishery organizations. General requirements for the composition and properties of water in reservoirs and streams of the corresponding categories after the release of wastewater into them, which has been plunged to the necessary treatment, are given in Table. 8.3.

Requirements for the release of wastewater into the sea comply with the standards for the reception of treated wastewater into inland watercourses and reservoirs. However, there are some peculiarities. According to the "Rules for the Sanitary Protection of the Coastal Waters of the Seas", the boundaries of the seawater use area along the coastline are taken into account when developing relevant projects. Towards the sea, it is taken at least 2 km from the coastline, then 10 km in both directions from the boundaries of the water use area along the shore and towards the sea. The first belt of sanitary protection is envisaged. Within the boundaries of the water use area, the discharge of treated industrial domestic wastewater, including ship wastewater, is prohibited.

Table 2.1.

Indicators of the composition and properties of water in the reservoir after the release of wastewater	Requirements for the composition and properties of water in the reservoir household and cultural and domestic purposes	Requirements for the composition and properties of water in the reservoir fisheries
	Categories of household and cultural and domestic purposes	Categories of fishery purpose
	I II	I II
Suspended solids content	It is allowed to increase by no more than 0.25 mg/l I 0.75 mg/l | 0,25 mg/l | 0,75 mg/l	
	For water bodies containing more than 30 mg/l of natural minerals in the lowland, an increase in the content by *5%* is allowed (suspended substances with a deposition rate of more than 0.4 mm/s for flowing water bodies and more than 0.2 mm/s for reservoirs to the descent are prohibited).	
Films of petroleum products, oils, fats and other floating impurities	Not allowed	
Smells, tastes and coloring	Odors and tastes with an intensity of not more than 2 points (directly or after chlorination of water) are allowed. Colour should not be detectable in a column of water 20 cm high 1 10 cm	Foreign odors, tastes and color of water affecting fish meat are not allowed.
Water temperature	An increase of not more than 3 ° C in relation to the average monthly	It is allowed to increase by no more than 5 ° C to the natural water temperature (in the

	temperature of the hottest month is allowed.	presence of cold-water fish - salmon, whitefish - the total water temperature should not exceed 20T in summer and 5 ° C in winter; in other cases - 2843 and 8 * 0.
Hydrogen index	Must not go beyond 6.5 to 8.5	
Mineral composition of water	The dry residue should be no more than 1000 mg / l (including chlorides up to 300 and sulfates up to 100 mg / l).	Not standardized
Presence of dissolved oxygen		

	Must be at least 4 mg/l		must be at least 6 mg/l	In winter, under the ice should be at least 4 mg / l, in summer - at least 6 mg / l
Biochemical demand in oxygen - BPKmm at a temperature of 20 ° C	Must not exceed			
	3 mg/l	6 mg/l	■ mg / l (if in winter the oxygen content in the water decreases for water bodies of I category to 6	

			mg / l, P category up to ■ mg/L, then only water discharge that does not affect BOD is allowed).
Causative agents of diseases	Not allowed (after disinfection of biologically treated waters, the coli index should not exceed 1000 with a residual chlorine content of 1.5 mg / l).		
Toxic substances	They are not allowed in concentrations that may have a direct or indirect harmful effect on living organisms.		

The discharge of wastewater containing radioactive substances into the household wastewater disposal system is regulated by the "Sanitary Rules for Working with Radioactive Substances and Sources of Ionizing Radiation".

For an unidentified mixture of radioactive substances containing α, β and γ radiation, the MPC is $3 \cdot 10^{11}$ curies / l.

Radioisotopes are biologically active in microquantities. They are able to selectively accumulate on various substrates of animal and plant origin. Therefore, it is forbidden to discharge wastewater containing radioactive elements into water bodies intended for the breeding of fish and waterfowl.

The discharge of wastewater into non-flowing water bodies, seas or reservoirs has recently become more common in sanitary practice. This issue has not been sufficiently studied with regard to dilution and self-purification. When releasing wastewater into non-flowing water bodies due to the limited volume of their volume, one cannot count only on dilution without finding out the degree of stability of substances in wastewater. For the possibility of releasing wastewater into such reservoirs, a scientific justification of the conditions for the discharge of wastewater is necessary.

In connection with the above circumstances, various methods and their combinations are used for wastewater treatment: mechanical, chemical, physico-chemical and biological.

The choice of method depends on many factors, in particular, on the requirements for the quality of treated wastewater, on the location of the enterprise and the availability of energy and material resources necessary for the implementation of the wastewater treatment process, etc.

2.3.Mechanical wastewater treatment

2.3.1. Overview

Mechanical treatment is the separation from wastewater of undissolved coarse impurities located in them, which are of a mineral and organic nature. To do this, the following methods are used:

filtering - retention of the largest contaminants and partially suspended substances on grates and sieves;

sedimentation - the release of suspended substances from wastewater under the influence of gravity on sand traps (for the release of mineral impurities), settling tanks (to detain smaller settling and popping up impurities), as well as oil traps, oil and resin traps. A variation of this method is centrifugal settling, used in hydrocyclones and centrifuges;

filtration - retention of a very fine suspension in suspension on mesh and granular filters.

With uneven formation of industrial wastewater before supplying to treatment facilities, they are averaged in terms of flow and concentration in averagers of various designs.

Currently, as an independent method, mechanical cleaning is rarely used. Such a possibility exists if, when using only mechanical treatment under the conditions of discharge into the reservoir, the necessary water quality is ensured (for industrial wastewater - re-return to the technological process).

Basically, mechanical treatment is used as a preliminary stage before biological treatment or as a post-treatment of wastewater.

In facilities for mechanical wastewater treatment (Fig. 2.1), the largest contaminants are first separated on the grates and sieves installed in the head of the treatment facilities, and then suspensions with a fraction size, usually more than 0.15 ... 0.2 mm. The main amount of suspended solids is removed in settling tanks or clarifiers used for this purpose.

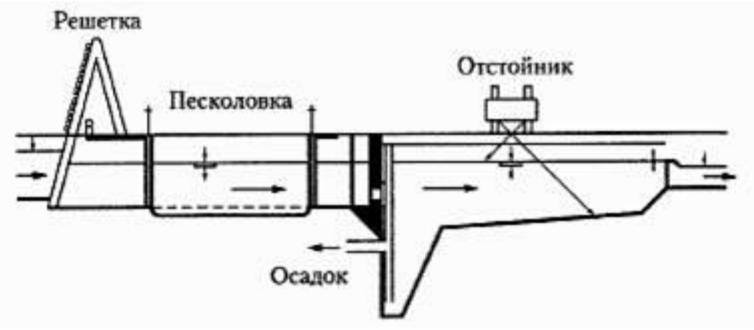


Fig. 2.1 – Scheme of mechanical wastewater treatment

2.3.2. Grids

Grates are installed at treatment plants usually with gaps of 16...20 mm, although recently technical solutions have appeared that allow the use of grids with smaller gaps, up to 4 mm. The area of the prosors of the working part of the lattice should be at least twice the live section area of the supply channel during manual cleaning and at least 1.2 live sections during mechanical cleaning. Usually the grilles are installed at an angle to the horizon of 60°.

Quite widespread in domestic practice were mechanical rotary grates of the MGT type of the Giprokommunvodokanal design and mechanized small-sized vertical RMV 600/800 designs of MosvodokanalNIIproekt.

Coarse grates are very popular in the United States, and in European countries they are practically not used. In Europe, sewage treatment plants are relatively small, it is easier to provide a higher degree of purification, and probably that is why step screens, grates of ribbon and rotary types are popular there.

The appearance on the market of the first stage grille in 1984 is associated with the name of the Swedish company "Hydropress Wallander & Co" (now a division of the company "Huber Technology"). Various modifications of stepped gratings are produced by such companies as "Meva" (Sweden), "Preseco Pomiltek Oy" (Finland), LLC "Riotek" (Russia), NIIlegmash OrelSTU (Russia).

In Europe, belt lattices have been produced for more than 20 years. The grille is a steel frame (made of stainless or carbon steel, protected by an anti-corrosion coating) with a moving tape made of impact-resistant plastic. The tape is assembled from elements with hooks (teeth) for transporting garbage. After dropping the waste, the tape is cleaned with a rotating nylon brush. Such fine grates are available with gaps: 0.5–10 mm ("Sereco S.r.l."); 3–15 mm (Andritz AG); 1.5–25 mm ("Passavant-Geiger GmbH"); 5–10 mm (JSC "Vladimir plant "Elektropribor").

Andritz produces the Aqua-Screen ribbon grid, which is made of perforated stainless steel (Fig. 2.2). The diameters of the holes can be 3, 6, 10 or 15 mm. Step-like panels, of which the tape consists, move using a powerful chain protected from impurities by brushes made of polyester. Cleaning of the tape after the discharge of waste is carried out in two stages. First, the tape is washed with water from the nozzles, then cleaned with rotating brushes. The Aqua-Screen grilles are 0.5–2.5 m wide.

Рисунок 2.2 – Решетка Aqua-Screen Andritz

Recently, drum (rotary) grates with integrated washing and compaction of recoverable waste have become popular. For example, a Rotamat grid manufactured by Huber (Figure 2.3) is a rotating basket consisting of wedge-shaped slats and is installed in a channel or container at an angle of 35 (Fig.). The magnitude of the prozor is from 6 to 10 mm and the diameter of the drum is up to 3000 mm.

The principle of operation of the Rotamat drum grille is based on a patented technology that allows combining several functions in one installation at once - retention, washing, transportation, dehydration and unloading of waste.

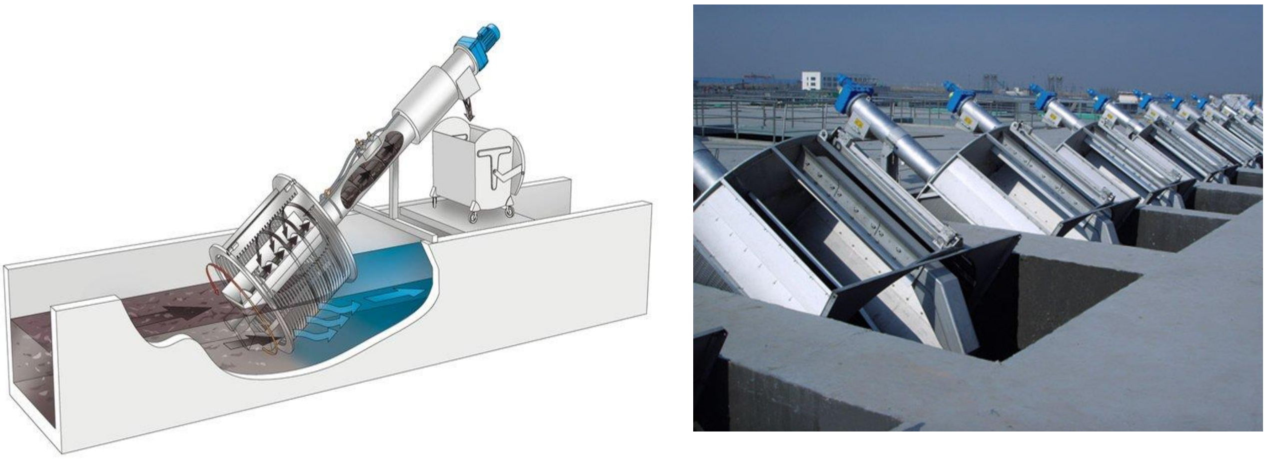


Fig. 2.3 – Rotamat grille from Huber

If there are fibrous inclusions in the wastewater, belt or drum sieves are used. A belt sieve is a tape woven usually of bronze wire with hole sizes of 0.5 x 0.5 mm or more and rotated on two blocks. Cleaning of sieves from captured contaminants is most often done with water or with the help of brushes.

Drum sieves have the form of cylinders, the surface of which is covered with a metal mesh, and the axis of the cylinder is installed normally or along a moving stream. When the drum rotates, the level of fluid in it rises, which contributes to the self-cleaning of the drum.

2.3.3. Sand trap

Sand traps are used to remove sand and other suspended particles from wastewater (Figure 2.4). They are divided into horizontal, vertical, tangential (with rotational fluid motion) and aerated. Horizontal and sand traps with rotational fluid movement (tangential and aerated) are used at a flow rate of about 10,000 m^3 / day. Vertical ones are used less often due to their less stable mode of operation and low cleaning efficiency.

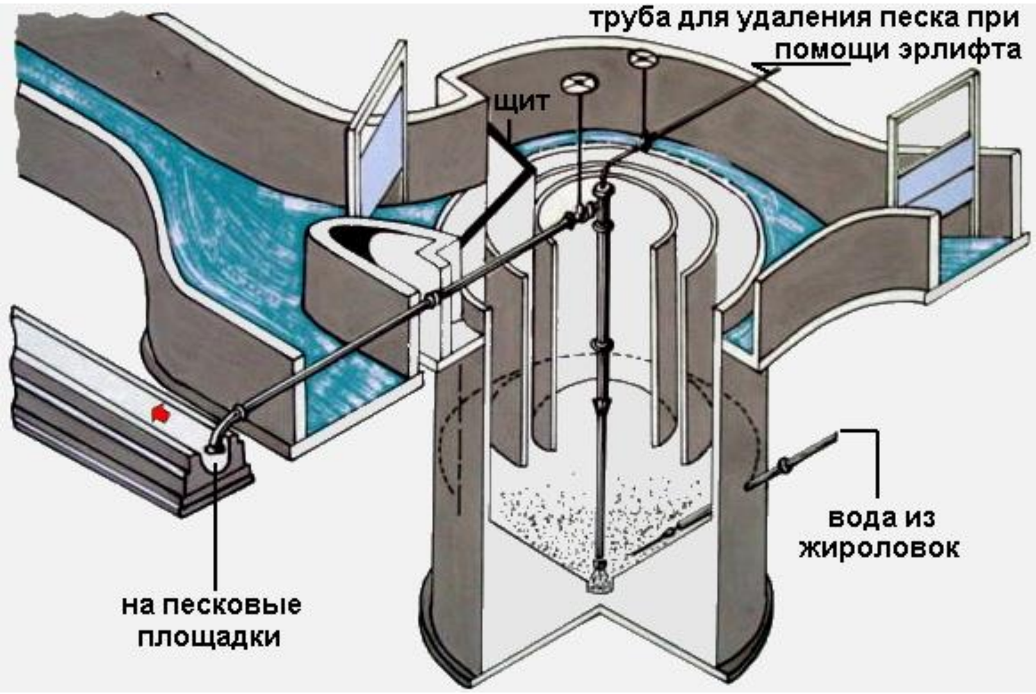


Fig. 2.4 - Scheme of water movement in a sand trap

Tangential sand traps and hydrocyclones for normal operation require constant maintenance and are most often used for additional cleaning of sediments before their processing.

Horizontal sand traps, as a rule, are equipped with mechanical scrapers with a chain drive. When the scrapers move against the flow of water along the bottom of the structure, the sand is shifted into a pit located at the beginning of the sand trap, from where hydro elevators are pumped to the sand platforms. Such a sludge removal system is extremely unreliable. At the same time, the most vulnerable link is the chain drive of scrapers.

For the countries of Western Europe, the most developed operation is the removal of sand with the help of submersible sand pumps, which are placed on special bridges that move along the length of the structure. The sand pulp is pumped into special gutters located above the water level in the sand trap. Such a system successfully works in Zelenograd (Moscow).

In horizontal sand traps with circular movement of water, hydraulic elevators have proven themselves well, the only drawback of which is their rapid abrasion.

Underwater hydro flushing systems did not justify themselves, since for 20 years it was not possible to find a single structure on which this system would successfully work.

Many Vodokanals independently try to solve the issues of reliability of sand removal from sand traps. For example, at the Lyuberetsky wastewater treatment plants in Moscow, Meva reciprocating scraper mechanisms were used.

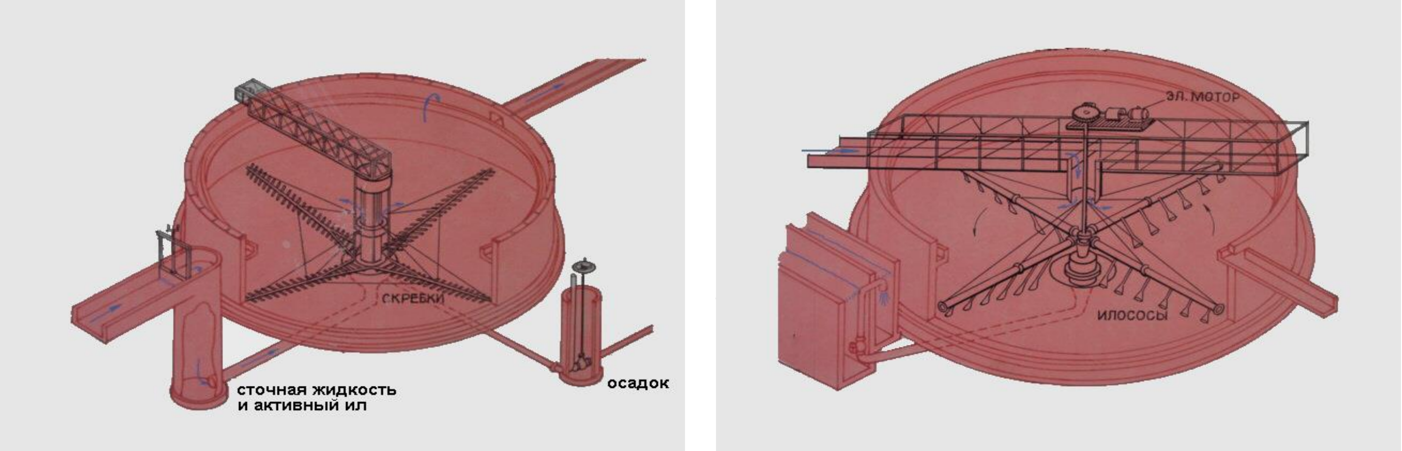
2.3.4.Sedimentation tanks for wastewater treatment

For the separation of sedimentation or floating substances from wastewater with a size of approximately less than 0.1 mm, settling tanks are most often used (Fig. 2.5).

Sedimentation tanks are classified according to the technological role, direction of movement and other signs, for example, the method of flocculation of contaminants and unloading of sediment.

Sedimentation tanks, which are installed in the head of biological treatment facilities, are called primary, and at the end of the structures secondary or tertiary, depending on the scheme of treatment facilities used.

In the direction of movement of the main flow of water, vertical, horizontal and radial are distinguished. Vertical settling tanks are used at treatment plants with a capacity of about 10,000 m^3 / day. Horizontal settling tanks are installed at treatment plants with a wastewater consumption of 10,000 15,000 m÷^{3} / day. Radial settling tanks (Figure 2.5) are most often used for wastewater consumption of more than 20,000 m^3 / day.



(a) b)

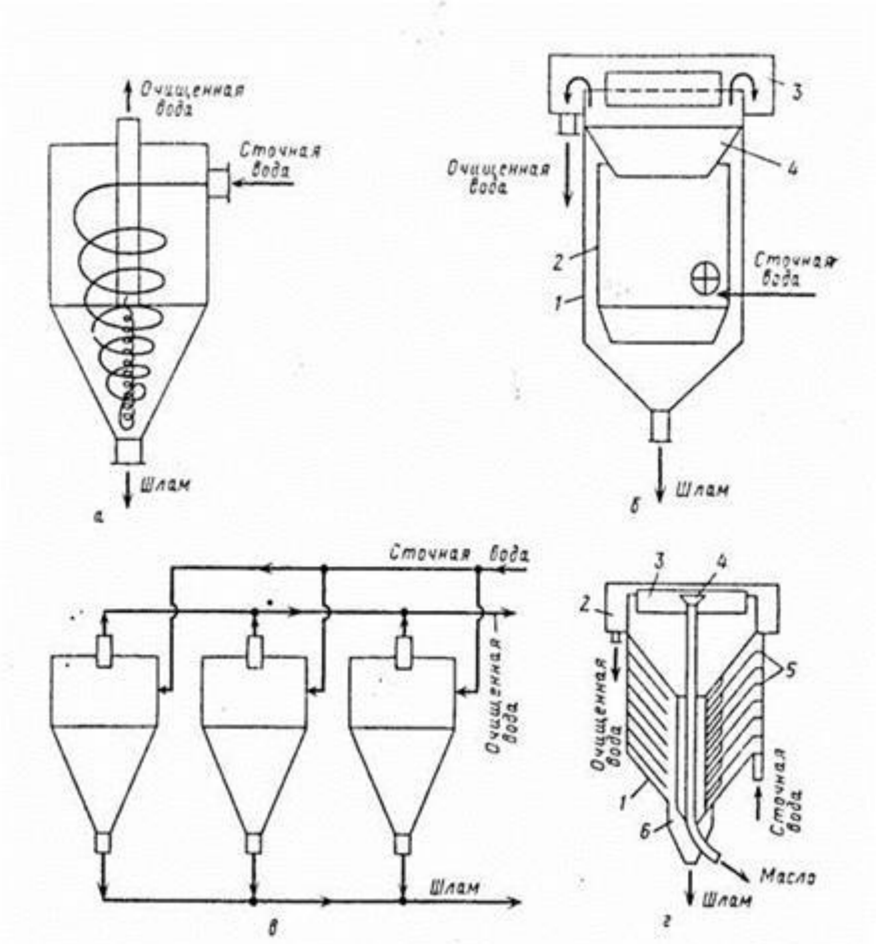
Fig. 2.5 - Schemes of water movement in radial sedimentation tanks (a - primary; b - secondary).

Sedimentation tanks are the simplest and most reliable in operation devices of treatment facilities. The calculation and recommendations for their use as well as other devices and facilities for wastewater treatment are described in special literature, incl. SP 32.13330.2012. Code of Practice. Sewerage. Outdoor networks and structures. Updated version of SNiP 2.04.03-85.

2.3.5. Hydrocyclones and centrifuges

It is possible to intensify the release of suspended particles from wastewater in centrifugal fields using hydrocyclones and centrifuges.

For mechanical treatment of wastewater from suspended substances, open and pressurized hydrocyclones are used (Figure 2.6). Open hydrocyclones are used to isolate pop-up and settling coarse impurities with a hydraulic size of more than 0.2 mm / s and coagulated suspension. Pressure hydrocyclones are used to separate coarse impurities from wastewater mainly of mineral origin. Hydrocyclones are used in the processes of wastewater clarification, condensation of sediments, enrichment of lime milk, washing of sand from organic substances, including petroleum products. When clarifying wastewater, small devices provide a greater treatment effect. When condensing sediments of mineral origin, hydrocyclones of large diameters (over 150 mm) are used.



а — напорный;
б — с внутренним цилиндром и конической диафрагмой: 1 — корпус; 2 — внутренний цилиндр; 3 — кольцевой лоток; 4 — диафрагма;
в — блок напорных гидроциклонов;
г — многоярусный гидроциклон с наклонными патрубками для отвода очищенной воды: 1 — конические диафрагмы; 2 — лоток; 3 — водослив; 4 — маслосборная воронка; 5 — распределительные лотки; 6 — шламоотводящая щель

Fig. 2.6. Hydrocyclones

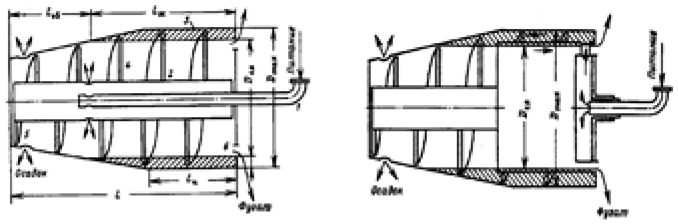
Removal of the released sludge from open hydrocyclones can be under hydrostatic pressure, hydro elevators or mechanized means.

Depending on the required efficiency of wastewater treatment and the degree of condensation of sediments, wastewater treatment in pressurized hydrocyclones can be carried out in one, two or three stages by sequentially connecting the devices with and without jet rupture.

To reduce water loss with the sediment to be removed, the sludge pipe of the first stage hydrocyclone is hermetically attached to the sludge tank. In the first stage c, large hydrocyclones are used to detain the bulk of suspended solids and large suspension particles that can clog small hydrocyclones used in subsequent stages of the installation.

Sedimentation centrifuges of continuous or periodic action are used for the separation of finely dispersed suspended substances from wastewater, when reagents cannot be used to separate them, as well as, if it is necessary, to extract valuable products from the sludge and dispose of them.

Принципиальная схема осадительных шнековых центрифуг



а) противоточной　　б) прямоточной

1 - устройство для подачи исходной суспензии; 2 - шнековый барабан; 3 - ротор; 4 - шнек; 5 - отверстие для выгрузки обезвоженного осадка; 6 - отверстие для слива фугата

Figure 2.7. Scheme of sedimentation centrifuges

Continuous centrifuges are used for wastewater treatment with a flow rate of up to 100 m3 / h, when it is required to isolate particles with a hydraulic size of 0.2 mm / s (countercurrent) and 0.05 mm / s (direct-flow); batch centrifuges - for wastewater treatment, the consumption of which does not exceed 20 m3 / h, with the release of particles with a hydraulic size of 0.05-0.01 mm / s. The concentration of mechanical pollutants should not exceed 2-3 g / l. Selection of the required size of the sedimentary centrifuge is made according to the size of the required separation factor, at which the greatest degree of purification is provided. The separation factor and the duration of centrifugation are determined by the results of experimental data obtained in the laboratory.

The use of centrifugal equipment, although not as widely used as, for example, settling tanks, but at the same time in some cases gives a significant effect of water purification from suspended substances.

2.4. Chemical wastewater treatment

The main methods of chemical wastewater treatment are neutralization and oxidation.

Wastewater containing mineral acids or alkalis is neutralized before being discharged into water bodies or before being used in technological processes. Practically neutral waters are considered to have a pH of 6.5... 8.5.

Neutralization can be carried out in various ways: mixing acidic and alkaline wastewater, adding reagents, filtering acidic waters through neutralizing materials, absorbing acid gases with alkaline waters or absorbing ammonia with acidic waters. In the process of neutralization, precipitation can form.

To neutralize acidic waters use: NaOH, KOH, Na2CO3, NH4OH (ammonia water), CaCO3, MgCO3, dolomite (CaCO3· MgCO3), cement. The most available reagent is calcium hydroxide (lime milk) with a content of 5...10% of the active lime Ca(OH)2. Sometimes production waste is used for neutralization, for example, slags of metallurgical production.

Reagents are selected depending on the composition and concentration of acidic wastewater. There are three types of acid-containing wastewater:

waters containing weak acids (H2CO3, CH3COOH);

waters containing strong acids (HCl, HNO3);

waters containing sulfuric and sulfuric acids.

When neutralizing industrial wastewater containing sulfuric acid, the reaction, depending on the reagent used, proceeds according to the equations:

$$H_2SO_4 + Ca(OH)_2 = CaSO_4 + 2H_2O$$

$$H_2SO_4 + CaCO_3 = CaSO_4 + H_2O + CO_2$$

When lime milk neutralizes wastewater containing sulfuric acid, gypsum precipitates ($CaSO_4$ · 2H 2O), which causes its deposition on the walls of pipelines.

To neutralize alkaline wastewater, various acids or acid gases are also used, for example, exhaust gases containing CO_2, SO_2, NO_2, N_2O_3, etc. The use of acid gases allows not only to neutralize wastewater, but also at the same time to purify the gases themselves from harmful components.

Neutralization of alkaline water with flue gases is a resource-saving technology, as this eliminates the discharge of wastewater, reduces the consumption of fresh water, saves thermal energy for heating fresh water, and also purifies flue gases from acidic components (CO2, SO_2, etc.) and from dust.

Chemical treatment of wastewater, along with neutralization, in some cases may include the oxidation of contaminants contained in wastewater. The oxidative method of purification is used to neutralize industrial wastewater containing toxic impurities (cyanides, complex copper and zinc cyanides) or compounds that are impractical to extract from wastewater, as well as to purify by other methods (hydrogen sulfide, sulfides). For wastewater treatment, for example, the following oxidants are used: gaseous and liquefied chlorine, chlorine dioxide, calcium chlorate, calcium and sodium hypochlorites, potassium permanganate, potassium dichromate, hydrogen peroxide, air oxygen, peroxosulfuric acids, ozone, pyrolusite, etc.

In the process of oxidation, toxic contaminants contained in wastewater, as a result of chemical reactions, turn into less toxic ones, which are removed from the water.

The activity of a substance as an oxidizing agent is determined by the value of the oxidative potential. The first place among oxidants is occupied by fluorine, which, due to its high aggressiveness, cannot be used in practice. For other substances, the oxidizing potential is: for ozone, 2.07; for chlorine, 0.94; for hydrogen peroxide - 0,68; for potassium permanganate - 0.59.

Oxidation with active chlorine. Chlorine and substances containing active chlorine are the most common oxidizing agents. They are used to treat wastewater from hydrogen sulfide, hydrosulfide, methyl sulfur compounds, phenols, cyanides, etc.

When chlorine is introduced into the water, hypochlorous and hydrochloric acids are formed:

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

Oxidation of cyanides with chlorine can be carried out only in an alkaline environment (pH >9...10)

$$CN^- + 2OH^- + Cl_2 \rightarrow CNO^- + 2Cl^- + 2H_2O$$

The resulting cyanates can be oxidized to elemental nitrogen and carbon dioxide:

$$2CNO^- + 4OH^- + 3Cl_2 \rightarrow 2CO_2\uparrow + 6C1^- + N_2\uparrow + 2H_2O$$

In the presence of ammonia, ammonium salts or organic substances containing amino groups in wastewater, chlorine, hypochlorous acid and hypochlorites react with them to form mono- and dichloramines, as well as nitrogen trichloride:

$$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$$
$$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$$
$$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$$

Oxygen oxidation of the air. The oxygen oxidation reaction takes place in the liquid phase at elevated temperatures and pressures. During the oxidation of wastewater from cellulose, oil refining and petrochemical industries, the following reactions occur:

$$2HS^- + 2O_2 \rightarrow S_2O_3^{2-} + H_2O$$
$$2HS^- + 3O_2 + 2OH^- \rightarrow 2SO_3^{2-} + 2H_2O$$
$$2HS^- + 4O_2 + 2OH^- \rightarrow 2SO_4^{2-} + 2H_2O$$

With increasing temperature and pressure, the reaction rate and the oxidation depth of sulfides and hydrosulfides increase.

Air oxygen is also used in the purification of water from iron. In this case, the oxidation reaction in the aqueous solution proceeds according to the scheme

$$4Fe^{2+} + O_2 + 2H_2O = 4Fe^{3+} + 4OH^-$$
$$Fe^{3+} + 3H_2O = Fe(OH)_3 + 3H^+$$

The process of destruction of sulfide compounds can also be carried out by carbon dioxide contained in flue gases. The formation of carbonates occurs according to the following equations:

$$Na_2S + CO_2 + H_2O \rightarrow Na_2CO_3 + H_2S$$
$$2NaHS + CO_2 + H_2O \rightarrow Na_2CO_3 + 2H_2S$$

The released hydrogen sulfide, carried by flue gases and steam, is sent for combustion, and when using carbon dioxide, it serves as a raw material for the production of sulfuric acid.

Ozonization. Ozone is a strong oxidizing agent with the ability to destroy many organic substances and impurities in aqueous solutions at normal temperature. Oxidation with ozone allows simultaneous discoloration of water, elimination of tastes and odors and disinfection. Ozone oxidizes both inorganic and organic substances dissolved in wastewater. Ozonation can purify wastewater from phenols, petroleum products, hydrogen sulfide, arsenic compounds, surfactants, cyanides, dyes, carcinogenic aromatic hydrocarbons, pesticides, etc. When treating water with ozone, organic substances decompose and disinfect water; bacteria die several thousand times faster than when water is treated with chlorine.

During the oxidation reaction of hydrogen sulfide in the first step, sulfur is released, and in the second step, oxidation directly to H2SO4 is observed:

$$H_2S + O_3 \rightarrow S + O_2 + H_2O$$

$$3H_2S + 4O_3 \rightarrow 3H_2SO_4$$

Reactions occur simultaneously, but with an excess of ozone, the second one prevails.

During the oxidation of cyanides, the following reactions occur:

$$CN^- + O_3 \rightarrow CNO^- + O_2$$

$$CNO^- + 2H^+ + H_2O \rightarrow CO_2 + NH_4$$

The action of ozone in oxidation processes can occur in three different directions: direct oxidation involving a single oxygen atom; attachment of a whole ozone molecule to an oxidizable substance to form ozonides; catalytic enhancement of the oxidizing effect of oxygen present in ozonized air. Oxidation of substances can be direct and indirect, as well as be carried out by catalysis and ozonolysis.

Indirect oxidation is the oxidation of radicals formed as a result of the transition of ozone from the gas phase into a liquid and its self-decomposition.

Ozonolysis is the process of fixing ozone on a double or triple carbon bond, followed by its rupture and the formation of ozonides, which, like ozone, are unstable compounds and quickly decompose.

The wastewater treatment process is greatly increased by the combined use of ultrasound and ozone, ultraviolet irradiation and ozone. Ultraviolet irradiation accelerates oxidation by 102 to 104 times.

An effective method is electrochemical oxidation. Electrochemical treatment methods are based on the electrolysis of industrial wastewater. Chemical transformations during electrolysis can be very different depending on the type of electrolyte, as well as the material of the electrodes and the presence of various substances in the solution. The basis of electrolysis consists of two processes: anodic oxidation and cathodic reduction.

Electrochemical treatment should be used in the treatment of concentrated organic and inorganic contaminants and low wastewater consumption. The efficiency of electrochemical oxidation is presented in Table. 2.2 on the example of electrolysis treatment of spent culture fluid of fodder yeast production at a current density of 20 mA /^{cm2} as a dependence of chemical oxygen consumption (COD, mg / l) on time t (min).

Table 2.2. Dependence of chemical oxygen consumption on the time of electrolysis treatment of spent culture fluid of fodder yeast production at a current density of 20 mA/^{cm2}

COD, mg/l	1468	1369	1247	1126	1024	879	742	652
t, мин	0	5	10	15	20	25	30	35

Analysis of those presented in Table. Figure 2.2 shows that during the electrolysis treatment of waste culture fluid of fodder yeast production at a current density of 20 mA /^{cm2} , the COD of the purified liquid is reduced by about 2 times within 35 minutes, which confirms the high efficiency of using electrochemical oxidation.

Electrolytically insoluble materials (coal, graphite, magnetite, lead, magnesium, ruthenium dioxides) applied to a titanium base are used as an anode, lead, zinc and alloy steel are used as a cathode. Of great importance in electrochemical oxidation is the current density.

To prevent the mixing of electrolysis products, especially gases (hydrogen and oxygen), which can form explosive mixtures, ceramic, polyethylene, asbestos and glass diaphragms are used that separate the anode and cathode space.

In the process of anodic oxidation, organic substances are destroyed by obtaining intermediate or final oxidation products (organic acids, CO2, H2O).

During the electrolysis of alkaline wastewater containing cyanides, oxidation of cyanide ions occurs at the anode with the formation of cyanate ions and their further electrochemical oxidation to the final products:

$$CN^- + 2OH^- - 2e \rightarrow CNO^- + H_2O$$

$$2CNO^- + 4OH^- - 6e \rightarrow 2CO_2\uparrow + N_2\uparrow + 2H_2O$$

In order to increase the electrical conductivity of wastewater, reduce energy consumption and intensify the oxidation process, tart water adds mineral salts. The most effective addition of sodium chloride, which decomposes with the release on the anode of chlorine atoms involved in the oxidation process:

$$2Cl^- - 2e \rightarrow Cl_2$$

$$Cl_2 + CN^- + 2OH^- \rightarrow CNO^- + 2Cl^- + H_2O$$

Methods of radiation oxidation are also known. Under the influence of high-energy radiation on aquatic media containing various organic substances, a large number of oxidative particles arise, which cause oxidation processes. Radiation-chemical transformations occur not due to the radiolysis of water pollutants, but due to the reaction of these substances with the products of water radiolysis: OH-, HO2- (in the presence of oxygen), H2O2, H + and ehydr (hydrated electron), the first three of which are oxidizing agents. Radioactive cobalt and cesium, fuel elements, radiation circuits can be used as radiation sources. electron accelerators.

2.5. Physical and chemical wastewater treatment

Methods of physicochemical treatment of wastewater usually include coagulation, flocculation, flotation, adsorption, extraction, ion exchange, ultrafiltration, reverse osmosis, evaporation, etc. The processes of coagulation and flocculation in wastewater occur in the same way as in the case of purification of natural waters for their use for household and drinking purposes.

Consider the physicochemical methods that are often used in the practice of wastewater treatment.

2.5.1. Water treatment with coagulants and flocculants

The use of coagulants and flocculants in the practice of wastewater treatment has become very widespread in the world practice of wastewater treatment.

The technology of reagent treatment of wastewater and natural waters is close, and in some cases the same. In this regard, the material presented in the first part of the manual (Part I. Water Treatment) essentially covers the issues of reagent treatment of wastewater.

The method of water treatment, aimed at removing substances that are in a colloidal state with the help of chemical reagents, is called coagulation. The chemicals used for this purpose are called coagulants. Water coagulation is used to clarify turbid and discolor colored waters. Along with colloidal impurities, coagulation removes coarse particles from the water, as well as plankton, bacteria and viruses. The following coagulants are used for water purification: aluminum sulfate $Al_2 (SO_4)_3 \cdot 18H_2O$, ferrous sulfate (II) $FeSO_4 \cdot 7H_2O$ (iron sulphate), iron (III) chloride $FeCl_3 \cdot 6H_2O$, aluminum hydroxochloride $Al_2(OH)_5Cl$, sodium metalaluminate $NaAlO_2$.

The main factor determining the rate of coagulation of water is the stage of flaking. The growth of flakes is as a result of sorption by sconagulated particles of aluminum or iron hydroxides of colloidal particles, water impurities, enlargement of the formed flakes by connecting them to each other. Enlarged flakes settle under the influence of gravity, dragging suspended particles with them. The faster the flakes grow, the greater their mass and size, the more intensive the sedimentation process is, the higher the degree of clarification of water.

In water discoloration, when humus compounds having the properties of hydrophilic colloids are removed from water, the main role is given to the specific adsorption of multi-charged aluminum cations by the surface of complex high-molecular humic acids. As a result, insoluble aluminum complexes are formed. Coagulation of humus compounds by aluminum coagulant is irreversible. The optimal pH values of the treated water with discoloration are 4.5 – 5.5. The coagulation process is quite fast, vigorous mixing of water is necessary after the intake of coagulant. The coagulation process is also affected by the temperature of the treated water. As the temperature decreases, the rate of thermal motion decreases and the number of effective collisions of colloidal particles decreases, so the stability of the system increases.

The amount of coagulant introduced into the water (mg / l, mg-eq / l, g / m^3 or g-eq / m^3) is called the dose of coagulant. The minimum concentration of the coagulant that meets the best clarification or discoloration of water is called the optimal dose. It is determined experimentally and depends on the salt composition, hardness, alkalinity of water, etc. The optimal dose of the coagulant is its minimum amount, which during trial coagulation gives large flakes and the maximum the transparency of water after 15-30 min. For aluminum sulfate, this concentration usually ranges from 0.2 to 1.0 mg-eq / l (20 - 100 mg / l).

Coagulation of colloidal particles of metal hydroxides occurs under

the influence of anions in the water, so soft waters (during flooding) have poor coagulability. Coagulation of impurities in soft waters under the action of aluminum sulfate occurs better at a pH of 5.7 - 6.6, in waters of medium hardness - at a pH of 6.6 - 7.2, hard - at a pH of 7.2 - 7.6. If you want to reduce the color of water, aluminum sulfate is used as a coagulant. The dose of coagulant for water discoloration is determined approximately by the formula

$$D = 4\,C$$

where D is the dose of aluminium sulfate per anhydrous salt, mg/L; C is the color of water on the platinum-cobalt scale, deg.

The process of water coagulation does not differ in the constancy of the parameters of the treatment facilities due to the continuous change in such indicators of water quality as temperature, chemical composition, concentration of impurities, the degree of their dispersion. To intensify water purification by coagulation, additional flocculant reagents are used to accelerate the processes of flaking and precipitation. The use of flocculants contributes to the formation of strong, quickly settling flakes, which speeds up the water treatment process.

Currently, the following classes of flocculants are used for water purification: 1) inorganic (activated silicic acid); 2) organic high-molecular compounds (HMC) obtained by processing natural products [sodium alginate, starch, carboxymethylcellulose (CMC)]; 3) synthetic high-molecular compounds (polyacrylamide, polyethyleneimine, praestol, etc.). In aqueous solutions, such high-molecular flocculants as starch, polyoxyethylene, cellulose esters are in an undissociated state. Flocculants of type VA-2, VA-202, VA-212, polyethyleneimine give an active cation (polycation). Some flocculants exhibit the properties of ampholites. These include hydrolyzed polyacrylamide. The mechanism of action of flocculants is based on the adsorption of flocculant macromolecules by scoagulated or suspended particles.

The most commonly used reagents for water purification (aluminum sulfate, lime, polyacrylamide, praestol) are solid or jelly-like substances. Before introduction into the water, they are dissolved in special tanks, from which they are fed into the mixers through dispensers. To speed up the dissolution process, mechanical stirrers are used or mixed with compressed air.

At large purification stations, the prepared concentrated solution is pumped into storage tanks located next to the mortar tanks, from which, as necessary, it is selected into the consumable tanks.

The consumption of a particular reagent is established on the basis of preliminary studies. The optimal dose of the reagent is selected from the possibility of achieving a certain degree of water purification necessary for these conditions. In general, in the technology of water purification, the optimal is understood as such a minimum dose of the reagent, at which, after the separation into the precipitate of the scagulated or sfloculated suspension of impurity particles, the least residual turbidity of water is achieved.

Determined on the basis of experimental studies, the flow rate of the reagent is easily dosed with special devices - dispensers. Recently, automatic dispensers are increasingly used that change the amount of reagent depending on the consumption of the purified water.

Devices for preparing and dosing a solution of the reagent are usually placed above the mixer so that the solution can enter it by gravity.

Flaking, which begins after mixing water with reagents, proceeds slowly, it takes several tens of minutes to obtain sufficiently large flakes. Therefore, the speed of movement of water after the mixer should be such that it does not cause the destruction of already formed flakes, for which special flaking chambers are installed immediately behind the mixer, where the process of formation of flakes that began in the mixer ends.

Coagulated water with the formed flakes from the flaking chambers enters the sedimentation tank, where the precipitation of enlarged suspension particles occurs.

2.5.2. Flotation wastewater treatment

2.5.2.1. Treatment of industrial and municipal wastewater

When solving environmental problems, flotation equipment is used mainly in two main areas, namely in the processes of wastewater treatment and in the thickening of activated sludge. In the first case, almost all the main methods of flotation are used: mechanical (impeller), pneumatic, pressure and electroflotation, and only in some cases is the use of flotation known due to gases released as a result of chemical and biochemical reactions (Figure 2.8).

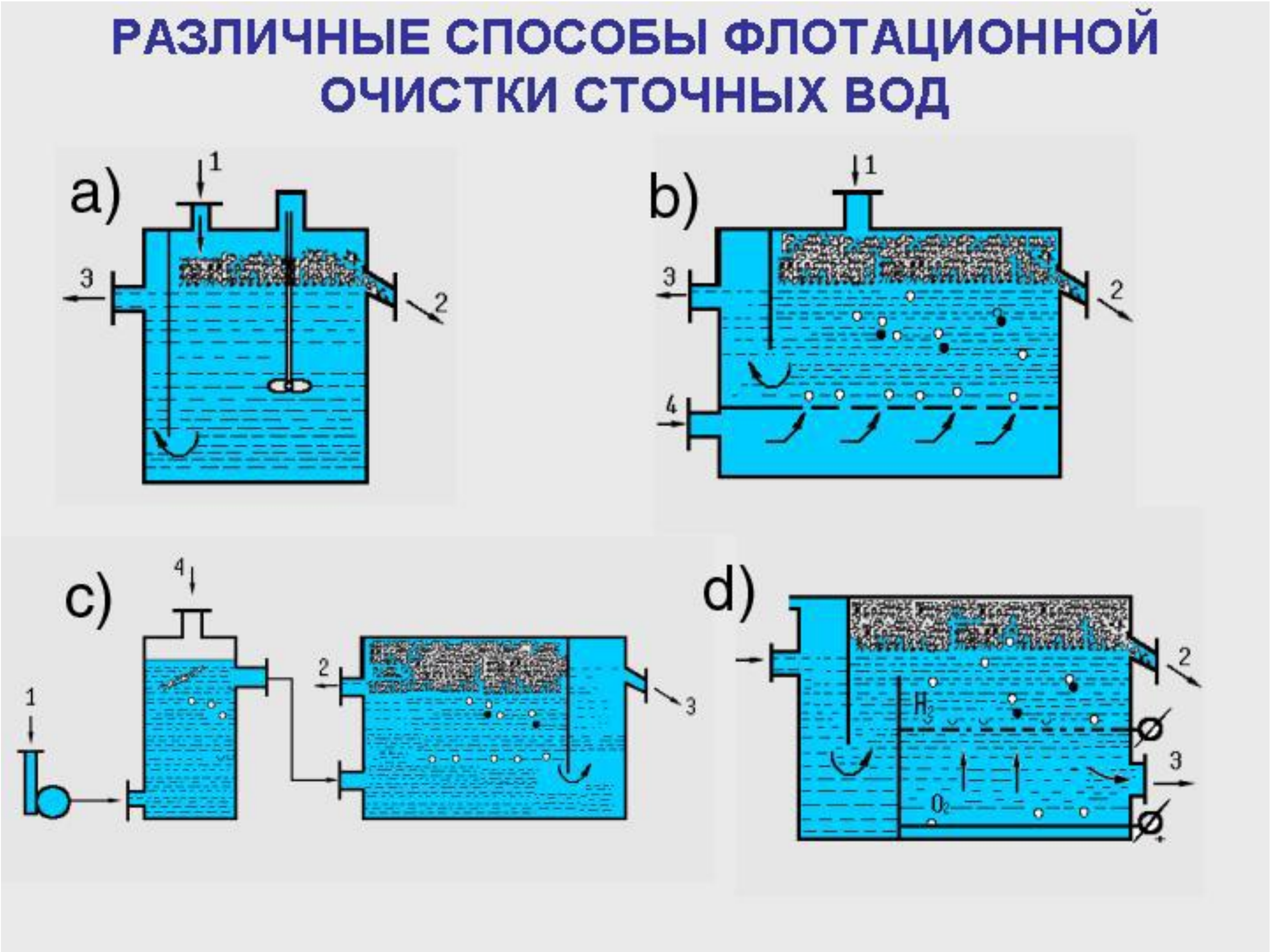


Figure 2.8 - Schemes of flotation machines and wastewater treatment apparatus: (a) and (b) - mechanical and pneumatic flotation machines; c) and (d) pressure and electroflotation apparatus

In the second case, mainly pressure flotation is used. The use of flotation techniques with a different method of aeration of liquids in the first case is due to the presence in the liquids of particles with both well-defined hydrophobic properties (for example, petroleum products and fats) and the presence of particles having a surface with both hydrophobic and hydrophilic sites (for example, microbial cells). The main types of pressure flotation devices, which are most widely used in the practice of water purification, are presented in Fig. Devices of other designs and the principle of operation are used much less often.

The use of impeller flotation machines has also become widespread in the purification of liquids containing petroleum products, oils, fats. According to the company "Vemko" (USA), when purifying oil-containing wastewater in a four-chamber flotation machine, water purification from petroleum products reaches 10 mg / l. When using combined methods of flotation treatment using impeller flotation, it is possible to achieve the concentration values of petroleum products, as shown by the results of research, up to 2 3 mg / l. Such results were achieved using a combined flotomachine GosNIIsintezbels of the design of Ksenofontov B.S. (Figure 2.9). The intensification of flotation wastewater treatment in this case consists in increasing the degree of aeration of liquids while reducing energy costs.÷

The use of pneumatic flotation machines is most common in the flotation of fine-grained pulps and circulating fluids. Aeration of liquids in this case is carried out by passing air or any gas through various porous elements, for example, ceramics, porous rubber, etc.

Pressure flotation has become quite widespread in wastewater treatment processes, for example, from petroleum products, oils, fats, etc. At the same time, pressure flotation is carried out both using reagents and without adding various chemicals. The widespread use of this method of treatment is due to both a fairly high effect of wastewater treatment and simple equipment design.

The high effect of wastewater treatment when using pressure flotation is achieved due to the fact that the release of gas bubbles in the flotochamber occurs directly on the particles of contaminants. In this case, the probability of adhesion of pollution particles with a gas or air bubble is close to the theoretically possible.

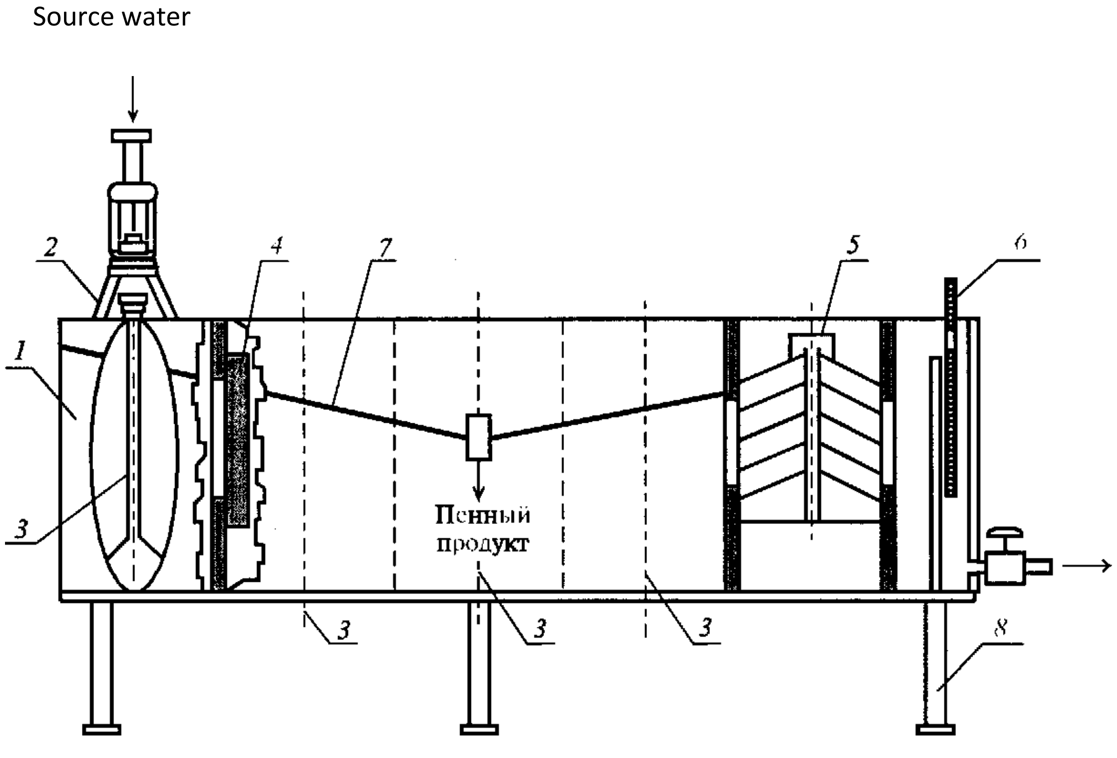


Fig. 2.9 - Combined mechanical" flotation machine of author's design

1 – building; 2 – aeration unit: 3 – impellers; 4 – grid; 5 – illuminator

At the same time, the efficiency of the process is significantly increased when using gases that dissolve differently in water. Thus, the sequential introduction of air and carbon dioxide into the water accelerates the flotation process by 2 to 3 times. The essence of the intensification of this method lies in the fact that the air injected first at a pressure of the order of 0.40.6 MPa is released in the floto chamber in the form of bubbles of 0.20.5 mm in size.÷÷÷

The possibilities of electroflotation in the treatment of various wastewaters are well known. However, the practical implementation of this method showed many shortcomings of both hardware and technological nature. First of all, this refers to the phenomenon of passivation of electrodes. When using this phenomenon in the processes of electrical treatment of liquids, it is established that it is possible to overcome to a certain extent the negative consequence of passivation of the electrodes, although the efficiency of the cleaning process cannot be maintained constantly at a high level.

Studies have shown that electroflotation treatment is most effective in the treatment of electrically conductive media, for example, waste liquids containing salts, as well as wastewater from galvanic industries. The practice of operating the electroflotation apparatus introduced at the Fizpribor plant (Moscow) for about 10 years has shown that it is possible to use small installations with a capacity of 1÷$^{3\ m3}$ / h to neutralize galvanic stands, for example, from trivalent chromium, as well as nickel and other heavy metals.

Electroflotation technology has been used for wastewater treatment for decades. However, there are still problems for the widespread use of this method. Our research over about 30 years to find out the possibilities of using the electroflotation method of wastewater treatment has shown the effectiveness of its use only in isolated cases when other technologies do not give an effect. This is also indicated by the world experience in the use of electroflotation equipment, including leading companies in the field of wastewater treatment. It should be noted that in the case of using electroflotation technology of low productivity (approximately 1... 5 cubic meters. mph) it is possible to obtain competitive advantages of this method in comparison with others. Our unique industrial experiment to test an electroflotator with a capacity of 100 cubic meters / h showed that in small production conditions the operation of such a device is difficult due to the high consumption of electricity. The electrical power of such a device is approximately 150 ... 300 kW depending on the qualitative composition of wastewater, including their specific conductivity. These tests confirmed that electroflotation devices of this capacity should not be used in wastewater treatment processes. When using devices of low capacity and especially less than 1 cubic meter / h, it is profitable to use electroflotators in some cases. Our experience of implementation at various enterprises in Russia and Finland has confirmed this.

Further development of electroflotation technology is largely due to the development of the theoretical foundations of this method, as well as the use of new materials for electrodes, the improvement of the design of electroflotators, including the combined type. Individual developments of devices of this type were brought to implementation by us. However, there is still no theoretical basis for this method based on general ideas about the flotation process, which prevents its improvement. In this regard, it is proposed to consider this method on the basis of Ksenofontov's multi-stage flotation model, developed for other flotation methods. This takes into account the main features of the electroflotation method. Consider the processes occurring in an electroflotation machine with the release of oxygen on the anode and hydrogen on the cathode (Fig. 2.10).

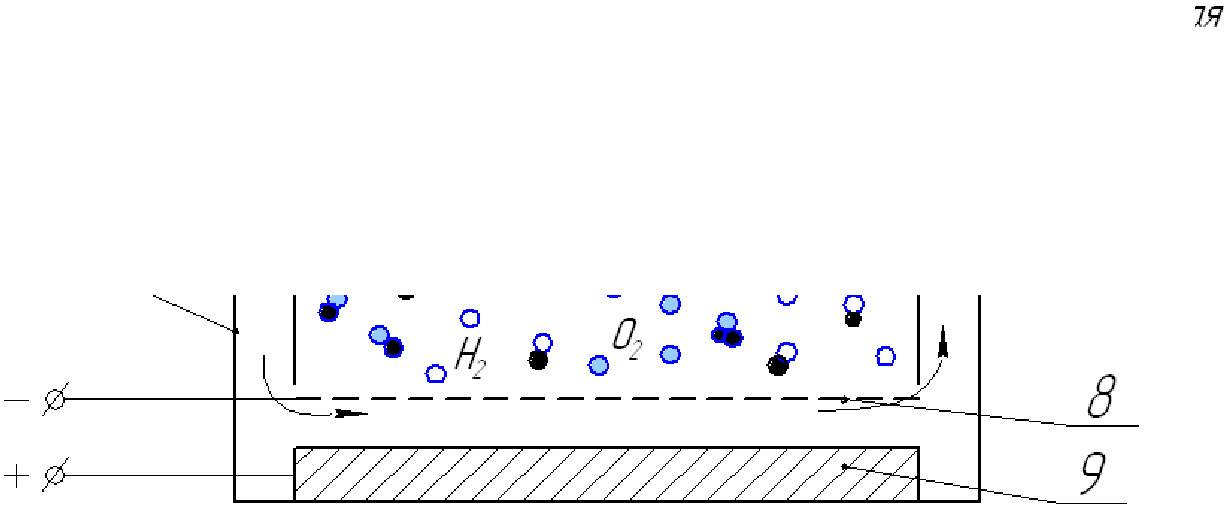


Fig. 2.10. Scheme of flotation machine: electroflotation on oxygen

1 — hull; 2, 7 — semi-submersible partitions; 3 — water supply pipe; 4 — foam gutter; 5 — foam drainage pipe; 6 — water drainage pipe; 8 — cathode; 9 — anode;

In this case, the process proceeds according to the scheme presented in Fig. 2. 11

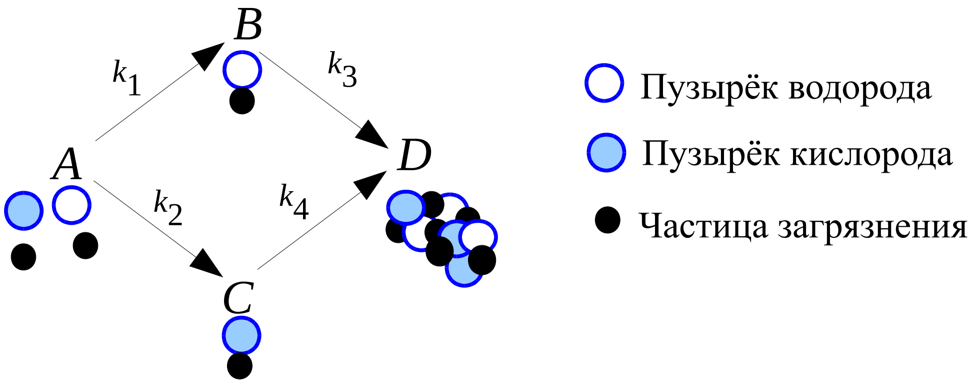
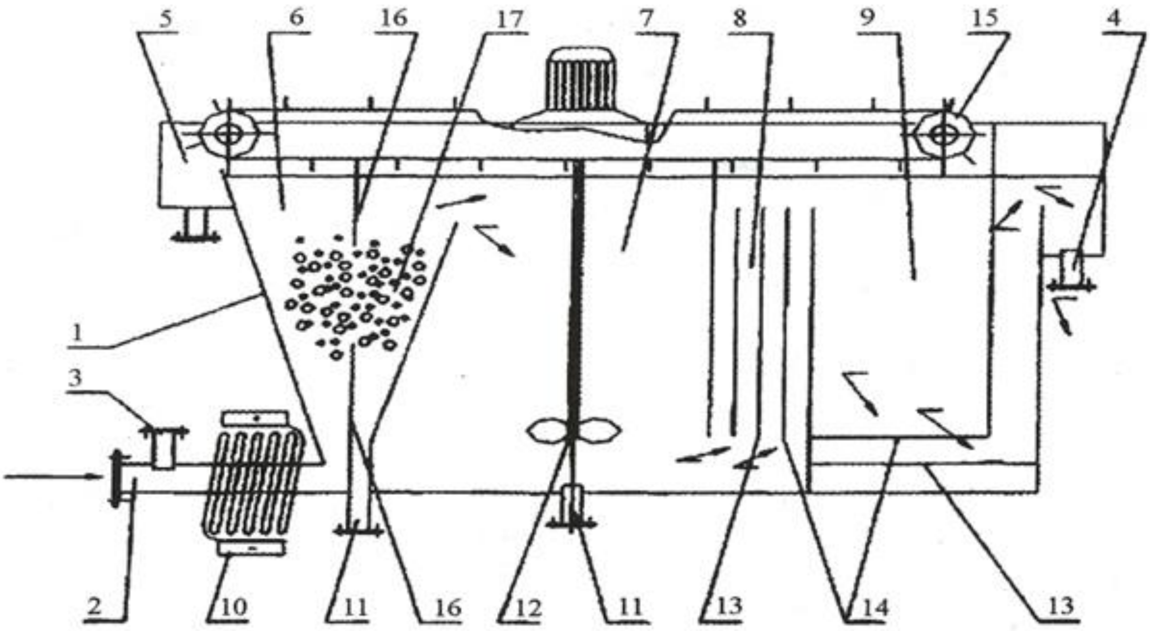


Fig.2.11. Diagram of the electroflotation process

In this scheme, *A* is the particles of pollution in the initial state, *B is* the flotation complexes with hydrogen bubbles, *C is* the flotation complexes with oxygen bubbles, *D is* the state of the particles in the foam layer; the constant k_1 characterizes the probability of the formation of the flotation complex during the interaction of the pollution particle with the hydrogen bubble, constant k_2 characterizes the probability of the formation of a flotation complex during the interaction of a pollution particle with an oxygen bubble, k_3 characterizes the surfacing of a flotation complex with a hydrogen bubble, k_4 characterizes the surfacing of a flotation complex with an oxygen bubble.

Along with the considered types of electroflotators, electroflotation devices of a combined type are also used, such as the one introduced by the author at the Fizpribor plant (Fig. 2.13), a distinctive feature of which is the mixing section, made in the form of a truncated pyramid. It receives wastewater along with the reagent, having previously been treated with an induced electric field on the section of the pipe on which the electromagnet is located on the outside. Next, mixing and flotation of floculated particles of a finely dispersed suspension occurs in the zone of creation of a fluidized layer of polymer particles with a size of 1.5 - between the lattices. Then there is a flotation cleaning in the chamber with an impeller and post-cleaning in the electroflotation chamber. The efficiency of such a device for petroleum products can reach 99%.2,5 mm



1. body of the electroflotation apparatus; 2 - dirty water supply pipe; 3 - reagent supply pipe; 4 – purge of purified water drainage; 5 – foam gutter with outlet pipe; 6 – reagent mixing chamber with dirty water; 7- mechanical flotation chamber; 8 – electrocoagulation chamber; 9 – electroflotation chamber; 10 – electromagnetic coil; 11- air supply pipe; 12 – impeller; 13, 14 – electrodes (anodes and cathodes); 15 – drive of the foam-removing device; 16 – inter-chamber partition; 17 – fluidized nozzle.

Fig. 2.13 - Diagram of the electroflotation apparatus of the combined type

This type of electroflotation apparatus is advisable to use in cases where it is necessary to use reagents, without which the process of fleet cleaning does not give the desired result.

Along with the considered main flotation methods of wastewater treatment, others have been developed, for example, ion flotation for wastewater treatment from metal ions.

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 well known. In 1959, F. Sebba (South Africa) was the first to describe this process. In the future, other developers, including our compatriots S.F. Kuzkin and A.M. Golman, developed this method to industrial implementation in the processes of mineral enrichment. Taking into account the fact that in the literature on water treatment this method is not sufficiently covered, we will give a more detailed description of this method.

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 precipitation - 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 - colligende ions (from the Latin colligere - to collect). Gas 7 is then supplied to the solution from below through the porous partition 3, forming air bubbles 4 (Figure 2.14). In this case, there is a sharp increase in the phase interface. The bubbles adsorb the surfactant together with the oppositely charged ions of the extracted 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).

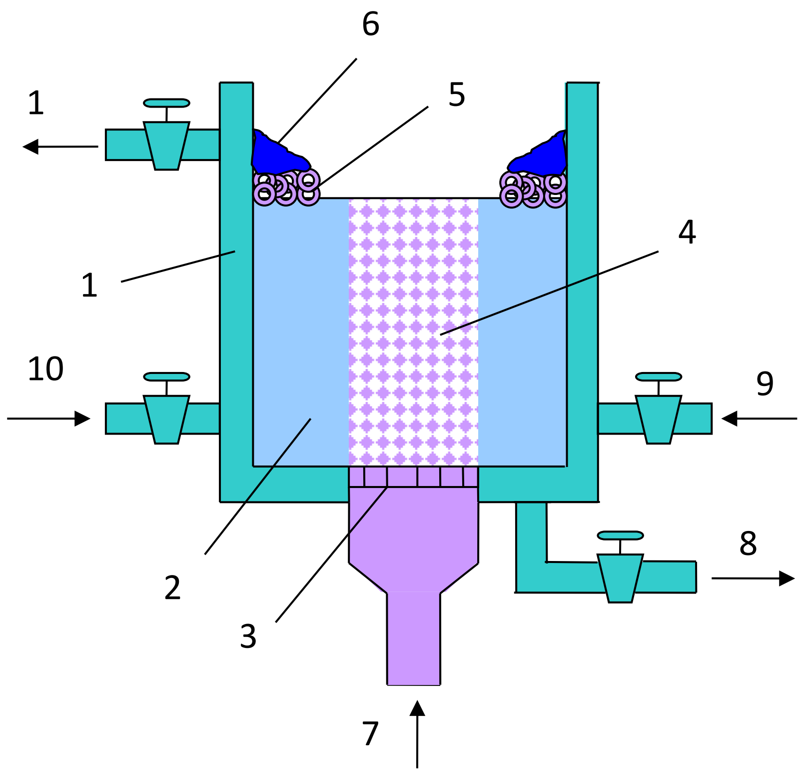


Fig. 2.14 - Diagram of the ion flotation chamber

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 surfactant organic compounds of polar-apolar (diphilic) structure (Figure 2.15).

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.

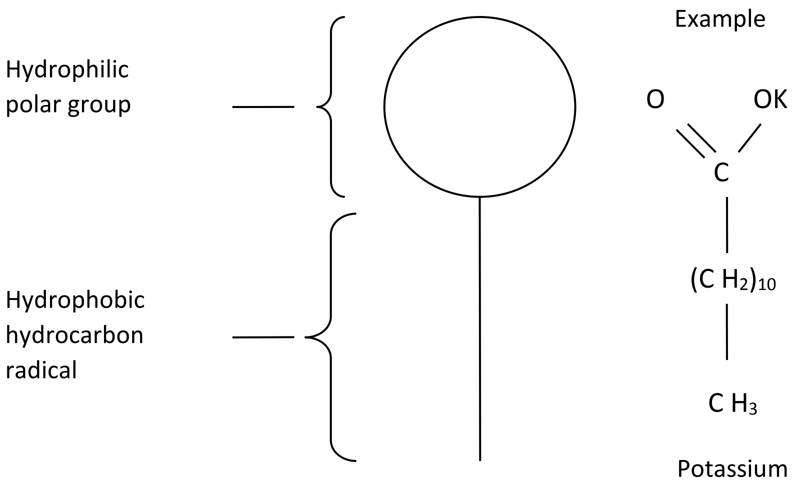


Fig. 2.15 - Diphilic structure of the collector molecule

A successful choice of the collector predetermines the success of the extraction of metals in this way.

Various schemes of wastewater treatment systems from heavy metals are proposed in the literature.

In general, the analysis of a particular technology is a multi-criteria task. Let's list the main criteria:

Cleaning efficiency

duration of the cleaning process

Energy consumption

resource intensity (including reagents)

cost

simplicity of construction (in production and operation)

quantity and hazard class of waste

possibility of recycling and reuse of waste

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 to be extracted. 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 is shown in Figure 2.16.

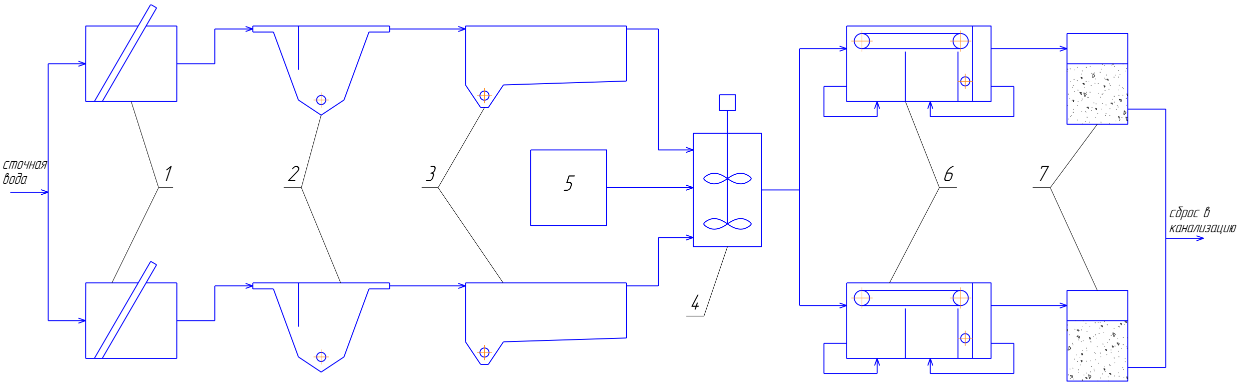


Fig. 2.16 - Schematic diagram of treatment facilities

1 – grilles; 2 – sand traps; 3 – settling tanks; 4 – mixing reactor;

5 – tank with reagent; 6 – flotators; 7 – filters (clinoptilolite.)

According to the diagram in Fig. 1 First, the wastewater is subjected to mechanical treatment on standard equipment: grates, sand traps and settling tanks. The water then enters the mixing reactor, where the reagent (EMCO collector) is in turn added. The resulting suspension falls on flotators, where deep cleaning of heavy metals takes place. At the final stage, there is a post-treatment of wastewater on a filter with a load of clinoptilolite to remove residues of suspended solids and heavy metals in order to achieve water quality requirements for its discharge into the city sewerage.

According to the proposed scheme of treatment facilities, at the initial stage, wastewater passes through a grate to remove large mechanical contaminants. Since we have two parallel lines of equipment, we need to select two grids with a capacity of at least 12^{m3} / h each. As a result, the mechanical grille ROTAMAT RO 5 was chosen with the following technical data:

1. capacity 18 m^3/h
2. width of prozors – 4 мм
3. tilt angle - 60º

Next, the water enters the sand traps, where the gravitational separation of the sand occurs (the size of the removed particles >). For a small flow of wastewater, it is advisable to use vertical sand traps. Based on the available data, a vertical sand trap 0,15 ммLPB 450 was selected, which has the following parameters:

1. maximum flow rate – 5,5 l/s (19,8^{m3}/h)
2. diameter of the working part of the case – 450 мм
3. efficiency of removal of suspended solids – η_p= 40%

As a result of the capture and separation of sludge, the flow rate of wastewater entering the next equipment will decrease. To determine the new flow rate, let's make an equation of mass balance for suspended solids:

$$m_1 = m_2 + m_3$$

where m$_1$ is the mass flow rate of suspended solids entering the sand traps;

$_{m2}$ is the mass flow rate of suspended solids coming out of sand traps;

$_{m3}$ is the mass flow rate of captured suspended solids.

The mass flow rate is equal to the product of the concentration of the substance and the flow rate of water:

$$C_1 Q_1 = C_2 Q_2 + C_3 Q_3$$

whereS$_1$ = 200 mg / l = 0.2 kg / m^3 - the concentration of suspended substances at the entrance to the sand traps;

Q$_1$=24 m^3/h – flow rate of inlet water flow;

C$_2$ = C$_1$ * (1-pη) = 0.2 * (1-0.4) = 0.12 kg / m^3 - the concentration of suspended substances at the exit from the sand traps;

Q$_2$=Q 1-Q $_3$ – water consumption at the exit from the sand traps;

C$_3$ = 100 kg / m^3 - the concentration of suspended substances in the sediment (90% humidity);

$_{Q3}$ is the flow rate of water leaving with the sediment.

Taking Q_3 for the unknown from the equation we find that Q_3 = 0.01922 m^3 / h, and Q_2 = 23.98 m^3 / h. The calculated values are entered in table 2.3.

Table 2. 3 - Results of calculation of the required efficiency and performance of the equipment.

They're going down-- Docking	Concentration at the entrance, mg/l		Concentration output, mg/l		Efficiency, %		Water consumption, m^3/h
	2015-2015 expert.	copper	2015-2015 expert.	copper	2015-2015 expert.	copper	
1. Grids	200	0,85	200	0,85	-	-	24
2. Sand trap	200	0,85	120	0,85	40	-	24
3. Sumps	120	0,85	54	0,85	55	-	23,98
4. Flotators	54	0,85	54	0,009	-	98,9	23,95
5. Filters	54	0,009	10	0,003	82	70	22,75

After that, the water enters the settling tanks for purification from mechanical impurities with a size of > 5 µm. Due to the low flow rate, we choose a vertical settling tank with the following characteristics:

1. capacity – 12^{m3}/h
2. efficiency – 55%.

Let's calculate the required area of the deposition zone of the vertical settling tank according to the formula:

$$F = \frac{\beta \cdot q}{3,6 \cdot \nu}$$

whereβ is the coefficient taking into account the volumetric use of the settling tank (β = 1.3);

q – calculated water consumption, m3/h;

ν - Calculated upstream velocity (for water purification without the use of a coagulant = 0.15 mm/s).ν

Substituting the known values into the formula for determining F, we obtain:

$$F = \frac{1{,}3 \cdot 12}{3{,}6 \cdot 0{,}15} = 28{,}9 \text{ м}^2$$

This area corresponds to a cylindrical apparatus with a diameter of .6 м

As a result of the calculation and considering the humidity of the sediment equal to 95%, we get that the flow rate of water leaving with the sediment is 0.03169 m^3 / h, which means that the water flow rate coming to the flotator is 23.95 m^3 / h.

At the stage of flotation, heavy metals are released with an initial concentration of 5.38 mg / l. According to JSC GosNIIIntezbelok (author's data), the withdrawn foam is 5% of the total water flow through flotators, i.e. 1.2 m^3 / h, and 22.75 m^3 / h passes for subsequent cleaning.

As the final stage of cleaning, we use filters with clinoptilolite loading. According to the calculations, at the inlet to the filters, the concentration of suspended solids is 54 mg / l, and heavy metals (copper) - 0.009 mg / l. The use of the filter allows to achieve the required cleaning efficiency for both suspended substances and heavy metals.

According to the initial data, the flow rate of water passing through one apparatus:

q=12 m^3/h=3,33*10-3 m^3/s

In accordance with SNiP 2.04.03-85, the height of the working area is taken H = 1 m.

The velocity of the liquid in the chamber should be no more than 5 mm / s, so let υ = 2.5 mm / s = 2.5 * $^{10\text{-}3}$ m / s.

Then let's calculate the width of the chamber B, m, according to the formula:

$$B = \frac{q}{v \cdot H} = \frac{3{,}33 \cdot 10^{-3}}{2{,}5 \cdot 10^{-3} \cdot 1} = 1{,}33 \text{ м}$$

Let's take B = 1.6 m and recalculate the velocity of the liquid for the obtained dimensions of the passage section:

$$v = \frac{B}{v \cdot H} = \frac{3{,}33 \cdot 10^{-3}}{1{,}6 \cdot 10^{-3} \cdot 1} = 2{,}08 \cdot 10^{-3} \frac{\text{м}}{\text{с}} = 2{,}08 \text{ мм/с}$$

This value satisfies the requirements.

According to SNiP 2.04.03-85, the duration of flotation τ is 20-30 minutes.

Based on the calculated speed of movement of the liquid in the apparatus, we get the required working length of the flotator:

$$L = v \cdot \tau = 2{,}08 \cdot 10^{-3} \cdot 1200 = 2{,}496 \text{ м}$$

We take L = 2.5 m. Then the flotation time τ will be:

$$\tau = \frac{L}{v} = \frac{2{,}5}{2{,}08 \cdot 10^{-3}} = 1202 \text{ с} \approx 20{,}0 \text{ мин}$$

According to SNiP 2.04.03-85, the hydraulic load in the flotation apparatus should be equal to G = 3 - 6 m^3 / (m^2 * h). Check the fulfillment of this condition:

$$\Gamma = \frac{q}{B \cdot L} = \frac{12}{1{,}6 \cdot 2{,}5} = 3 \text{ м}^3/(\text{м}^2 \cdot \text{ч})$$

This value satisfies the requirements.

The device will be divided into 2 chambers long.1,25 м

Thus, the calculated flotation machine will have the following dimensions of the working part:

H=1 m;

B=1,6 m;

L=2.5 м.

The working volume of the device Vr = H * B * L = 4 m^3. The volume of one chamber is . The designation of the device is as follows: PFM-2. The total volume of the device is . Then the coefficient of technical use is: K = Vr / Vo = 4 / 6.17 = 0.652 $\text{м}^3$6,17 м^3

To capture microflot complexes in the flotomachine, a thin-layer unit is provided. It is a multi-tiered structure of inclined corrugated plates. By analogy with the thin-layer block in the settling tanks, we take the angle of inclination of the plates to the horizon of 60^0.

According to our data, the average ascent rate of the microflotome is $υ_b$ = 0.5 mm / s. The height of the tier, i.e. the vertical projection of the distance between the plates, is assumed to be equal to h_{in} = 20 mm. Then the time of surfacing of the flotation complex is determined:

t= h_v/ $υ_v$=20/0,5=40 s

During this time, microflotocomplexes reach the surface of the upper plate, where coalescence occurs, and the resulting larger flotation complex floats to the surface.

The remaining dimensions of the plates are taken for design reasons and based on the requirements of the SNiP for the horizontal speed of water movement in the apparatus (not more than 5 mm / s). As a result, we have 25 plates that form 24 slits.

Let's find the speed of movement of water in one slit between the plates.

$$v_0 = \frac{q}{S_0 \cdot n} = \frac{3{,}33 \cdot 10^{-3}}{(10 \cdot 10^{-3} \cdot 1{,}59) \cdot 24} = 8{,}73 \cdot 10^{-3}\,\frac{\text{м}}{\text{с}} = 8{,}73\ \text{мм/с}$$

The horizontal projection of the water velocity will be equal to half the velocity in the slit υ_g = 4.36 mm / s (which meets the requirements).

Let's determine the length of the plate:

$$l_1 = v_0 \cdot t = 8{,}73 \cdot 40 = 349{,}2 \approx 350\ \text{мм}$$

Calculation of the dimensions of the jet apparatus (ejector) for aeration of water in flotation machine

Initial data for calculation:

working medium pressure in front of the ejector p_p = 300 kPa;

air pressure in front of the ejector p_n = 100 kPa;

volumetric flow rate of ejected air V_{in} = 5 m3/h

water-air mixture pressure after diffuser p_c = 108.8 kPa;

working fluid temperature t_p = 20 ^{0}C

The volumetric ejection coefficient is determined by the formula:

$$u_0 = \frac{0{,}35 \cdot (p_\text{р} - p_\text{с})}{\frac{p_\text{с}}{2{,}7} - p_\text{п}} = \frac{0{,}35 \cdot (300 - 108{,}8)}{\frac{108{,}8}{2{,}7} - 2{,}34} = 1{,}76$$

where p_n = 2.34 kPa is the partial pressure of saturated vapor at the temperature of the working fluid.

Then the flow rate of the working fluid required for air ejection is:

$$V_\text{р} = \frac{V_\text{в}}{u_0} = \frac{5}{1{,}76} = 2{,}84\ \text{м}^3/\text{ч}$$

The flow rate of the working fluid from the ejector nozzle will be found according to the formula:

$$v = \varphi \sqrt{\frac{2 \cdot (p_\text{р} - p_\text{н})}{\rho_\text{в}}} = 0{,}95 \cdot \sqrt{\frac{2 \cdot (300 - 100) \cdot 10^3}{10^3}} = 19\ \text{м/с}$$

where=0.95 is the velocity coefficient. φ

The diameter of the working nozzle is:

$$d_{\text{р}} = \sqrt{\frac{4 \cdot V_{\text{р}}}{3600 \cdot \pi \cdot 19}} = 7{,}27 \cdot 10^{-3}\ \text{м} = 7{,}27\ \text{мм}$$

Примем $d_{\text{р}}$ = .7,3 мм

The optimal ratio of the cross-sections of the mixing chamber and the working nozzle (the main geometric parameter of the ejector) is found from the expression:

$$\left(\frac{f_3}{f_{\text{р}1}}\right)_{\text{э}} = 1{,}25 \cdot u_0 + 1 = 1{,}25 \cdot 1{,}76 + 1 = 3{,}2$$

Then the diameter of the mixing chamber is determined from the expression:

$$d_3 = d_{\text{р}1} \cdot \sqrt{\frac{f_3}{f_{\text{р}1}}} = 7{,}3 \cdot \sqrt{3{,}2} = 13{,}06\ \text{мм}$$

Примем d_3 = .13,1 мм

The minimum working water pressure at which the ejector can operate is:

$$p_{\text{р}}^{min} = \frac{p_{\text{с}}}{2} \cdot \left(\frac{f_3}{f_{\text{р}1}}\right)_{\text{э}} = \frac{108{,}8}{2} \cdot 3{,}2 = 174\ \text{кПа}$$

This value does not exceed the specified one, which means that the ejector is operable at the pressure specified in the initial data.

The length of the mixing chamber is determined by the following formula:

$$l_{\text{кс}} = m \cdot d_{\text{р}1} \cdot \left[\left(\frac{f_3}{f_{\text{р}1}}\right)_{\text{э}} - 1\right] = (10 \div 20) \cdot 7{,}3 \cdot [3{,}2 - 1] = (161 \div 321)\text{мм}$$

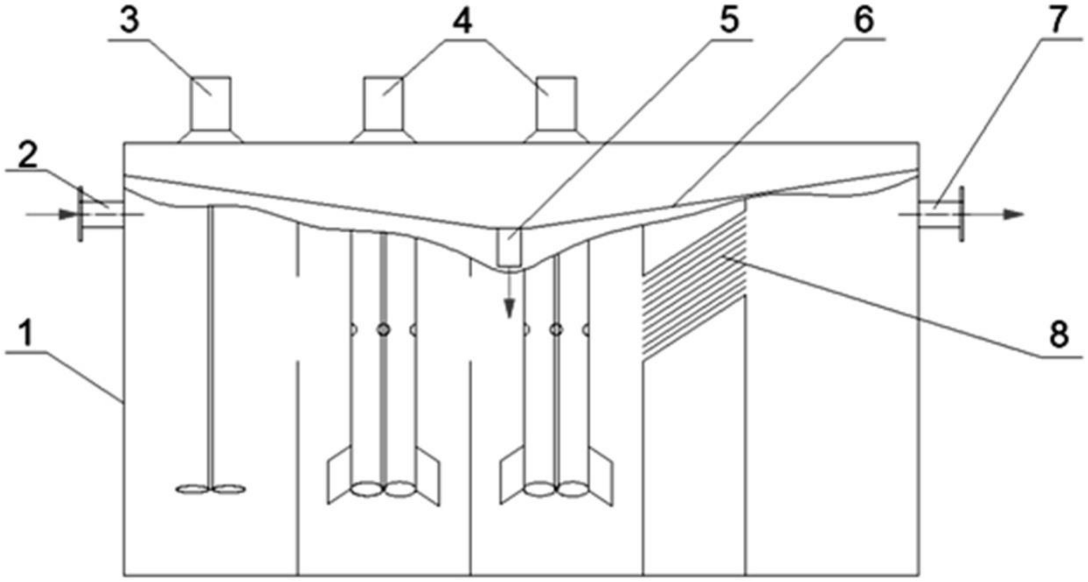
We take l_{ks} = . Other sizes are taken on the basis of design considerations.250 мм

Improvement of flotation technology by combining various functions in one body of the device is being developed by many developers, including us. At the same time, in one body of a flotation machine or apparatus, for example, aeration units are installed for the flotation process and structural elements characteristic of the settling process, and as a result, we have a combined apparatus - a flotation settling tank. Flotation machines are also well known, which combine the functions of air conditioning and flotation devices. However, there are still no clear methodological approaches to the development of multifunctional devices, in which the main process is flotation.

In recent years, we have made successful attempts to create such combined devices - flotation combines, in which such preparatory processes as coagulation, flocculation and others are consistently carried out, which contribute to the separation of the clarified system, as well as directly the processes of flotation, settling and filtration.

Examples of the creation and implementation of such flotation combines are carried out by us at the treatment facilities of various industries.

Ksenofontov B.S. developed mechanical flotation machines, in particular FKMO-0.15 (Fig.2.17), on the basis of a combined method for extracting hydrophobic contaminants, allowing to intensify the flotation process. They differ from the known ones by the presence of additional jet aerators in the form of a collector with pipes inside which nozzles are installed, as well as a plate clarifier in the form of a block of inclined shelves installed at a distance of 5 - from each other. The use of the above jet aerators increases the degree of aeration and reduces the size of air bubbles, and the plate clarifier of a special design allows you to reduce the removal of particle complexes - microbubbles that do not have time to surface in previous chambers, thus significantly increasing the cleaning efficiency.10 см



1 - building; 2 – branch pipe for wastewater supply; 3 – mechanical agitator; 4 – jet aerators; 5 - branch pipe for foam draining; 6 – foam gutter; 7 – branch pipe for draining purified water; 8 – thin-layer clarification unit

Figure 2.17 - Diagram of a multi-chamber flotation mechanical machine

Currently, in all flotation apparatus of any type, it is observed that the smallest flotation complexes, which, due to the low rate of surfacing, do not have time to reach the foam layer, are carried away with the flow of the liquid being cleaned.

Comparative indicators of the effectiveness of wastewater treatment from petroleum products of combined flotation machines (flotation combines) and foreign analogues (Wemco, USA) are presented in Table. 2.4.

Table 2.4 - Wastewater treatment from petroleum products on combined flotation machines

Type of flotation machines and apparatus	Concentration of petroleum products, mg/l	
	Original	Ultimate
Mechanical FKMOs*	50-100	5-10
Pneumatic PCFs*	50-100	0.5-5
Pressure*	50-100	1-5
Electroflotation*	50-100	1-5
Mechanical (Wemco, USA)**	50-100	10

*Test data

**Advertising data

Analysis of those presented in Table. Fig. 2.4 of the data shows that in terms of the efficiency of wastewater treatment from petroleum products, most of the developed combined flotation machines and devices are superior to modern foreign analogues. The most effective are combined pneumatic flotation machines, but as mentioned above, they have a number of drawbacks, the elimination of which will guarantee to achieve the normative values of the main indicators of the quality of water purification, especially when it is discharged into an open reservoir.

The principle of operation of combined flotation vehicles (flotation combines) can be simplified in the form of a diagram shown in Figure 2.18.

Fig. 2.18. Scheme of water purification in the flotical combine

Wastewater treatment in flotation combines is carried out using several technological processes, but flotation is dominant. Consider the scheme and principle of operation of the simplest flotation combine (Fig. 2.19). Such a flotation combine combine includes a housing, on the outside of which there are branch pipes for supplying dirty water, reagents, working fluid (water with air bubbles) and branch pipes for draining 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).

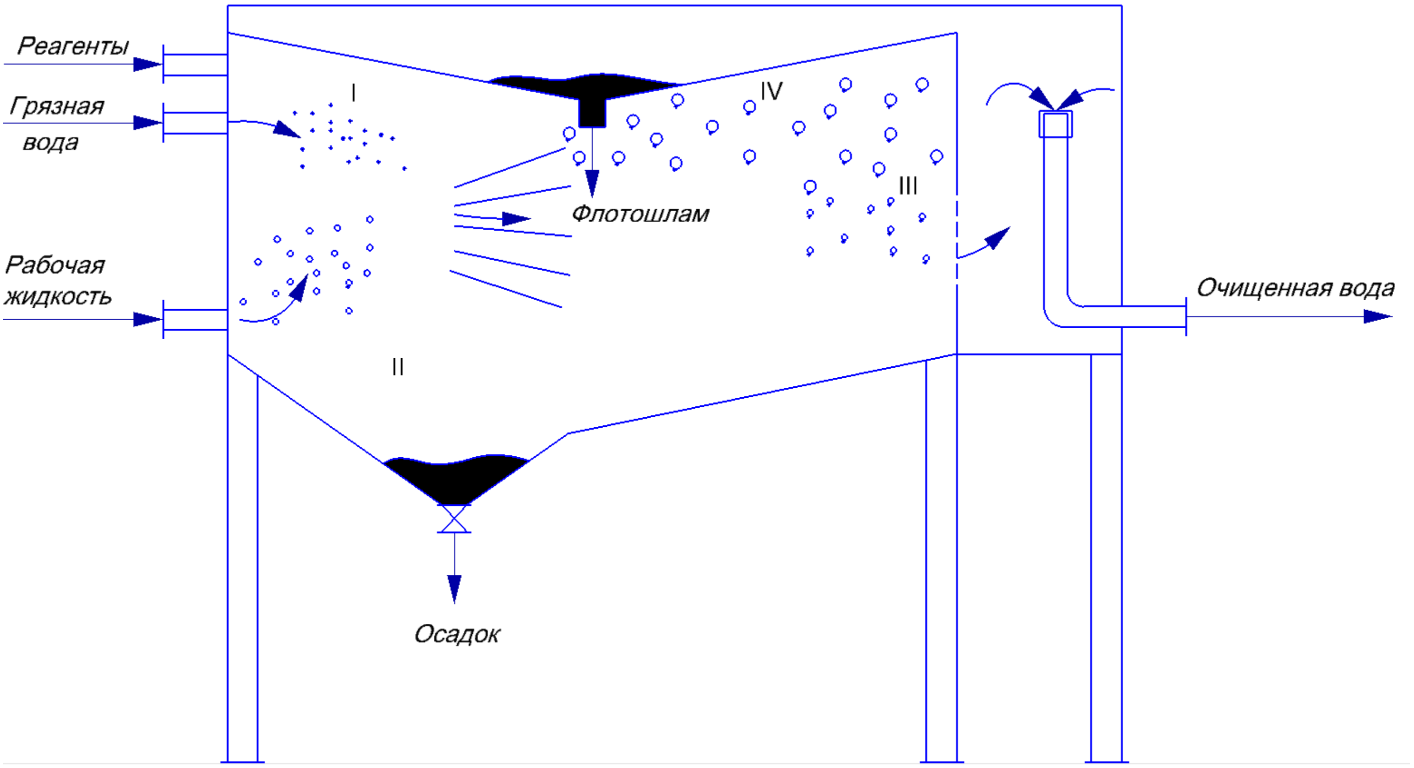


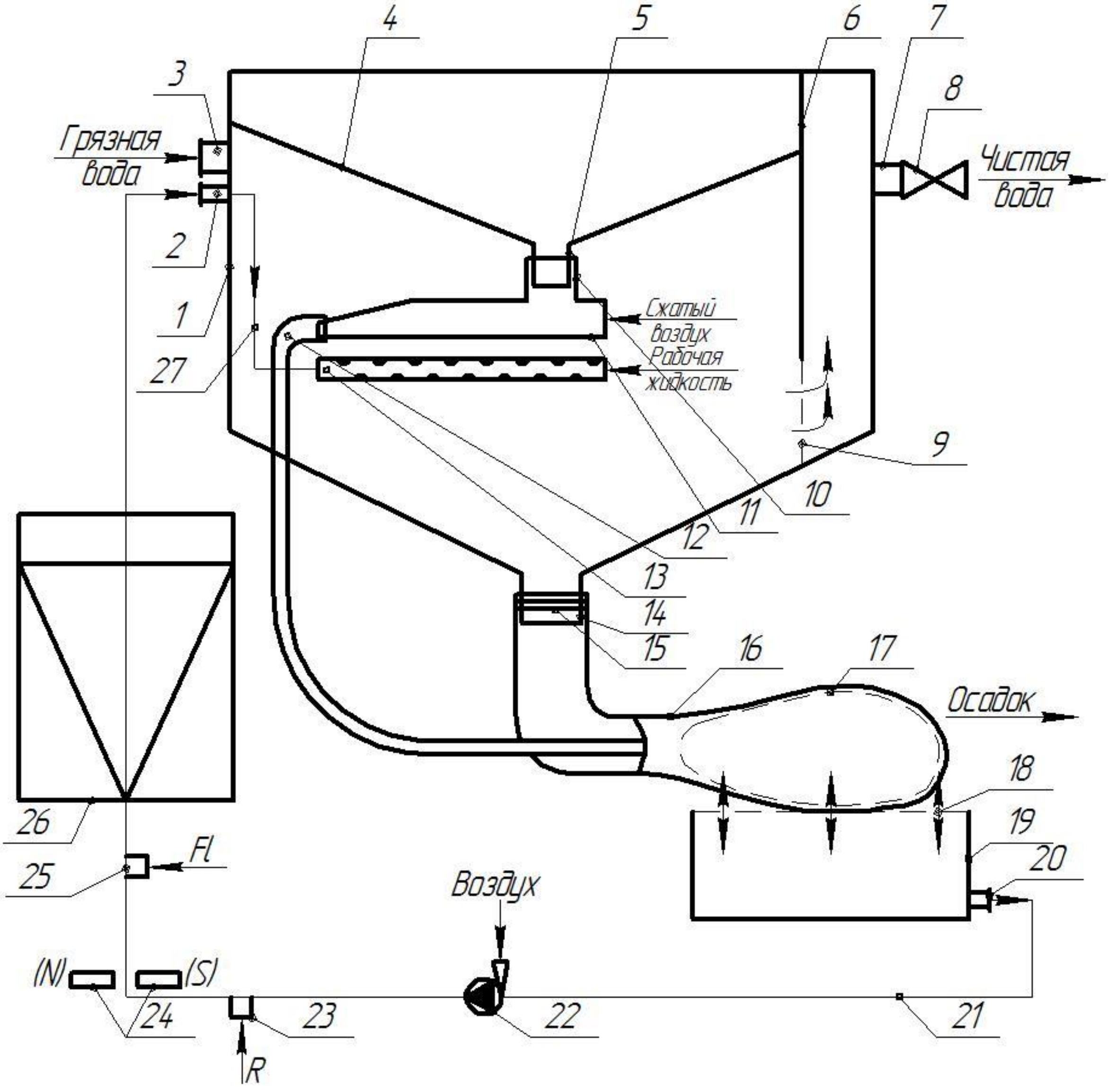
Fig. 2.19. Scheme of water purification in the flotocombine

The principle of operation of the flotocombine is as follows. At the stage of conditioning, the formation of particle-bubble flotation complexes occurs (zone I). 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 II). The sequence and scheme of the processes occurring in the flotation combain can be mathematically

Particles stuck together with small bubbles form microflotocomplexes (zone I), which slowly surface and in this connection they are carried away by the flow of purified liquid moving in a horizontal direction. Such microflotocomplexes, reaching the mesh septum, contact each other with the formation, as a rule, of larger bubbles (zone III), which quickly surface, forming a flotillam (flotation zone IY). Purified water passing through the mesh partition is removed using a special device and then removed from the flotical combine through the outlet pipe. Analysis of these stages shows that, in general, they are connected by the flotation process of water purification.

The approach we are developing to solving flotation and related problems is based on the analogy of considering these processes as sequential and reversible reactions.

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 flotical combine developed by us is presented in Fig. 2.21.



Flotocombine housing; 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 – sludge 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. 2.20 – Scheme of the flotocombine

The developed flotcombine for wastewater treatment includes a housing 1 (Fig.1), on the outside of which there are branch pipes 2 and 3 respectively for the supply of recycling liquid and source (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, on which the cover 15 of the bag 16 is worn, 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 flotical 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.

In the simplest version of the flotation combain in the form of a flotation settling tank, it is possible to carry out deeper wastewater treatment compared to the use of conventional equipment, 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 indicators of known marine sedimentation tanks.

A flotation settling tank was tested and implemented (Figure 2.22).

Fig. 2.21 - Photo of the industrial sample of the flotation settling tank

Fig. 2.22 – Photo of the industrial sample of the flotation settling tank

The results of these tests are presented in Table. 2.5.

Table 2.5 - Results of pilot tests of a combined flotation unit

Name of the ingredient to be determined	Standard mg/dm^3	The result of measuring the concentration of pollutants, mg/dm^3									
		*1**		*2*		*3*		*4*		*5*	
		Entrance	*Exit*	*Entrance*	*Exit*	*Entrance*	*Exit*	*Entrance*	*Exit*	*Entrance*	*Exit*
Hydrogen pH	6.5-8.5	7.83	7.93	10.51	8.63	7.76	8.38	7.74	7.96	8.7	7.9
Zinc	2.5	0.63	0.44	0.27	0.13	0.184	0.048	0.192	0.026	0.117	0.055
Iron General	1.0	0.35	0.104	0.19	0.09	0.81	0.19	0.44	0.13	0.34	0.16
Sulphates	<300	222	184	**	-	125	110	175	138	263	133
Surfactants (surfactants)	0.1	0.615	0.012	0.328	<0.025	0.157	0.052	0.56	<0.025	0.235	<0.025

Petroleum products	0.5	1.16	0.068	1.9	0.09	2.03	0.016	1.35	0.12	1.6	0.162
Total phosphorus	0.2	0.27	0.071	-	-	1.30	0.141	0.14	0.09	0.17	0.131

* Test mode numbers

** data not available

Presented in Table. 2.6 the data do not exceed the established standards, which confirms the high efficiency of wastewater treatment using a flotation settling tank. If necessary, the intensification of the cleaning process can be achieved by using additional units, for example, by installing electrical treatment units, vibration action, etc. In some cases, the cleaning efficiency from the use of these additional units can be increased by 40 - 50%.

2.5.2.2. Flotation technology of surface wastewater treatment

Numerous developers of local treatment plants (facilities) of surface wastewater claim that their use makes it possible to obtain treated wastewater with regulatory indicators. However, in practice, in most cases, it is not possible to achieve normative indicators for various reasons, including improper operation, as well as due to the low technical level of development. As it was found, the efficiency of local surface wastewater treatment plants largely depends on the technical level of the devices with which the extraction of petroleum products takes place, in particular the flotator and post-treatment filters. In this regard, we have developed a facility that allows us to extract contaminants to standard indicators.

Let us consider in more detail the proposed scheme for the treatment of surface wastewater. Surface wastewater from the production area, passing through the grate, is collected in a sedimentation tank (Fig. 2.23).

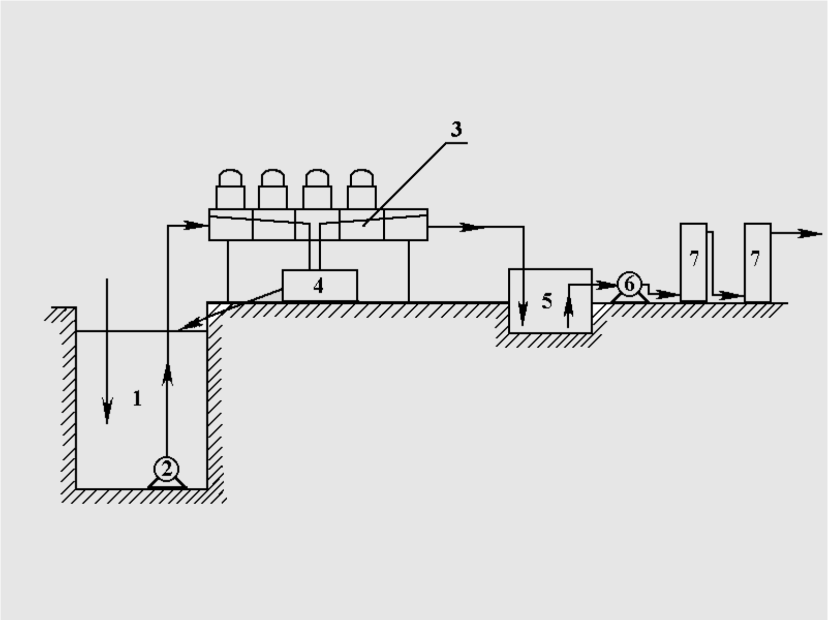


Fig. 2.23. Scheme of surface wastewater treatment

C, the exact water from the tank 1 is pumped out by pump 2 and fed into a pneumatic flotation machine 3 of type PFM-0.5 with a thin-layer clarification unit (Fig. 2.24).

In this flotation machine of the original design, finely dispersed droplets ofpetroleum products are extracted when they float together with air bubbles formed during the dispersion of air by supplying it under pressure through porous aerators made of special rubber. Aerators in the amount of 12 pieces are installed in each of the four chambers of the specified flotation machine. In the additional fifth chamber of the flotation machine, a block is installed thin-layer clarification for additional extraction of finely dispersed droplets of petroleum products.

The treated wastewater passes through all these chambers sequentially, while the captured oil pollution in the form of a foam product is collected at the top of the layer of purified water. Pop-up petroleum products together with air bubbles create a foam layer, which is removed by gravity into the foam product 4 (supplied with the flotation machine). After settling the foam product, which is a mixture of water and captured petroleum products, the decanted

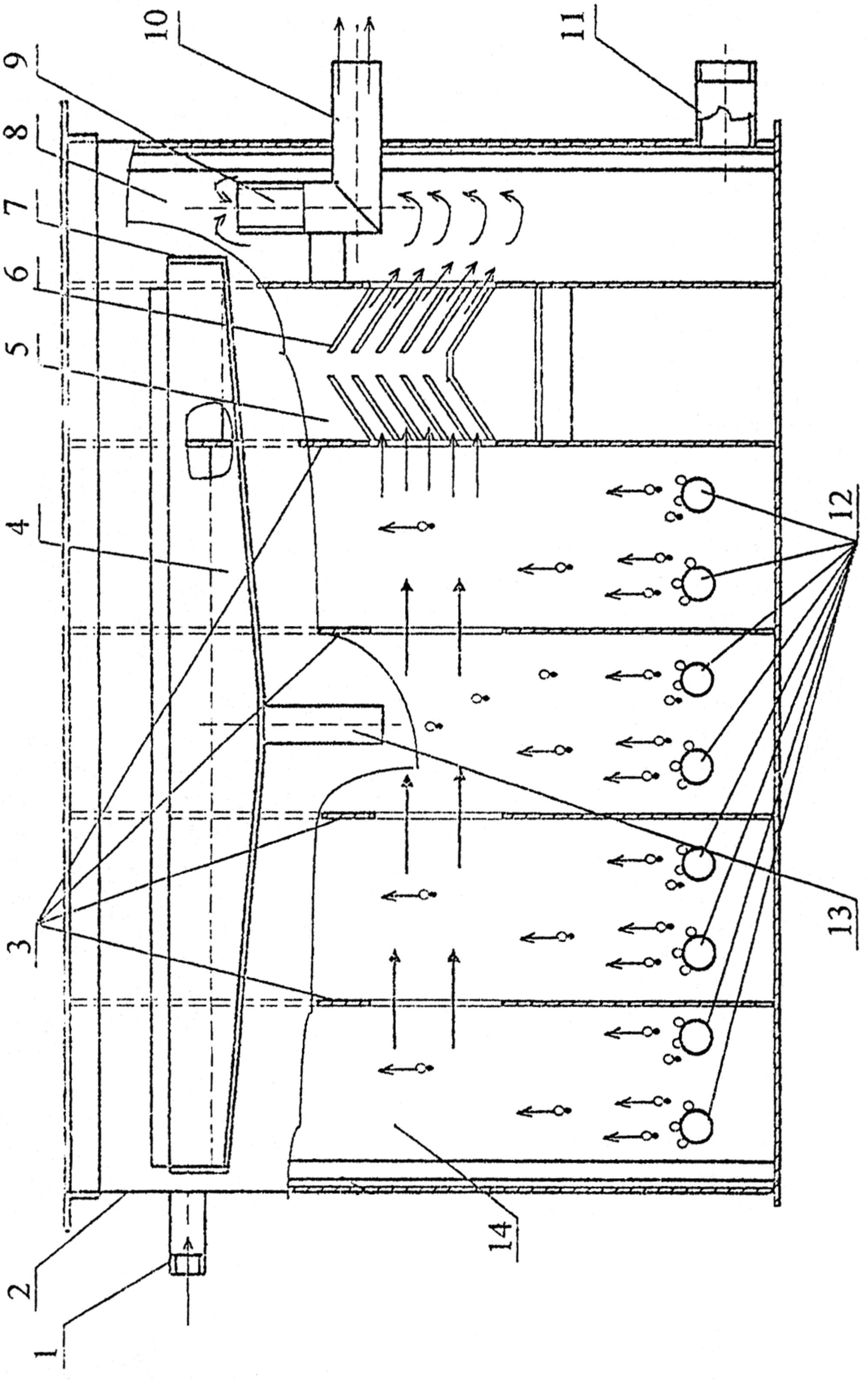


Fig.2.24. Pneumatic flotation machine

water is drained into a recessed container 1. The purified liquid is removed from the flotation machine by sequentially passing through the thin-layer clarification unit and the device for maintaining a given level of the purified liquid in the flotation machine and by gravity enters the intermediate tank (collection) 5 with a working volume of at least 3 m^3. The intermediate tank 5 is made of monolithic or precast concrete.

By means of a surface pump 6, the pre-purified water is supplied for further purification to the sorption filters 7. The first filter in the course of movement of the liquid has a combined loading, including a layer of claydite (the lower layer) and a layer of activated carbon, and the second filter is fully loaded with activated carbon. These pressure filters use coal similar in its properties to the AG-3 coal grade. This allows for deep post-treatment of surface wastewater to a residual content of petroleum products of not more than 0.05 mg / l. Taking into account the seasonal specifics of the treatment plant, it is proposed not to regenerate the coal loading, but to use it only during one season. It is advisable to eliminate the spent load by burning, for example, in a boiler room or in a special furnace where coal is used as fuel. Purified wastewater with a content of petroleum products not exceeding 0.05 mg / l can be discharged on the relief or in a nearby reservoir.

The pneumatic flotation machine (Figure 2.16) includes a housing 2 divided into four chambers 4 with porous aerators 12 installed in the lower part, made of deformable (e.g., rubber or polyethylene) or non-deformable (e.g., ceramics or metal) material. In the prototype of the pneumatic flotation machine, a special porous rubber with pore sizes of 0.5 mm was used as a material for aerators. In the fifth additional chamber 5, a thin-layer clarification unit 6 was installed, as well as a liquid level control device 9. On the outside of the flotilla housing there is an inlet 1 and an output 10 branch pipe, respectively, for the input and output of wastewater, as well as a foam chute 7 with an outlet pipe 13 for the output of captured contaminants in the form of an emulsion.

The principle of operation of the pneumatic flotation machine is as follows. The original (dirty) water is supplied through the inlet pipe 1 and then it moves in a horizontal direction through the chambers 4 with porous aerators 12 and the auxiliary chamber 5 with the thin-layer clarification unit and is removed from the machine through the level control device 9 and the outlet pipe 10. When water moves through the first four chambers, it is aerated (bubbling) by bubbles of air supplied under pressure through porous aerators. At the same time, air bubbles stick together with hydrophobic pollution and float in the form of flotation complexes of droplets of petroleum products-air bubbles. Captured contaminants in the form of a foam product (emulsion with a concentration of petroleum products of 10-20%) are removed by gravity through the gutter 7 and the outlet pipe 13.

It is known that the efficiency of the flotation machine largely depends on the type and design of aerators. In this regard, it is necessary to consider in more detail the design and principle of operation of the aerators used in these machines.

In pneumatic flotation machines, tubular aerators are mainly used, which are usually a welded structure of pipes consisting of a frame with a central collector on which the supply and condensate pipes are installed. At the same time, fittings are evenly distributed on the frame, on which dispersing elements made of perforated rubber tubes are installed and fixed with cuffs.

The aerator works as follows. When compressed air is supplied to the central collector, it is evenly distributed throughout all dispersing elements. Holes in the rubber tubes open and at the same time there is an exit of air into the water in the form of bubbles. The air flow through such aerators is determined by the pressure at the inlet, the size of the dispersing elements, their number, as well as the size of the pores on the dispersant.

When the air supply to the aerator is stopped, the pores on the dispersing element are closed and prevent water, with contaminants in it, from entering the aerator frame. Such tubular aerators ensure uniformity of aeration, good dispersion of air bubbles and reliability in operation. The operating pressure at the inlet to the aerator, depending on the depth of immersion in the flotation machine, is 0.15-0.25 MPa.

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A flotation machine of this type was introduced at various enterprises and in this regard, the technological scheme of wastewater treatment in some cases differed from the one described above. Installations for wastewater treatment, including a flotation machine, the scheme of which is presented in Fig. 2. 24, implemented at various energy and transport enterprises.

Noticeably better data on the efficiency of water purification are achieved when using a flotation machine with a filter element, including a housing that is divided by partitions into chambers, with aerators installed inside them at the bottom and located in the last chambers of the thin-layer clarification unit and a device for regulating the level of wastewater located on the outside housings of the inlet and outlet pipes, and on the side of the gutter for the removal of captured contaminants, and at the same time a distinctive feature of the proposed flotation machine, is an additionally installed intermediate chamber, between the thin-layer clarification unit and the liquid level control device, with a filter element located in it made in the form of hollow two cylinders with perforated surfaces, with loading located between them, and the interval of live values the cross-sections of the perforated surface were checked as a result of experimental studies and amount to 10-25% of the total area. At the same time, it was found that with a live section of less than 10%, an increase in the efficiency of wastewater treatment is not achieved, and with a live section of more than 25%, the achieved treatment effect does not change.

Loading is made of adsorption material, for example, active carbon, sipron, visopron, megasorb, etc.

The flotation machine for wastewater treatment consists of a body 1 (Figure 2.25), on the outside of which there is a branch pipe 2 for the supply of source wastewater, a foam gutter 3 and a branch pipe 4 for the removal of contaminants in the form of a foam product, a branch pipe 5 for the discharge of purified water. Inside the housing are disc aerators 6 through which gas (air) is supplied, as well as semi-submersible partitions 7, a thin-layer clarification unit 8, a device for regulating the level of the liquid 10 and a filter element including a frame 10 with perforated external and internal surfaces 11, between which the filter load 12 is located.

The principle of operation of the flotation machine for wastewater treatment is as follows. The original wastewater is supplied through the branch pipe 2 and further to the lower part of the body of the flotation machine 1 to the aeration zone created by the disk aerators 6, which are gas (air) bubble generators. When water moves in the aeration zone, hydrophobic contaminants in contact with bubbles stick together into complexes (particle - bubble). The resulting flotation complexes, particles of contaminants and air bubbles rise up, forming a foam layer, which is spontaneously or forcibly removed from the machine body through the foam chute 3 and the branch pipe 4 into the sludge collector. The purified water from the aeration zone is discharged through the thin-layer bubble capture unit 8. Fleet complexes that fall into the inter-regiment space quickly reach the top shelf due to the small distance between the shelves (from 10 to 150 mm). Flotation complexes stuck to the top shelf are combined (coalesced) into large units, which contributes to the appearance of a large buoyant force and the rapid floating of these complexes into the upper foam layer. The purified liquid that has passed the inter-shelf space enters the filtration zone, in which the filter element of the adsorption type is located. The adhered flotation complexes on the outer perforated surface 11 of the filter element are cossed together in the same way as in the thin-layer clarification unit. Inside the filter element is a special material 12 that captures contaminants that are in suspension. Further, the purified water passes through the liquid level control device 9 and is removed from the body of the flotation machine through the branch pipe 5.

The efficiency of wastewater treatment in the proposed flotation machine is 98-99.5%.

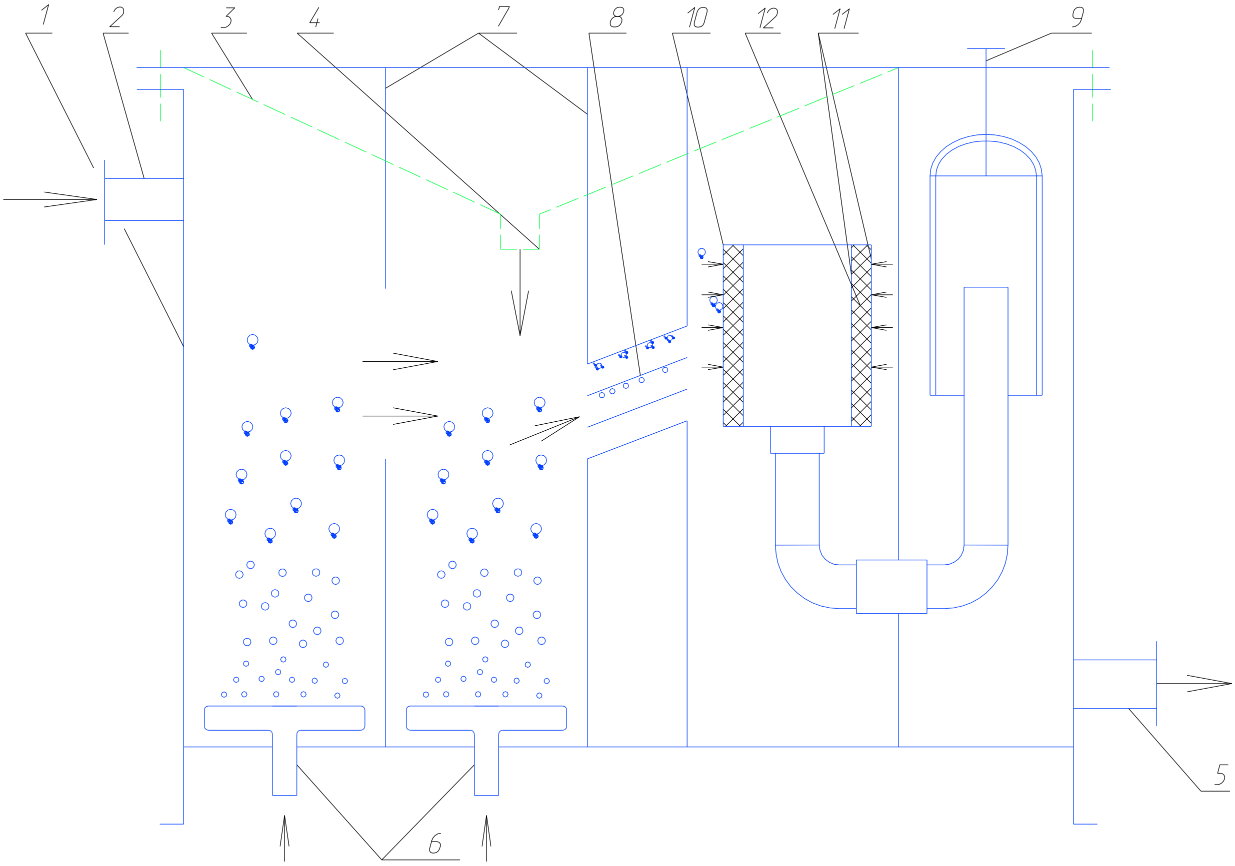


Fig.2.25. Scheme of flotation machine with filter elements

2.5.2.3. Flotation thickening of activated sludge and biosuspensions

Along with wastewater treatment, the most important direction of application of flotation technology in solving environmental problems is also the thickening of excess activated sludge. For these purposes, pressure flotation is used almost everywhere. The process of pressure flotation for thickening excess activated sludge is carried out both by direct saturation of the suspension of excess activated sludge with air under excessive pressure of the order of 0.5 ... 0.6 MPa, and by saturation of the working fluid with air under pressure and its subsequent mixing with a suspension of excess activated sludge in a ratio of 1: 1 to 3: 1, respectively. The choice of one or another embodiment of the pressure flotation method depends on the specific conditions associated with both the properties of the excess activated sludge and the possibility of instrumentation of this process.

It is known that flotation methods are used not only for wastewater treatment and thickening of activated sludge, but also in biotechnological production processes, for example, in hydrolysis plants that produce fodder yeast, to thicken biosuspensions.

In hydrolysis plants, flotators with a pneumatic aeration system are used to isolate yeast biomass. In most cases, the flotator has a cylindrical body, inside of which a glass is installed to collect the foam product, and the process of flotation of yeast cells takes place in the ring space between the body and the glass, divided into 4-5 sections. At the same time, between the first and last sections there is a continuous partition that does not allow mixing the input and output flows. The principle of operation of such a device is as follows. The suspension of yeast from the yeast plant apparatus enters the first section, in which the flotation of yeast cells occurs due to the air contained in the original suspension. When a suspension of yeast is passed through other sections, flotation occurs due to the air supplied through the bubblers from the blower. Thus, with the sequential passage of the flotator sections, there is a continuous process of extracting yeast cells from the liquid into the foam. To extinguish the foam layer formed during flotation, a mechanical defoamer is installed at the top of the glass in the central part of the flotator, for example, in the form of a disk driven by an electric motor. Mechanically destroyed foam enters the glass and then - for separation.

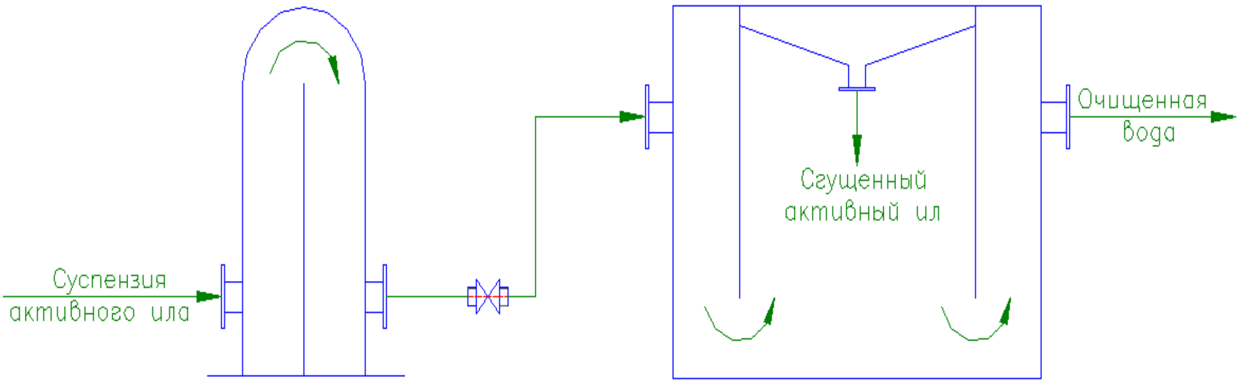
The use of a flotator of this design for the preliminary thickening of the yeast suspension is quite effective and can significantly reduce the number of separators used in the further condensation stage. However, the use of this flotator to thicken the slurry of excess activated sludge is inefficient and practically unacceptable. To use the flotator of the design described above to thicken the activated sludge, as the results of experimental studies show, it is advisable to convert into a pressure flotator or replace the 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, and according to a special technology as an apparatus operating under pressure, 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.

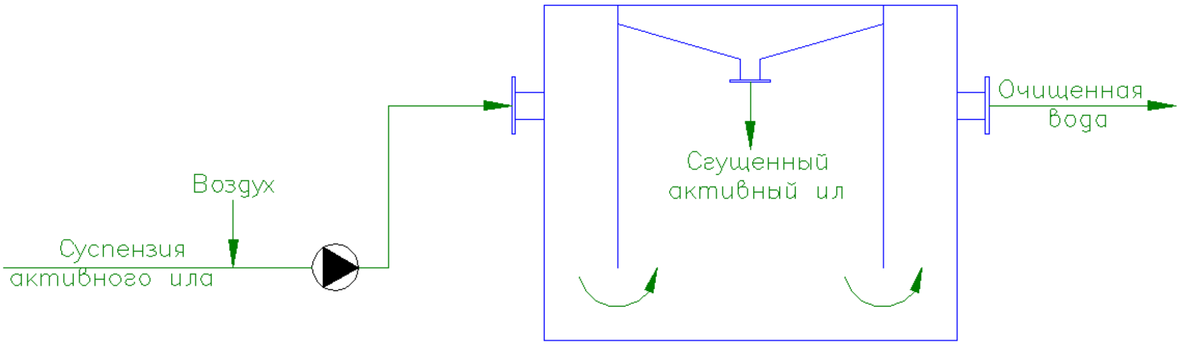
The scheme of operation of the flotator without a saturator includes the supply of air under pressure to the pipeline in front of the pump (Fig. 2.24, option b). In this case, there is no need to manufacture a saturator, which is the undoubted advantage of this scheme. However, excess non-dissolved air in the liquid phase, sucked in by an ejector or directly supplied from the compressor, is removed from the slurry in the flotator itself, usually in the form of large bubbles, which worsens the flotation process of the activated 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. 2.24). 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. In addition, it is possible to supply air directly to the saturator, which significantly prevents possible disruptions in the air supply with the help of an ejector in the event of its clogging. 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.

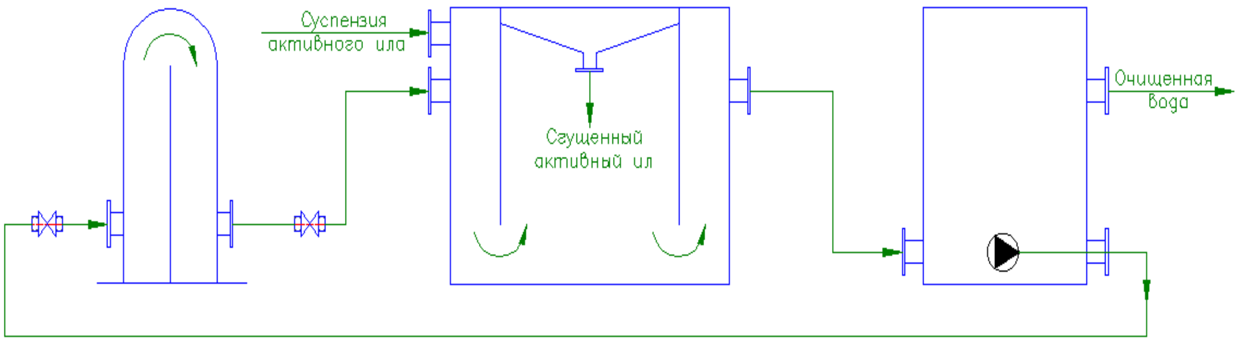
All shown in Fig. 2.26 Variants of flotation thickening of the sludge sludge are implemented in practice, and the choice of one or another method depends on the specific conditions and tasks to be solved. In the case where, after flotation thickening, the sludge of activated sludge is fed to the filter press for dewatering to a residual humidity of about 60-70%, option B, Figure 2.26, can be applied. 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 bring additional problems. Of course, in the case of large costs of sludge slurry, this can lead to additional costs and this, of course, must be taken into account.



(a)



b)



c)

Fig. 2.26 - Technological schemes of flotation condensation of activated sludge suspension:

a) - pressure version (with a saturator) without working fluid, b) - without a saturator using a pnemodidravalic aeration system; c) - pressure version (with a saturator) with a working fluid.

The effect of the method of air saturation of the sludge suspension on its concentration in the foam product after flotation is shown in Figure 2.27. These average data indicate some advantage of the method of saturation of the suspension of activated sludge with a saturator.

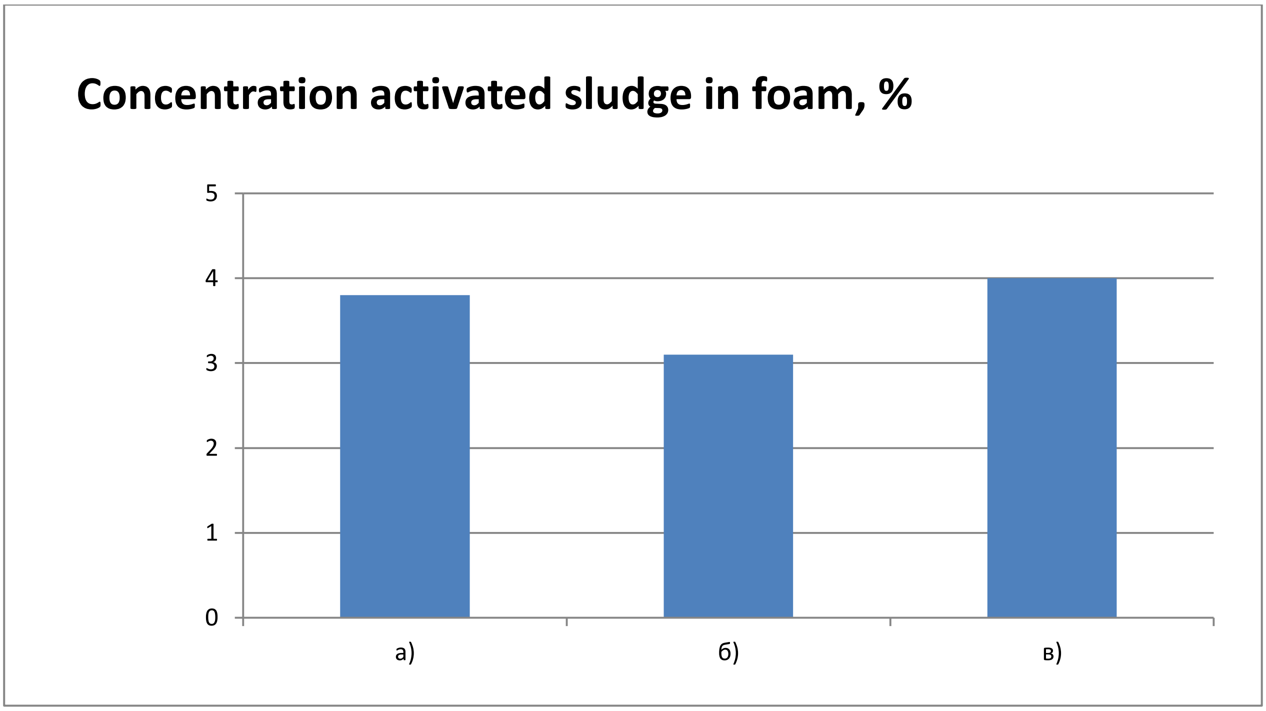


Fig. 2.27 - Average values of the concentration of activated sludge in the foam product after flotation thickening depending on the method of air saturation of the original sludge sludge (variants: a, b, c - see Figure 2.24)

The intensification of the flotation thickening process of the activated sludge suspension also depends on its pre-treatment, for example, with the use of chemical reagents, various physical effects, in particular heating. During the physicochemical treatment of the suspension of activated sludge, the processes of aggregation of microorganisms occur, in particular, under the action of polysaccharides released during such treatment. In Table. Figure 2.6 shows the concentrations of polysaccharides in the liquid phase of the heated sludge of activated sludge up to 85 °C. At the same time, it is observed that an increase in pH to 8.5, the concentration of polysaccharides increases by 3-5 times and at the same time the effect of aggregation is visually observed.

Table 2.6 - Effect of thermostatic treatment of activated sludge suspension on the concentration of polysaccharides in the liquid phase of the suspension (concentration of activated sludge in suspension 0.5%)

N, p/p	Processing parameters			Concentration of polysaccharides, mg/l	Clarification efficiency (%)
	t, ºC	pH	Holding time, min		(Turbidity measurement on FEC)
1 (control)	20	7,2 (ex.)	-	11	54,3
2	40	7,2	5	35	62,8
3	80	7,2	5	52	73,1
4	85	7,2	5	54	75,8
5	90	7,2	5	53	74,6
6	20	8,0	5	9	52,3
7	20	8,5	5	9	51,7

8	85	8,5	5	8	50,9
9	85	8,5	10	35	61,6
10	85	8,5	30	31	60,7
11	85	8,5	45	31	61,1
12	85	8,5	60	9	50,8

The data obtained indicate the feasibility of such physical and chemical treatment as one of the methods of intensification of flotation thickening of activated sludge. Another, in most cases more effective way, is the pre-treatment of the sludge suspension with reactants, in particular cationic active flocculants such as Praestol 644 and 852. Data on the influence of these flocculants on the process of flotation thickening of the suspension of activated sludge are given in Table. 2.7.

Table 2.7. Averaged data on the effect of a dose of cationically active flocculants on the efficiency of flotation thickening of activated sludge

Flocculant type	Flocularity 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 those presented in Table. 2.6 of the data indicates that the use of praestol 852 cationic flocculant leads to better results than the flocculant praestol 644 at the same doses. In this regard, the flocculant Praestol 852 was recommended for further use in the practice of flotation thickening of the sludge of activated sludge.

Thus, the conducted studies have shown that in the practice of flotation thickening of activated sludge, flotation apparatus with a pneumohydraulic aeration system can be used and it is advisable to use praestol 852 cationic flocculant to intensify this process.

2.5.3. Basics of adsorption technology of wastewater treatment

The adsorption process is based on water filtration through special microporous granular materials - sorbents (adsorbents) with a large internal surface (up to 1.0-1.5 thousand^{m3} per gram of sorbent), due to which impurities contained in it are extracted from water, including those in the state of true solutions, i.e. in a molecular state.

Adsorption is carried out due to the diffusion of molecules of organic substances through the liquid film surrounding the particles of the adsorbent to its surface and further internal diffusion of molecules. The speed of the last stage is determined by the structure of the adsorbent and the size of the molecules of the sorbed substance. Sorption is economically feasible to use at low concentrations of contaminants, i.e. at the stage of deep purification. In this case, in the process of sorption, it is possible to obtain residues close to zero.

The speed and efficiency of adsorption is affected by the structure of the sorbent, the chemical nature and concentration of contaminants, temperature, and the active reaction of the medium. With an increase in temperature, the degree of adsorption decreases, despite the increase in the rate of diffusion; a decrease in the pH value causes an increase in the sorption of organic substances of wastewater. With the help of sorption, biologically resistant organic substances can be extracted from water. Main characteristics of sorbents:

1) porosity - the ratio of the volume of pores to the total volume of the sorbent, (%);

2) capacity - the amount of absorbed substance per unit mass or volume of the sorbent (kg / m3, kg / kg);

3) specific surface area - the surface area of the sorbent per unit mass (m2 / kg).

<u>Types of sorbents used for wastewater treatment:</u>

1. synthetic sorbents;
2. active coals - are the most universal adsorbents;
3. some industrial waste – sawdust, ash, slag, etc.;
4. mineral sorbents – silica gels, clays, hydroxides and aluminogels of metals.

The sorption method has a number of advantages over other methods: it provides cleaning from almost any contaminants and to a given depth; is characterized by the absence of secondary contaminants and the need for reagents, ease of sale and maintenance, is the only method of cleaning from chemo- and bio-resistant contaminants, allows you to repeatedly use the sorbent by regeneration, the purification process during the extraction of petroleum products and other organic impurities (by burning spent sorbents together with absorbed substances) is waste-free. In some cases, the substances (sorbates) absorbed by the sorbent cannot be burned together with the sorbent, such as in the sorbation of heavy metal ions (which, when burned, can turn into combustion products), radionuclides or substances that form toxic wastes during combustion. However, even in these cases, sorption purification can have advantages over other methods, as it provides a greater depth of water purification and at the same time - a large concentration of sorbate (thousands and millions of times - depending on the initial concentration of sorbate in the purified medium), creating conditions for compact burial of harmful substances.

Most often, active coals are used as an adsorbent, which makes it possible to obtain residual concentrations of the main ingredients below the normative values. For example, the concentration of petroleum products in purified water after adsorption treatment does not exceed in most cases 0.05 mg / l, which corresponds to the MPC for fishery reservoirs.

Active carbon is a porous carbon adsorbent with a developed inner surface. An indispensable condition for the effective use of active carbon in a particular process is the correct choice of the type of coal. Compliance of its adsorption properties with the conditions of this process. Important physical and mechanical characteristics of granular and crushed active carbons are bulk density, fractional composition, mechanical strength. The main characteristic that determines the adsorption properties of active carbon is the porosity of its structure.

On the basis of adsorption and capillary phenomena, the pores of active carbon are classified by size into micropores ($x<0.6\div0.7$ nm), supermicropores ($0.6\div0.7<x<1.5\div1.6$ nm), mesopores ($1.5\div1.6<h<100\div200$ nm) and macropores ($x>100\div200$ nm). Micropores are the smallest type of adsorbent pores. In their linear size, micropores are commensurate with adsorbable molecules. Due to the imposition of adsorption potentials of opposite walls, the adsorption energy in micropores is significantly higher than in non-porous adsorbents of a similar chemical nature. The specific surface area of micropores is from 200 to 2000 m^2 / g. Mesopores are larger pores, which are characterized by layer-by-layer filling of the surface with adsorbable molecules, which ends at higher equilibrium relative pressures of the adsorbate with their volumetric filling by the mechanism of capillary condensation. The specific surface area of the mesopore is from 100 to 200 m^2 Supermicropores are a transitional region of porosity between micro- and mesopores, during which the characteristic properties of micropores gradually degenerate, and the properties of mesopores, respectively, manifest themselves.

Macropores are a larger type of pores, the specific surface of which is usually 0.5-2 m2 / g. Macropores do not fill up during adsorption, but act as transport channels for the delivery of adsorbate to adsorbent pores.

The adsorption properties of active carbon are also affected by the nature of the surface of the adsorbent. Active carbon contains chemically bound oxygen, which, depending on the method and conditions for obtaining coal, forms surface chemical compounds of a basic or acidic nature.

During sorption, coal should not receive water containing suspended and colloidal substances that shield the pores of active carbon. Coal that has exhausted its sorption capacity (capacity) is regenerated (restored) or completely replaced.

Currently, the following brands of active carbons are produced for adsorption from liquid media: AG-OV, AG-3, AG-3A, AG-3V, AG-3I, AG-8, AD-2, AD-4, AGM, SKD-515, SKD-915, SKD-2000, VS-1, VS-2, AGS-4, AGS-4U, KAD. CAD-iodine, CAD-ground. KAD-E, KAD-G, Hydrosorb, Gidrosorb-MVK, UAF, UAM, PFM, SKT-O, SKT-M, AG-3-O, ACB-O, BAU, DAK, OU-E, OU, ADU, ADU-V, AD. AU-E, SPDK-27D, FTD-D, TVZ, FAS-3, Technosorb-1, AG-90, AG-95, AG-2000.

Consider the properties of the most popular coals.

Active coal AG-3 (GOST 20464-75) is obtained in the form of cylindrical granules (diameter 1.5 mm) from dark gray to black color from coal or charge of coal and coal semi-coke and binder by granulation of coal-tar paste, carbonization and combined-cycle activation. The main manufacturers are JSC "Zarya", JSC "Sorbent".

The physical and chemical characteristics of AG-3 coal are presented in Table 2.8.

Table 2.8. Physical and chemical characteristics of AG-3

Index	Meaning
Fractional composition determined by mass fraction of residue, %:	
on a sieve with a canvas:	
No. 36, not more than	0,4
No. 28, not more than	3
No 15, not more than	86
No. 10, not less than	10
on a pallet, not more than	0,6
Abrasion strength of granules, %, not less than	75
Bulk density, g/dm^3	400-500
Mass fraction of moisture, %, max	5
Total volume of pores in water, cm^3/g, not less than	0,8
Dynamic benzene activity, min, not less than	40
Total pore volume V_Σ, cm^3/g	0,83-0,98

Activated crushed wood coal (GOST 6217-74) of the DAK type is obtained by treating raw charcoal with water vapor at a temperature of over 800 °C. The main manufacturers are Sorbent OJSC, EHMZ OJSC, Zarya OJSC.

The physical and chemical characteristics of DAK coal are presented in Table 2.9.

Table 2.9. Physical and chemical characteristics of DAK coal

Index	Meaning
Fractional composition determined by mass fraction of residue, %:	
on a sieve with a canvas:	
No. 36, not more than	2,5
No 15, not more than	-
No. 10, not less than	95,5
No. 5, not less than	-
on a pallet, not more than	2
Abrasion strength of granules, %, not less than	-
Adsorption activity for iodine, %, not less than	30
Total volume of pores in water, cm^3/g, not less than	1,4
Bulk density, g/dm^3, not more than	Not standardized
Mass fraction, %, not more than:	
Ash	6
Moisture	10

Sorption properties are possessed by many natural materials, such as quartz sand, chalk, diatomite, anthracite crumb, opoki, diatomaceous earth, dolomite, magnetite, zeolite, sapropel, peat, etc.

Natural sorbents have developed specific porosity and high adsorption capacity due to low volumetric weight and high natural porosity. These properties cause a wide distribution of natural sorbents in industry.

An economical and widespread natural sorbent in technological processes is zeolite. Heat treatment of zeolites up to 700 ° C increases sorption properties by increasing the specific surface.

To obtain sorbents based on zeolites with high strength and water resistance, they are heated at a temperature of 1000 ° C with chloride and sodium carbonate. With rapid heating of zeolites, their foaming occurs, due to which the volume and porosity of materials increase by 5-20 times.

Hydrophobicity to zeolites is given by treatment with organosilicon compounds, due to which the sorption of petroleum products from water increases.

Zeolites treated with amines are used for sorption of lead and cadmium ions.

Minerals from the group of cristobalite rocks - opoki, diatomaceous earth, diatomite - are also used to sorpize oil from water. Since these sorbents have a high sorption capacity in relation to water, when purified from petroleum products, oil hydrocarbons undergo a high degree of drying.

Diatomite, activated by manganese oxide, is used to purify textile wastewater from lead and dyes.

Thermal activation of opoka and diatomaceous earth at a temperature of 1000 ° C in the presence of chloride and sodium carbonate gives sorption materials the property not to swell in water.

Aluminum oxyhydroxide powder in the ultradisperse state allows high efficiency to absorb dissolved hydrocarbons and emulsified petroleum products.

Aluminosilicate natural sorbent is characterized by a uniquely high sorption capacity to ions of heavy metals, including radioactive elements. This sorbent has a high specific surface area and retains sorption properties to a temperature of 700 ° C. Heat treatment in the presence of air modifies the sorbent, increasing its sorption capacity by 2-3 times.

Filtration on natural zeolites or other natural sorbents is used to increase the efficiency of biosorption purification. Even taking into account the variety of natural materials that can be used as sorbents, not all of them meet strict requirements, so the search and creation of new sorption materials for use in industry is always relevant.

The cost of natural sorbents is ten times lower than artificial ones, so they are often notregenerated. The results of a systematic study of the sorption properties of natural materials in the extraction of petroleum products of an azlar nature are known in the literature. To improve the quality of the treatment ofoil-containing waters by researchers combined multilayer sorbents have been developed that allow to extract oil impurities of a wide range of dispersion with a purification degree of 92-98%.

It was found that among the studied fibrous materials, the most technologically advanced is the use of pressed basalt or polypropylene fiber. Their oil absorption is 6.1–7.2 and 3.8–4.5

g/g, respectively. The use of carbon fabric, which has a higher oil absorption (10.2-10.6 g / g), significantly increases the cost of filter elements.

Sorption of heavy metals from solutions using biotechnology is an intensively developing field of research. Despite the variety of adsorbents used, many of them do not meet the whole range of requirements for materials of this type, and therefore the search and development of new sorption materials is carried out constantly.

Recently, a particular priority has been to obtain relatively cheap sorption materials based on industrial waste, since the waste is reused. Production waste as adsorbents is devoid of the main drawback of most of the adsorbents used, especially ion exchange resins, - high cost. As carbon sorbents, crumb rubber and tire coke, formed after pyrolysis of used tires, can be used. Ferrites of transition metals are increasingly used in modern technologies. One of the uses of ferrites is sorption from liquid and gas media. The ability of ferrites to adsorb heavy metal ions is used to purify water from strontium and uranium.

Semi-synthetic sorbents and catalysts for industrial needs are very promising and widely used. Sorbents are obtained from mineral raw materials processed in various ways - organic or inorganic compounds, deposition of simple or complex oxides on them, etc.

Areas of application of nanomaterials based on carbon and inorganic structures deserve special attention. The resulting sorbents have a porous structure that differs from the original mineral, and acquire additional useful properties of synthetic sorbents.

Synthetic sorbents are obtained from raw materials of the petrochemical industry. It can be a roll material made of polypropylene fibers, spongy or granular polyurethane, molded polyethylene or other plastic materials.

In practice, synthetic surface-modified materials are used as sorbents, chromatographic materials, biosensors, anti-corrosion coatings, implants, adhesives and anti-adhesives, carriers of enzymes and cells.

The group of granular carbon sorbents includes carbochromes and carbopacks. These are broadly porous materials with high sorption capacity and mechanical strength. The disadvantage of sorbents is a high cost, so their use is justified only for chromatography methods.

For cleaning from petroleum products, pressed basalt or polypropylene fibers are widely used. Their oil absorption rates: 6.1-7.2 g/g for basalt fibers; 3,8-4,5 g/g — for polypropylene.

The use of carbon fabric for sorption of oil increases the cost of filter elements, but shows a high purification effect - 10.2-10.6 g / g.

To improve the performance of the sorption filter, you can use a combined sorbent in the form of a sintered mixture of coal or polyethylene, or obtain coal fiber by carbonizing viscose.

The resulting sorbents have a structure in the form of a tangle of threads with a thickness of 6-10 µm, are characterized by a huge active surface and a large number of pores.

Disadvantages of synthetic sorbents: high cost and environmentally problematic disposal of waste materials. Synthetic sorbents do not undergo biological decay, so waste materials have to be burned.

Widely known in our country and neighboring countries **sorbent AC**, developed in Russia more than 10 years ago. To date, this sorbent is the most effective load when it is necessary to purify highly polluted waters from a whole range of various chemical dissolved and undissolved impurities, such as iron, phenols, aluminum, petroleum products and other contaminants.

The AC sorbent is a highly porous material and therefore has a low mass (light) and high strength (abrasion loss of less than 2% per year), which allows it to maintain ultra-low concentrations of contaminants in the water to be cleaned. The AC sorbent works in acidic solutions of untreated wastewater at pH = 6.5, even in the presence of hydrogen sulfide, and overchlorination or the introduction of other oxidants does not affect its sorption activity. This is one of the few sorbents that do not form a biofilm on the surface, and also have a coagulating effect.

Sorbent AS is produced according to TU 2164-001-15055998-2010 (serial production), the physical and chemical properties of the sorbent meet the requirements of GOST R 51641-2000 (see Table 2.10 - 2.11).

Table 2.10 - Main technical characteristics of the AC sorbent

Characteristic	Meaning
Bulk density	700 ± 20 kg/m^3
Specific surface area	150 ± 30 m^2/g
Abrasion	0.06%
Grindability	0,04%
Conditional mechanical strength	0.79%
Intergrain porosity	49 ± 3%

Grain shape coefficient	1.65-1.71
Tank for petroleum products in dynamic conditions	170 g/kg
Calculated capacitance for iron and suspended solids	1 g/l
Radionuclide distribution coefficient	10^3-10^4
pH	minimum 5.8
Filter media fractions	0.315-0.7; 0.7-1.5; 1.5-3.0 mm

Table 2.11 – Recommended operating conditions of the AC sorbent

Layer height	40-100 cm
Seepage velocity	10-20 m/h
Flushing speed at expansion 30-35%	20 m/h
Duration of backwash	10 min

In the last 20 years, ultra-cross-linked polystyrene sorbents have become widely used in analytical chemistry. To date, many companies offer ultra-cross-linked polystyrene sorbents for solid-phase extraction. Their characteristics are given in Table 2.12.

Table 2.12 – Characteristics of sorbents

Sorbent, company	Particle size, µm	Surface, m2/g	Pore volume cm3/g	Pore diameter, nm
Purosep 200 Purolite International, Великобритания	40-140	1000	1,1	2-3 and 85-100

Isolute ENV International Sorbent Technology, Великобритания	40-140	1100	1,1	2-3 and 85-100
LiChrolut EN Merck, Голландия	40-120	1200	0,75	3
HYSphere-1 Spark Holland, Голландия	5-20	>1100	-	-
HR-P Macherey Nagel, Германия	40-120	1300	-	2,5

In general, both in the Russian and foreign markets, a large number of various types of sorbents for water purification are produced and sold, among them C-VERAD, BIRM, Greensand, MLF, UIA, Lessorb, Unisorb, MIU-S, HES, coconut sorbent Shelltic W and many others. Data on the effectiveness of such sorbents are provided by the manufacturer and should be tested experimentally on specific effluents.

2.5.4. Electrochemical technologies of wastewater treatment

Technologies for the treatment of industrial wastewater using electrochemical processes are characterized by multi-stage and relative complexity of the physicochemical phenomena occurring in water treatment devices. The mechanism and speed of the individual stages depend on many factors, the identification of the influence and the correct accounting of which are necessary for the optimal design of electrolyzers and the rational management of water purification processes.

Methods of electrochemical wastewater treatment include methods that involve combining one or more methods of conversion and separation of effluent contaminants in one apparatus.

Based on the classification of methods of electrochemical wastewater treatment, it is necessary to choose the type of apparatus, which is determined primarily by the type of generated electrolytic effect in wastewater.

Devices for electrochemical treatment of industrial wastewater (electrolyzers) are classified according to the following characteristics:

1. on the organization of the process of wastewater treatment - devices of continuous or periodic action
2. according to hydrodynamic mode of operation – pressure and non-pressure
3. reactor type – open, closed, diaphragmatic and diaphragmatic
4. on the organization of the movement of wastewater in the interelectrode space - horizontal, angular, vertical with upward and downward movement of water
5. on the organization of water movement in the apparatus - single-flow, multi-flow and combined

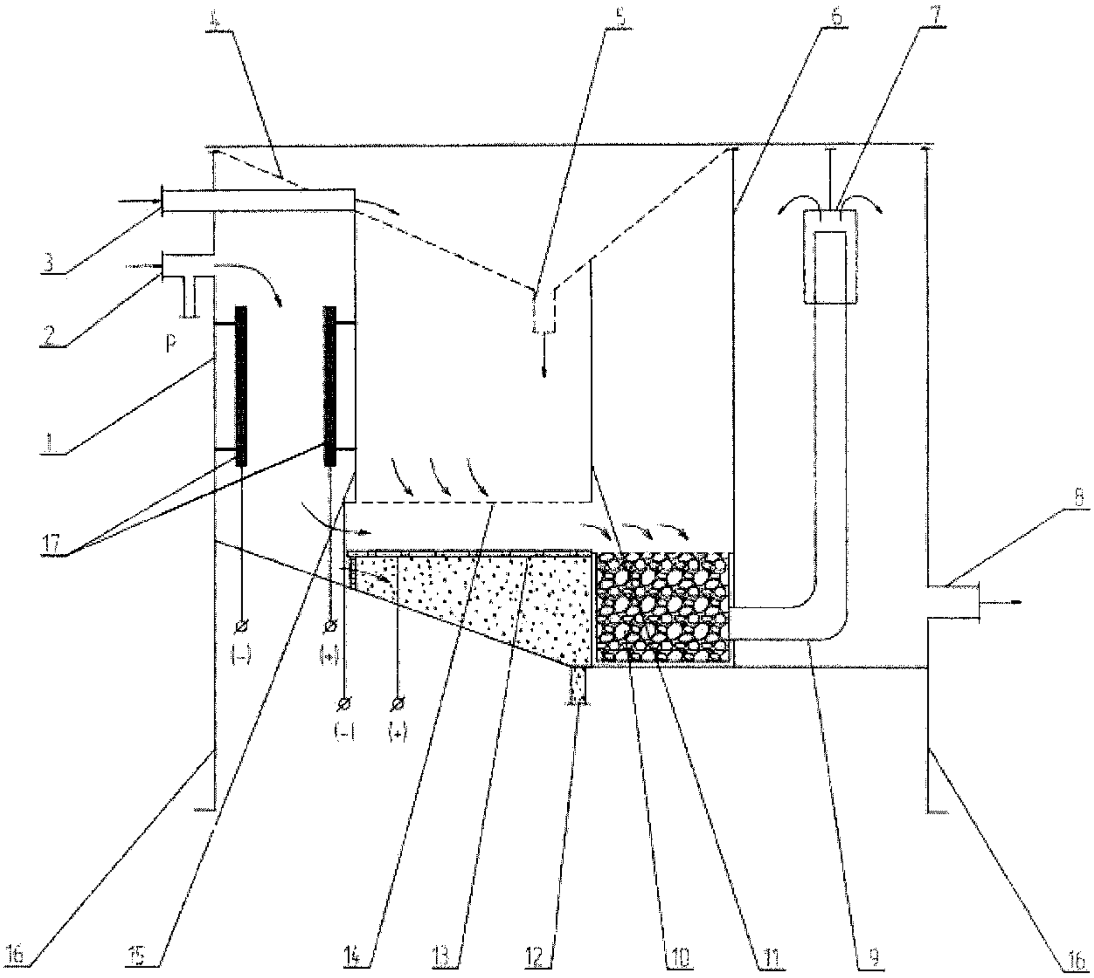
by type of impact on the dispersed system - electric field, electrode processes, electric discharge, complex effect

Wastewater treatment by electrocoagulation is based on their electrolysis using steel or aluminum anodes subjected to electrolytic dissolution. As a result, a coagulation process is carried out, similar to the treatment of wastewater with iron and aluminum salts. However, in comparison with reagent coagulation during electrochemical dissolution of metals, water is not enriched with sulfates and chlorides, the content of which in water is limited both when discharged treated wastewater into water bodies and when reused in industrial water supply systems.

The mechanism of electrocoagulation in series includes the following operations: electrophoretic concentration, that is, the directed movement of charged particles of impurities and their concentration at the surface of the electrodes; dissolution of the electrode and the formation of metal hydroxides; polarization coagulation of dispersed particles; packing of primary aggregates as hydroxide particles accumulate and flocculation; flotation of the formed units with gas bubbles.

The efficiency of electrocoagulation depends on the material of the electrodes, the anode current density, the composition and speed of movement of the treated liquid in the interelectrode space. A serious obstacle to electrocoagulation is the formation of oxide films on the electrodes - anode passivation. A significant drawback of the known devices of this type is also a very large energy consumption. The electroflotation apparatus developed by us, presented in Fig. 2.28, there are no such disadvantages. This is achieved by additional installation of a branch pipe for entering part of the clarified water and reagent solution, as well as an additional pair of electrodes, and installation of a granular-loading filter in front of the liquid level control device. In this case, the size of the loading particles is from 1 to 3 mm and the surface of the loading particles is hydrophilic to exclude the interaction between the gas phase and the surface of the loading particles.

The efficiency of water purification in the proposed electroflotation apparatus is 93-99%, with a corresponding unit energy consumption of 0.8-1.4 kWh /^{m3}.



1 – body of the device; 2 – a branch pipe for supplying part of the clarified water and the reagent solution; 3 – branch pipe for supplying the main part of the clarified water; 4 – foam gutter; 5 – branch pipe for removal of foam product; 6, 11, 15 – semi-submersible partitions; 7 – a device for regulating the level of clarified liquid with a supply hose; 8 - branch pipe for the output of clarified liquid; 9 – pipeline; 10 - filter with granular loading; 12-nozzle for sediment output; 13 – anode; 14 – cathode; 16 - special supports; 17 is an additional pair of electrodes (cathode and anode).

Fig. 2.28 - Diagram of the electroflotation apparatus for wastewater treatment

The principle of operation of the proposed electroflotation apparatus is as follows (Figure 2.28).

The main part of the source wastewater is supplied for treatment through the branch pipe 3, and a smaller part of the source wastewater with the solution of the reagent through the branch pipe 2 and further processed in the zone of exposure to a constant or alternating electric field in the space between the electrodes 17. Further, the main and auxiliary flows are mixed in the area of the electrodes 13 (anode) and 14 (cathode) connected to the DC source. In this zone, the formation of flotation complexes of pollution particles occurs - bubbles of electrolysis gases (oxygen and hydrogen) and their separation from the clarified liquid by their floating and removal through the foam chute 4 and further through the branch pipe 5. Small fleets that do not have time to surface are removed when the clarified clarified liquid enters the filter 10. Small flotation complexes before the water enters the filter coalesce, combining into large ones, which quickly float up and are separated from the clarified liquid. The purified water is discharged from the apparatus via the pipe (hose) 9 through the level 7 control device through the branch pipe 8.

In general, evaluating the proposed electroflotation apparatus, it should be noted the high efficiency of wastewater treatment in it with a decrease in specific energy costs compared to the corresponding indicators of analogue devices.

Combined methods of electrochemical wastewater treatment include methods that involve combining one or more methods of conversion and separation of effluent contaminants in one apparatus.

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-on the organization of the process of wastewater treatment - devices of continuous or periodic action;

-according to the hydrodynamic mode of operation - pressure and non-pressure;

-by type of reactor - open, closed, diaphragmatic and diaphragmatic;

- on the organization of the movement of wastewater in the interelectrode space - horizontal, angular, vertical with ascending and descending movement of water;

-on the organization of water movement in the apparatus - single-flow, multi-flow and combined;

- by the type of impact on the dispersed system - an electric field, electrode processes, electric discharge, complex effect.

2.5.5. Membrane methods of wastewater treatment

The use ***of membrane methods*** in the practice of wastewater treatment has received limited application due to the need for a sufficiently deep preliminary treatment of water supplied to the membrane, as well as due to the high cost of the relevant equipment. However, a situation may arise when deep post-treatment and desalination of wastewater before discharge or when it is used in the reverse cycle may be required.

In such cases, the following types of membrane wastewater treatment can be used:

1. Microfiltration,
2. Ultrafiltration
3. Nanofiltration,
4. Reverse osmosis.

The choice of process for use in a given area of mixture separation depends on various factors: the nature of the substances to be separated, the required degree of separation, the productivity of the process and its economic valuation.

Microfiltration is the process of membrane separation of colloidal solutions and suspensions under the influence of pressure. The size of the separated particles is from 0.1 to 10 µm. Microfiltration is a transitional process from conventional filtration to membrane methods.

For microfiltration, membranes with a symmetrical microporous structure are used. Pore sizes from 0.1 to 10 µm. Small particles of the solute and the solvent pass through the membrane, and the concentration of the trapped particles increases. The flow of solution along the separation membrane allows you to remove the concentrated layer, impurities of solid particles and other formations from which it was necessary to release the solution and solvent. The solvent that has passed through the membrane carries out microinclusions, which are sent to the process lines for separation in subsequent cycles.

The membrane method of microfiltration is widely used in the separation of suspensions, emulsions and purification of industrial wastewater contaminated with mechanical impurities, as well as in the production of sterile solutions.

During ultrafiltration, separation, fractionation and concentration of solutions occur. One of the solutions is enriched with a solute, and the other is depleted. Membranes allow solvent and certain fractions of molecular compounds to pass through. The driving force of ultrafiltration is the pressure difference on both sides of the membrane. This force is spent on overcoming the forces of friction and interaction between the molecules of the liquid phase and the polymer molecules of the membrane. Usually, the ultrafiltration process is carried out at relatively low operating pressures of 0.3 - 1 MPa.

The separation efficiency depends on the structure of the membranes, the flow rate and concentration of the dissolved solution, the shape, size and diffusion capacity of the dissolved molecules.

The disadvantage of the process is a strong concentration polarization, i.e. a dense precipitate - a layer of gel - can form on the surface of the membrane.

Of all the types of membrane separation, ultrafiltration has found the most diverse applications. An important industrial application of ultrafiltration is the separation of oil and water emulsions.

Ultrafiltration is a membrane process of purifying water from suspended substances, large organic macromolecules weighing more than 50,000 Dalton (Dalton) colloidal particles (colloidal solutions). Ultrafiltration plants assembled on can be assembled on the basis of tubular ceramic elements, rolled elements and hollow fibers. The pore size of UV membranes is 0.01 - 0.1 µm.

Ultrafiltration makes it possible to purify wastewater from impurities of petroleum products, when hydrophobic hydrocarbon molecules are retained by hydrophilic polar cellulose acetate membranes (ACM) with pore sizes exceeding the size of the molecules of the retained substances (Fig. 2.29).

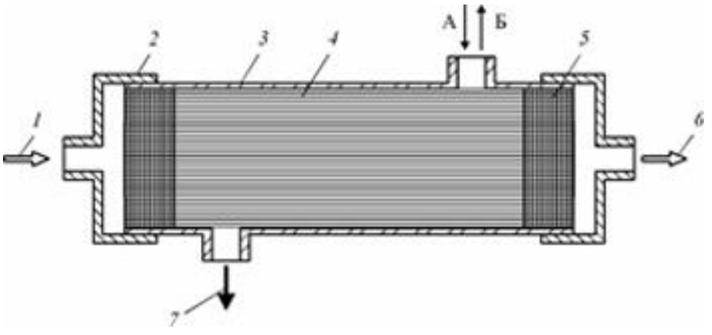


Fig.2.29. Ultrafiltration module: 1 - flow of the separated mixture; 2 - ultrafiltration module cover; 3 - ultrafiltration module housing; 4 - hollow fibers; 5 - block-collector; 6 - flow, concentration; 7 - flow, filtrate, A and B - options for feeding and diverting components of the shared system

Nanofiltration is a membrane process that removes from water multi-charged ions and molecules with a size of 0.01 - 0.001, molecules of organic substances weighing more than 200 Dalton (Dalton) and viruses. Selectivity in the purification of water from heavy metals and hardness salts is 98-99%, when removing single-charge ions of the order of 50% (see Table 2.13).

Nanofiltration has found application in the field of wastewater treatment and for the organization of circulating water supply, in particular for the reuse of water in laundries, after washing bottles, etc., as well as for technologies for returning valuable raw materials to production. Nanofiltration combines the features of ultrafiltration and reverse osmosis. With the help of naofiltration, it is possible to achieve selectivity of 90-98%, which is lower than reverse osmosis of 97-99.5%, but in some cases such high selectivity is not required, and therefore it is more profitable to use a less energy-intensive nanofiltration process (operating pressure is 1.5-2 times lower).

Table 2.13 - Selectivity of nanofiltration elements

Ion / Indicator	Selectivity, %
Calcium	93-95
Magnesium	92-94
Iron (III)	98-99
Aluminium	95-98
Sulphates	96-98
Phosphates	90-95
Bicarbonates	50-60
Silicates	90-95
Chlorides	40-60

Total Organic Carbon	90
COD	50-70
Surfactants (anionic and non-ionic)	90-95
Chromaticity (dyes)	95

Reverse osmosis plants provide the ability to purify water simultaneously from soluble inorganic (ionic) and organic contaminants, high-molecular compounds, suspended substances, viruses, bacteria and other harmful impurities.

As a rule, reverse osmosis is used in technological processes of desalination of sea and brackish water, production of ultrapure water for the pharmaceutical, radio-electronic and instrument-making industries, as well as in the creation of circulating water supply systems of enterprises (membrane concentration of wash water and desalination of treated wastewater in galvanic production and production of printed circuit boards). Abroad, the most widespread in the industry are membrane reverse osmosis plants: Dow Chemical "Filmtec", GE Osmonics, Toray, Norit, Inge, Hydranautics, etc. In Russia, for the assembly of reverse osmosis plants (Technopark of the Mendeleev Russian Chemical Technical University, FSUE "Research Center named after M. V. Keldysh"), both roll and floor-fiber elements of the above manufacturers, as well as domestic reverse osmosis cellulose acetate (AC) and polyamide (PA) polymer membranes produced by STC "Vladipor" (Table 2.14).

Table 2.14- Characteristics of membrane processes

Membrane process	Pore size, µm	Operating pressure, bar	Membrane elements	
			Material	Configuration
Microfiltration	0,02-4,0	<2	Polypropylene, PVDF, lavsan, fluoroplastic, ceramics	Rolled, hollow fibers, tubular
Ultrafiltration	0,02-0,2	1-10	Polypropylene, acrylonitrile, PVC,	Rolled, hollow-fiber, tubular

			polysulphon, ceramics	
Nanofiltration	0,001-0,01	5-35	Cellulose acetate, aromatic polyamides (polysulfone), ceramics*	Rolled, hollow-fiber, tubular*
Reverse osmosis	0,0001-0,001	10-70	Cellulose acetate, aromatic polyamides	Rolled, hollow-fiber, flat-frame

Special methods of wastewater treatment, including the use, for example, of extraction, are of only cognitive interest, since they are very rarely used in the practice of wastewater treatment.

2.5.6. Methods of wastewater disinfection

Almost all wastewater from settlements and enterprises contains organic pollution that causes the emergence of pathogenic bacteria, so for such objects it is required to use disinfection (disinfection) of wastewater.

The purpose of disinfection (disinfection) of wastewater is to destroy pathogenic microorganisms in wastewater and prevent them from entering the reservoir. The greatest danger is posed by pathogens, in cases where they can get to the places of bathing or drinking water intake with the flow of the reservoir.

Disinfection (disinfection) of water can be done in various ways. They vary greatly in the principle of operation, efficiency, reliability and degree of danger.

The choice of one or another method of treatment depends on the object of use, the volume and type of effluent, sanitary standards for the discharge of wastewater into the water intake (lake, river, city collector), etc.

For the disinfection of wastewater, the method of chlorination, ozonation and ultraviolet irradiation are used.

In the domestic practice of the second half of the twentieth century, wastewater treatment with chlorine and chlorine-containing agents was traditionally used. This was the most common method of decontamination in our country.

With all the prevalence of the chlorination method, it is also characterized by significant technological shortcomings, in particular, insufficient effectiveness against viruses. Chlorination of wastewater leads to the fact that chlorine derivatives and residual chlorine, getting into natural water bodies, have a negative effect on various aquatic organisms, causing them serious physiological changes and even their death, which leads to disruption of the processes of self-purification of water bodies. Organochlorine compounds are able to accumulate in bottom sediments, tissues of hydrobionts and, ultimately, enter the human body through trophic chains.

Grundfos (Denmark) uses chlorine dioxide as a disinfectant in its development.

Chlorine dioxide is extremely effective against all types of microbes and has a long-lasting effect. A great advantage of chlorine dioxide over other disinfectants is its effectiveness against biofilms. Thus, the company has developed a system for the production of chlorine dioxide Oxiperm Pro OCD-162 as a solution to combat legionella and other microorganisms that occur in drinking water, but can also be used in wastewater treatment (Fig. 2.30). Such a system produces chlorine dioxide using diluted solutions of sodium chlorite ($NaClO$ 2.7.5%) and hydrochloric acid (HCl, 9%).

Figure 2.30 – Devices for the production of chlorine dioxide Oxiperm Pro OCD-162 Grundfos (Denmark)

Disinfection systems with chlorine (sodium hypochlorite solution) are also being developed by Labko (Finland). These Labko DES systems consist of the following components: a reagent storage tank, a low-current dosing pump with a control system, a pressurized chemical pipeline and a contact tank in which wastewater is mixed with the reagent, as well as a contact time is ensured.

It should be noted that when developing and operating chlorine decontamination systems, safety rules must be strictly observed. It should be borne in mind that special insulated reactor chambers must be used to disinfect wastewater with chlorine. Chlorine fumes, when used improperly, can damage a person's airways, or cause burns. The materials from which the equipment is made must be resistant to the aggressive effects of chlorine.

Despite the technical difficulties in the transportation, storage and dosing of chlorine gas, its high corrosivity, the potential danger of emergency situations, the chlorination process is widely used at present.

Ozonation is the process of wastewater treatment by oxidation of organic and mineral substances, as well as their disinfection, carried out by mixing water with an ozone-air or ozone-oxygen mixture in devices of various designs (reactors). Ozonation belongs to promising environmentally friendly methods of treatment of industrial wastewater by oxidation, since when using it, chemical reagents are not used, which lead to the so-called secondary water pollution.

The main factors affecting the process of wastewater treatment by ozonation are the pH values of wastewater and the chemical nature of the oxidized substances.

Ozonation is widespread and is an effective method of oxidative destruction of the following substances contained in wastewater: phenol and its derivatives (chloro-, nitro-, aminophenols), polyphenols, complex compounds of a phenolic nature (hydrolysis lignin, lignosulfonic acids, water-soluble resolic resins, hydrolyzable and condensable tannides, gum-like substances, etc.), SPAV, dyes, etc.

The possibilities of using ozone for neutralization of wastewater containing cyanide compounds have been studied. When cyanides are oxidized, the following reactions occur.

$$CN^- + O_3 \rightarrow CNO^- + O_2$$

$$CNO^- + 2H^+ + H_2O \rightarrow CO_2 + NH_4$$

The method of ozonation can remove hydrogen sulfide from wastewater; in this case, in the first stage there is a release of sulfur, and in the second - oxidation directly to sulfuric acid.

$$H_2S + O_3 \rightarrow S + O_2 + H_2O$$

$$3H_2S + 4O_3 \rightarrow 3H_2SO_4$$

Reactions occur simultaneously, but with an excess of ozone, the second one prevails.

In the process of ozonation of water, simultaneous oxidation of impurities, discoloration, deodorization, disinfection of wastewater and its saturation with oxygen are possible.

Advantages of ozonation:

1) Ozone destroys all known microorganisms: viruses, bacteria, fungi, algae, their spores, protozoan cysts, etc.

2) Ozone acts very quickly — within seconds.

3) Ozone removes unpleasant odors and taste.

4) Ozone does not form toxic by-products.

5) Residual ozone is rapidly converted into oxygen.

6) Ozone is produced on site, without requiring storage and transportation.

7) Ozone destroys microorganisms 300-3000 times faster than any other disinfectants.

The main problem of disinfection of wastewater by ozonation is its main advantage - the rate of decay. Due to the high rate of decay in some cases, ozone does not have time to fully oxidize some organic compounds. Also, ozone is an unstable gas, so it is irrational to store and transport it; it is more appropriate to obtain ozone at the point of use, which entails high capital costs. Most often, atmospheric air is passed through the source of a smoldering discharge, in some cases pure oxygen is used. The efficiency of ozone production largely depends not only on the design of the generator, but also on the humidity of the transmitted air.

Ultraviolet disinfection has many advantages over oxidative disinfecting methods (chlorination, ozonation).

Ultraviolet radiation is electromagnetic radiation within wavelengths from 10 to 400 nm. For disinfection, the "near area" is used: 200 - 400 nm (the wavelength of natural ultraviolet radiation at the surface of the earth is more than 290 nm). The greatest bactericidal effect is possessed by electromagnetic radiation at a wavelength of 200 - 315 nm and the maximum manifestation in the region of 260 ± 10 nm. In modern UV devices, radiation with a wavelength of 253.7 nm is used.

The method of UV disinfection has been known since 1910, when the first stations for the treatment of artesian water were built in France and Germany. The bactericidal effect of ultraviolet rays is explained by the photochemical reactions occurring under their influence in the structure of the DNA and RNA molecules, which form the universal information basis of the mechanism of reproducibility of livingorganisms. The result of these reactions is irreversible damage to DNA and RNA. In addition, the action of ultraviolet radiation causes disturbances in the structure of the membranes and cell walls of microorganisms. All this ultimately leads to their death.

The main advantages of ultraviolet disinfection are:

1) UV irradiation is lethal for most aquatic bacteria, viruses, spores.

2) Ultraviolet disinfection occurs due to photochemical reactions inside microorganisms, so the change in water characteristics has a much smaller effect on its effectiveness than when disinfecting with chemical reagents.

3) In the water treated with ultraviolet radiation, toxic and mutagenic compounds that have a negative effect on the biocenosis of water bodies are not detected.

4) Disinfection with ultraviolet radiation is characterized by lower operating costs than with chlorination and, especially, ozonation.

5) There is no need to create warehouses of toxic chlorine-containing reagents that require compliance with special measures of technical and environmental safety, which increases the reliability of water supply and sewerage systems in general.

6) Ultraviolet equipment is compact, requires minimal space, its introduction is possible in the existing technological processes of treatment facilities without stopping them, with minimal volumes of construction and installation work.

7) Ultraviolet does not give the water smell or tastes.

8) The bactericidal plant does not need reagents, it is compact, its operation can be easily automated.

In Russia, the development, production and implementation of UV equipment for wastewater disinfection since the 80s has been engaged in a number of development firms, including NPO LIT (Fig. 2.31).

The experience gained by developers has shown that there are a number of problems. First of all, this is due to the strict requirements of Russian standards for microbiological indicators of wastewater discharged into water bodies. In the course of numerous studies, the company has developed and released into production a wide range of equipment, which is divided into four groups: UDV, UDV Pro, MLP and MLV.

In each of the groups – UDV, UDV Pro, MLP and MLV – UV equipment is divided into series: A, B, E, K, G, F, N – depending on the quality of the treated water, especially its transparency in the UV range. The equipment of each series is most optimally used in the specified ranges of transparency (τ) of the treated water in terms of maximum efficiency of UV radiation use and minimization of head losses.

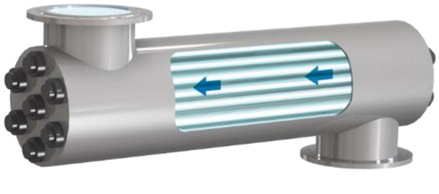


Figure 2.31 - Group of housing (pressure) equipment with the location of lamps along the treated water flow (UDV) of NPO "LIT"

Wastewater that has been pre-treated from pollutants at the treatment facilities through the inlet pipe enters the sealed UV disinfection unit. Inside the decontamination unit are UV lamps with radiation in the ultraviolet range. Their radiation effectively destroys the protoplasm of microorganisms in disinfected water. Disinfected water is directed by gravity into the outlet pipe. During repair work, the drain can be redirected through the bypass, bypassing the UV decontamination unit.

3.Biological wastewater treatment

3.1. General information on biological wastewater treatment

The most widespread method of wastewater treatment is biological, which has been known for more than 100 years. In modern methods of biological purification, in fact, all known metabolic features of microorganisms are used.

After mechanical and possibly physicochemical purification, water is mixed with active sludge, which is a complex community of microorganisms of various systematic groups: bacteria, actinomycetes, protozoa fungi, algae, etc. Mixing is carried out in special structures - aeration tanks, which are open containers of a sufficiently large volume with bubble, mechanical, jet or other type aerators located in them (Fig. 2.32).

Fig. 2.32. General view of the aeration tank

As a result of a sufficiently long contact (for about 10 to 36 hours) of microorganisms with water under air aeration conditions, biodegradation of organic impurities that were not removed at the previous stages of purification occurs.÷

Briefly consider the features of biochemical oxidation of certain substances" in particular, hydrocarbons, alcohols, aldehydes and ketones.

Primary alcohols up to C_{10} are oxidized quite easily, with a number of carbon atoms 16, oxidation is insignificant, and at C_{18} it is almost impossible. Comparing the oxidation state of alcohols with the corresponding alkanes shows that the introduction of an OH group increases the ability to oxidize. Secondary alcohols are oxidized to a lesser extent than primary ones, and the location of the OH group at the third and fourth carbon atom gives almost the same effect, as the second.

Alcohols are oxidized by a variety of bacteria with a predominance in active sludges, usually pseudomonads.

Oxidation of alcohols can occur in different ways, for example:

primary alcohol – aldehyde – acid – $CO_2 + H_2O$

or

secondary alcohol – ketone – acid – $CO_2 + H_2O$.

Aldehydes are oxidized easily, but somewhat worse than the corresponding primary alcohols. The oxidation of C_2 - C_5 aldehydes occurs most easily, with a further increase in the number of carbon atoms, the oxidation state decreases. Formaldehyde is toxic, but when the culture adapts, it can be oxidized. The branching of the carbon chain reduces the ability of aldehydes to biooxidize.

Ketones are more resistant to oxidation than aldehydes, which is due to the nature of the addition of the carbonyl group. It is noted that the introduction of the second carbonyl group makes the substance toxic to microorganisms, and the introduction of the hydroxyl group increases the degree of bio-oxidation.

It should be emphasized that the development of the theory of the relationship between the chemical structure of organic substances and their biological oxidation is just beginning and is passing the stage of accumulation of reliable results of theoretical and experimental research. The complexity of solving the problem is explained by the fact that the patterns reflecting the biochemical decay of various organic substances are due not only to the chemical structure of the substance, but also to other factors, including physicochemical and biological factors.

Biologically purified water is sent further to the sedimentation tanks to separate the activated sludge from the water. At the same time, the amount of microbial biomass of activated sludge increases. Excess activated sludge from the settling tanks enters the processing line of disposal, and the rest of the sludge is returned to the aeration tank.

In biological wastewater treatment, it is important to create aerobic conditions for the functioning of activated sludge microorganisms. In this regard, flotation for the separation of activated sludge microorganisms has a significant advantage over other methods, for example, settling. When separating the biomass of activated sludge from water by flotation, microorganisms continue to be in aerobic conditions. At the same time, biochemical processes occur that contribute to the reutilization of the substrate consumed from wastewater by microorganisms of activated sludge. It is known that the flotation sealing process lasts 1.5 3 hours, sometimes longer. During this period, at least partial subutilization of the substrate occurs. To intensify biochemical processes in the cells of microorganisms of the fleeted activated sludge, an additional amount of air is introduced into the foam layer. As a result, not only an additional amount of oxygen is supplied, but also coalescence of air bubbles occurs, contributing to a change in the multiplicity of the foam. This ultimately reduces its volume and thins the layers of liquid between the air bubbles in the foam layer.÷

Regeneration of activated sludge under foam layer conditions is particularly effective in flotation with ozone or an air mixture enriched with oxygen. In this case, the driving force of mass transfer increases, which also allows to intensify the additionalization of the substrate absorbed by the cells of the microorganisms of the activated sludge.

3.1.1. Basics of biological wastewater treatment from organic nitrogen-containing compounds

Organic nitro compounds are part of explosives, dyes, solvents, have a variety of applications. Nitro compounds are quite difficult to destroy by microorganisms, although the enzyme nitrate reductase, which restores the nitro group, is characteristic not only of bacteria, but also of animals. Destruction of nitro compounds by active sludge is very slow, and the reaction rate is adversely affected by the presence of other nitrogen compounds in the medium. According to C. I. Rogovskaya (1951), microorganisms use trinitrotoluene better as a source of nitrogen than as a source of carbon.

P. I. Gvozdyak and his colleagues studied the processes of restoration of various nitro compounds, aniline derivatives. Some species of genera of bacteria *Pseudomonas* and Bacillus have been shown to be able to use nitrobenzoic acid and nitroaniline as the only source of carbon and nitrogen. The mixture of strains had more destructive activity than individual strains. The destruction of nitro compounds is carried out either by reducing the nitro group to amines, or by cleavage of the nitro group to form nitrites and nitrates. A large group of synthetic nitrogen-containing the compounds are made up of various polyamides, including capron. The main raw materials for the production of polyamides are synthetic organic nitrogen compounds, in particular lactams. The production of lactams produces a large amount of wastewater that requires treatment.

Studies conducted by a number of authors have shown that caprolactam is subject to microbial destruction. For example, caprolactam has been shown to be used by all the studied strains of *the bacteria Bacillus subtilis* and *Bac. mesentericus* without prior adaptation. The same authors obtained active strains that can destroy caprolactam and the toxic compound hexamethylenediamine.

The issues of industrial wastewater treatment with the help of selective cultures of microorganisms are currently being dealt with by researchers both in our country and abroad.

Wastewater treatment from polyamines with the help of a complex of *strains of Pseudomonas* and *Bacillus* was carried out by I. A. Makarov and his colleagues.

V. I. Romanenko and V. 14. Korenkov (1977) used the microorganisms *Vibrio dechloraticans* and *Pseudomonas dechromaticans* isolated by them to treat wastewater containing perchlorates, chromates and dichromates. The process is carried out under anaerobic conditions in the presence of organic substances. Perchlorates, chromates and dichromates served as a source of oxygen for the oxidation of organic compounds, while chlorine was reduced to chlorides, and hexavalent chromium to trivalent.

E. N. Azarowics (1975) proposed a two-stage treatment of oily wastewater, with specific microflora used at each stage.

In addition to the use of specially selected cultures of microorganisms, other possibilities of microbial destruction are being investigated.

In particular, conditions are created to activate the vital activity of the normal microflora of treatment facilities. Thus, A. N. Illyaletdinov (1977) and his colleagues proposed to introduce additional sources of carbon, such as plant residues, into the water of sedimentation ponds of non-ferrous metallurgy enterprises, for example, plant residues, to neutralize industrial effluents containing cyanides. Cyanides at the same time served as a source of nitrogen for heterotrophic microflora**.**

Much attention is also paid by the developers to the study of the possibilities of using enzymes for wastewater treatment. As a source of enzymes, for example, destroyed bacterial cells of microorganisms-destructors and extracts from cells are used. Experiments are carried out to purify wastewater containing fiber, caprolactam and other compounds. These works are still at the stage of experimental research and have no practical application.

3.1.2 Biological treatment facilities. Aeration tanks.

The process of biological purification of pollutants in aeration tanks occurs by direct contact of wastewater with the optimal amount of activated sludge organisms in the presence of an appropriate amount of dissolved oxygen (for the required period of time), followed by the separation of activated sludge from purified water in secondary sedimentation tanks.

The main parameters of the biological treatment process should be interrelated, namely: the volume of aeration tanks, the amount and oxidizability of pollutants in wastewater, the time of contact of wastewater with activated sludge. In addition, the sedimentation properties of activated sludge, which are determined by all of the listed parameters, must correspond to the technological capabilities of the secondary sedimentation tanks used - satisfactorily separate the treated wastewater from the sludge (for the established time spent in them).

Usually, an aeration tank is a rectangular tank through which wastewater mixed with activated sludge flows. Air, introduced by pneumatic or mechanical devices, mixes the treated liquid with active sludge and saturates it with oxygen necessary for the vital activity of bacteria, protozoa and multicellular animals.

The designs of the aeration tanks used are divided according to the method of supplying wastewater and its flow into three main types: displacers (Fig. 2.33) with a "piston" flow of wastewater, mixers with a dispersed or central (Fig. 2.34) supply and discharge of wastewater and aeration tanks of intermediate type (Fig. 2.35).

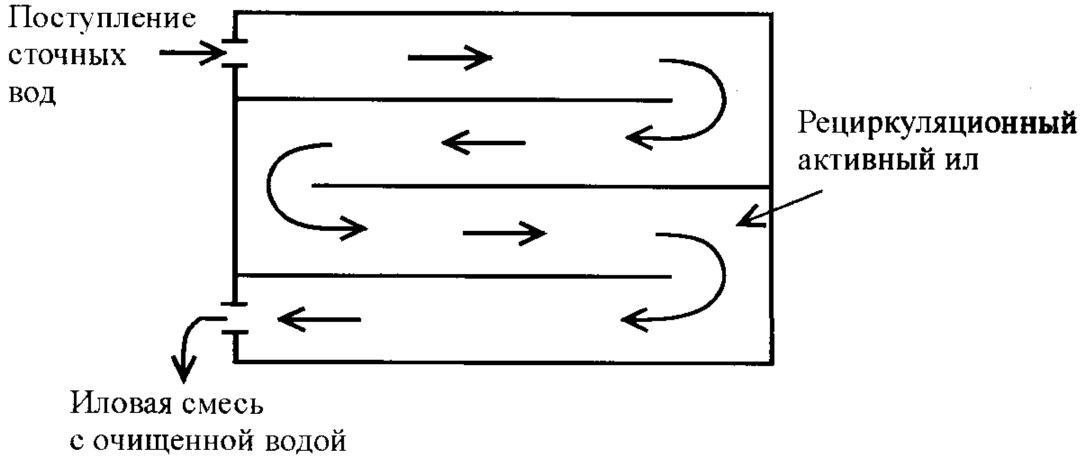


Fig. 2.33. Scheme of wastewater flow in a four-corridor aerotank-displacer.

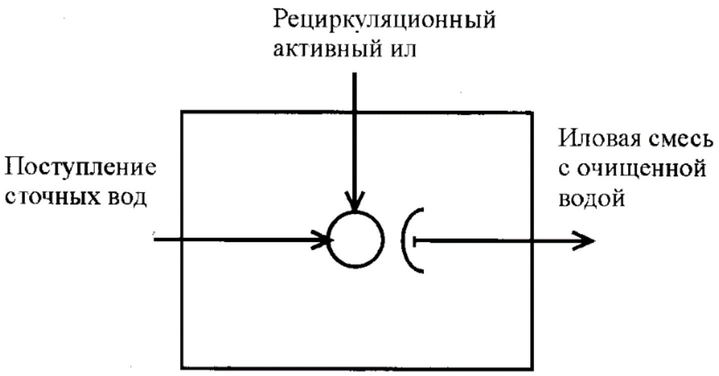


Fig. 2.34. Scheme of the aeration tank-mixer with the central supply of wastewater and silt to the aeration zone.

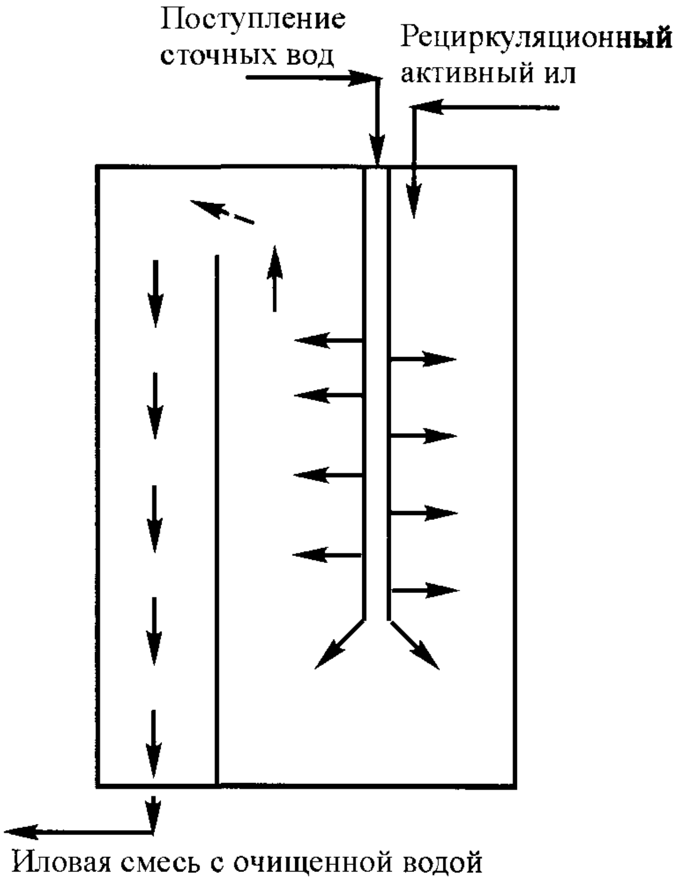


Fig. 2.35. Scheme of wastewater movement in an intermediate type aeration tank: mixer-displacer.

Displacers include one-, two-, etc. corridor aeration tanks, in which the corridors are separated from each other by longitudinal guide partitions that do not reach one of the end walls. At the ends of the aeration tank there are channels for the intake and discharge of wastewater. Depending on the geometric dimensions in these aeration tanks, the condition of complete displacement of the wastewater flow is fulfilled to one degree or another. A feature of the process taking place in aeration tanks-displacers is a change in the concentration of pollutants in wastewater and the speed of purification along the length of the aeration tank. The oxidative process in aeration tanks-displacers occurs unevenly: at the beginning of the aeration tank - faster, and as you approach the end and reduce the amount of substrate - slower.

Aeration tanks-displacers are preferred in the treatment of wastewater of complex composition containing a significant proportion of industrial discharges. In aeration tanks-mixers, complete and rapid mixing of wastewater with the mass of activated sludge is ensured, in the established mode they work at uniform speeds of the treatment process. The preferred use of aerotanks-mixers in the treatment of highly concentrated industrial wastewater, similar in composition to domestic (food plants, beer plants, fish factories), as well as with uneven inflow and frequent volley overloads, was justified by Professor N.A. Bazyakina in. However, when using mixers, there is a threat of swelling of activated sludge, in any case, they are more susceptible to it than other designs of aeration tanks due to high loads on active sludge throughout the entire volume of structures. Aeration tanks of the intermediate type include, for example, corridor aeration tanks with a wastewater supply dispersed along the length and with the intake of activated sludge into the beginning of the corridor.1948 г

Aeration tanks are also divided by type of aeration into aeration tanks with mechanical or most often used in practice pneumatic aeration.

Oxidative organic pollutants in aeration tanks occur due to the vital activity of aerobic microorganisms that form flaky clusters - active sludge. Part of the organic substances continuously coming from wastewater is oxidized, and the other provides an increase in the bacterial mass of activated sludge.

The high saturation of wastewater with activated sludge and the continuous supply of oxygen provide intensive biochemical oxidation of organic substances, so aeration tanks are one of the most advanced facilities for biochemical purification.

3.1.3. Disruption of biological wastewater treatment processes

Our work over several decades to improve the operation of biological treatment plants has shown that in some cases the observed phenomena of fluffing of activated sludge lead to significant consequences, including at the stage of separation of activated sludge from purified water. It should be emphasized, however, that the efficiency and reliability of treatment depend to a large extent on the quality of the deposition step, which is in fact the last link in the treatment chain before discharge into open water sources. Let's take a closer look at this phenomenon.

Active sludge consists of flocculating bacteria, filamentous and free bacteria, as well as various protozoa and multicellular. In the process of functioning of the purification system, a relative biological equilibrium is established, when the density of free bacteria is minimized by two mechanisms - flocculation and predation of protozoa and multicellular, while flocculating bacteria are the main competitors of filamentous bacteria.

The main reasons for the growth of filamentous bacteria responsible for swelling and foaming are a deficiency of the nutrient substrate and an excess of certain chemicals, for example, sulfides that promote the growth of filamentous bacteria such as *Thiothrix spp* and *Beggiatoa sp*).

An important role is played by the age of active sludge **-** an increased age contributes to the growth of actinomycetes, especially *Nocardioformes*.

Bacteria can develop in three types of growth:

Dispersed growth: Dispersed bacteria in the intercellular fluid at the start of the purification station and under conditions of high weight load. New cells can disperse or remain within colonies structured with exopolysaccharide mucus.

Flocculated growth: Bacteria combine into aggregates around an organic or mineral carrier. Coalescence is produced by exopolysaccharides. This type of growth is most common in the implementation of the wastewater treatment process.

Filamentous growth: This type of growth results in filaments up to 500 µm in length. Environmental conditions are the determining factor in this type of growth.

The main problems of disruption of the functioning of treatment facilities are associated with the presence of high concentrations of filamentous bacteria. Dysfunction of structures manifests itself in two forms:

- poor sedimentation of activated sludge caused by an increase in the volume occupied by bacteria;

- foaming (a thick layer of foam on the surface of structures).

An excess of filamentous bacteria leads to the swelling of activated sludge, which is characterized by an increase in the silt index of activated sludge. The development of filamentous microorganisms greatly limits the hydraulic potential of the secondary sedimentation tank and can lead to the release of activated sludge into the natural environment.

In treatment plants, the swelling of activated sludge is often associated with a deterioration in the quality of the treated effluent and the formation of foam.

Foams are floating substances, very stable with a viscous structure from light to dark brown in color. Their density tends to increase gradually over time.

Foams are weakly destroyed by surface mixing and quickly restored in the absence of mixing. Microscopic analysis of the foam reveals the presence of filamentous bacteria associated with the flocules or floating freely in the water. Generally, the density of these microorganisms is slightly higher in foam samples than in samples taken directly in activated sludge.

Practice shows that foams can make up to 1/3 of the total biomass with a high concentration of dry matter and a thickness of more than one meter.

A reliable and stable state of activated sludge requires compliance with three conditions: compliance with nominal pollution loads, providing microorganisms with the necessary amount of dissolved oxygen, and eliminating external toxic effects on activated sludge.

To obtain a high cleaning efficiency, it is most preferable to combine various methods of combating foam.

Among the main types of foam treatment, the following should be highlighted:

biological, which limit the development of filamentous bacteria in the active sludge and thus reduce the likelihood of foam formation;

- chemical, consisting in the addition of chemical reagents (iron or aluminum salts) to the medium, which, although they cannot prevent the development of filamentous bacteria, but allow them to be maintained in a bound form in floccules;

- Chlorination of active sludges (or foams), the principle of which is to destroy microflora by oxidation of filamentous bacteria responsible for foaming.

Biological methods to combat foaming require the identification of microorganisms responsible for the implementation of this process.

Studies have shown that for a biological solution to the problem of defoganization, it is imperative to limit the growth of filamentous microorganisms.

The presence of filamentous microorganisms may be associated, among other things, with a state of fermentation or with a noticeable imbalance in the nutrient medium.

The following measures can be considered as measures to combat foaming at treatment plants:

- restriction of the intake of fats and other lipids, the intake of decaying wastewater, - limiting the periods of prolonged shutdown of aerators (aeration tanks),

- restriction on the duration of stay in the anoxid zones,

- Restriction on the duration of sludge and activated sludge in primary and secondary sedimentation tanks.

The mechanism of foam formation is as follows.

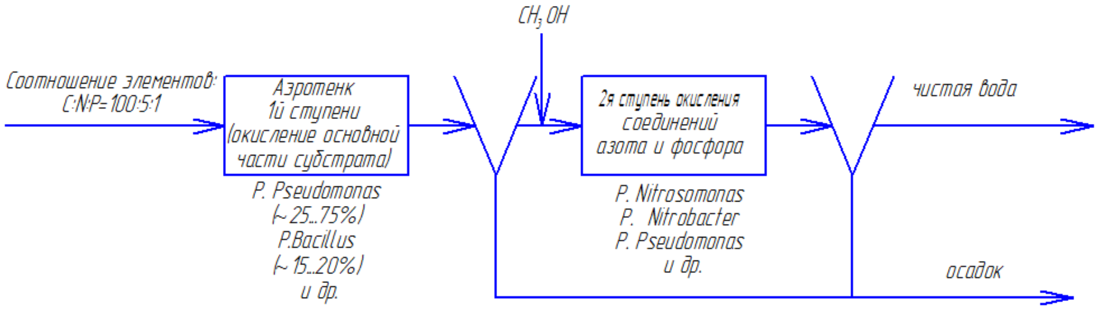
Factors controlling the processes of foaming are the return of activated sludge from the seal, aeration adjustment, active sludge management, the length of sewage networks, the presence of dead zones, malfunctions of the grease trap.

Chemical methods of combating foaming are associated with the use of reagents containing iron, aluminum, chlorine, and other substances. We often used and gave effect to the method of increasing the pH of the sludge mixture, which in some cases, along with other methods, led to the inhibition of filamentous bacteria, and, consequently, to the improvement of the water purification process.

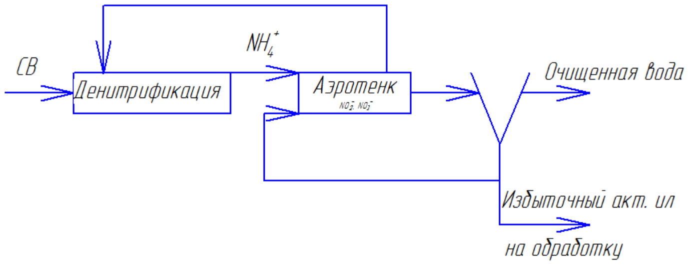
3.1.4. Wastewater treatment from biogenic elements

Treatment of nutrients is dictated by the need to discharge treated wastewater without exceeding the concentration of nitrogen and phosphorus compounds.

There are 2 main technological schemes for the treatment of wastewater from biogenic elements (Fig. 2.36).



(A)



B)

Fig. 2.36. Schematic technological schemes for the removal of biogenic elements:

To carry out the process of denitrification (conversion of nitrites and nitrates into molecular nitrogen), it is necessary to create appropriate conditions in the denitrification chamber:

- the presence of nitrites and nitrates (NO-2, NO-3);

- the presence of nitrifying microorganisms (Nitrosomonas, Nitrobacter, etc.);

- Creation of anaerobic conditions.

In the case of high concentrations of ammonium nitrogen in the starting water (especially when the concentrations of ammonium nitrogen and biologically oxidizable organics are commensurate), the removal of nitrogen compounds should be carried out prior to biological treatment using physicochemical methods.

To intensify the denitrification process, various mixing devices are used:

agitators;

pneumatic systems in the form of large-bubble aeration;

due to flow regeneration, etc.

In the case of mixed conditions (i.e. oxid and anaerobic zones), the processes of denitrification and biological removal of phosphorus can occur simultaneously.

It should be noted that biological nitri-denitrification technology is a common method for removing nitrogen from wastewater.

In general, it should be noted a fairly large variety of technological schemes for biological wastewater treatment, for example, presented in Fig. 2.37 a - 2.37 b.

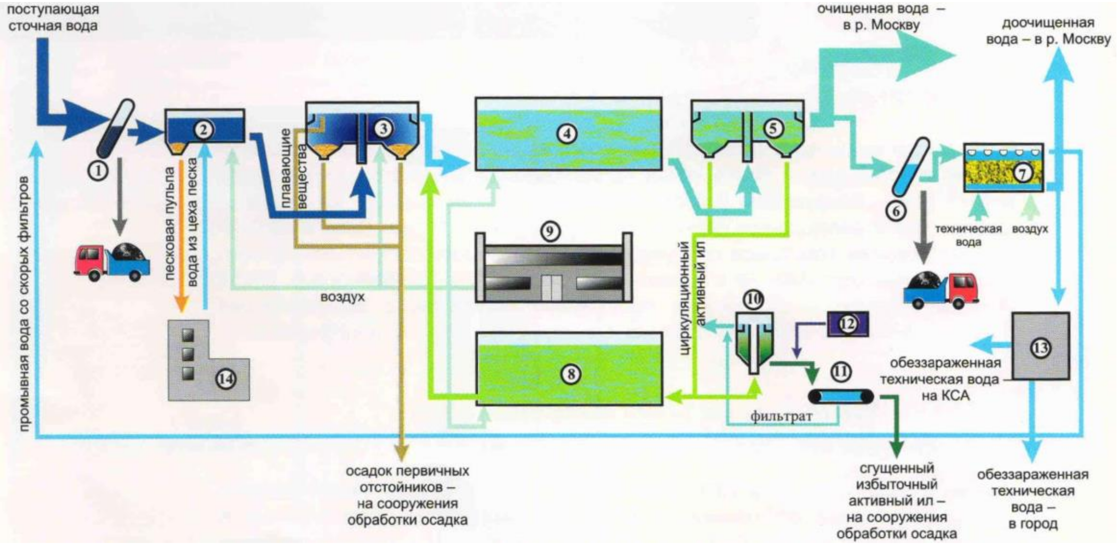


Fig.2.37 a. Scheme of wastewater treatment at a modern aeration station

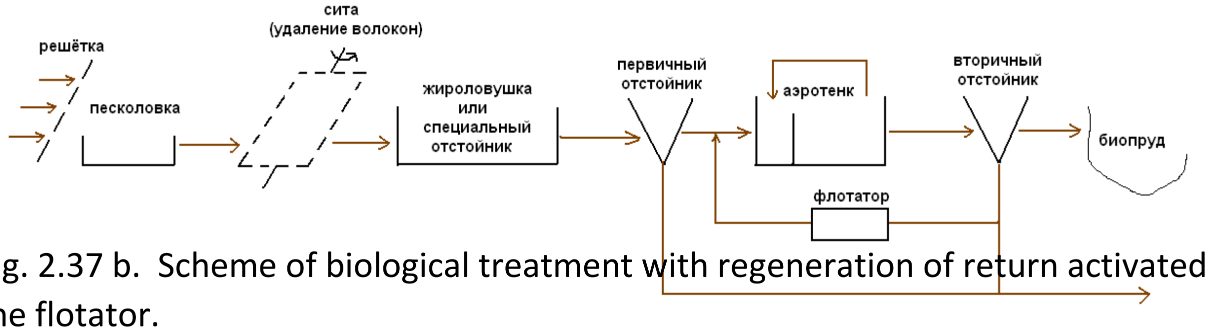


Fig. 2.37 b. Scheme of biological treatment with regeneration of return activated sludge in the flotator.

In biological wastewater treatment, it is important to create aerobic conditions for the functioning of activated sludge microorganisms. In this regard, flotation for the separation of activated sludge microorganisms has a significant advantage over other methods, for example, settling. When separating the biomass of activated sludge from water by flotation, microorganisms continue to be in aerobic conditions. At the same time, biochemical processes occur that contribute to the reutilization of the substrate consumed from wastewater by microorganisms of activated sludge. It is known that the process of compaction of activated sludge by pressure flotation can last 1.5 - 3 hours, and sometimes longer. In this case, flotation technology is used according to the usual standard scheme (Fig. 2.38).

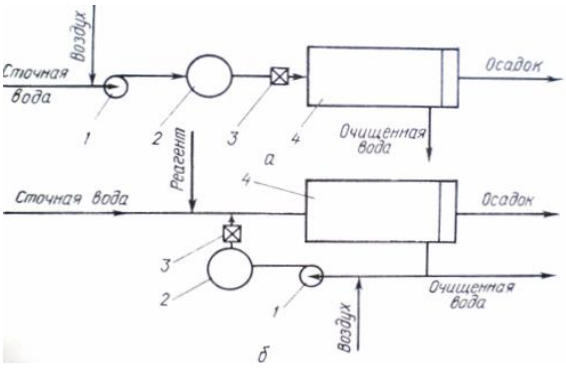


Fig. 2.38. Typical scheme of flotation technology

Depending on how the supersaturation of the water-air solution is created, pressure flotation can be carried out according to option a or b (Fig. 2.38).

Pressure flotation technology is carried out in several stages: the introduction of air into wastewater; dissolution of gas in wastewater; reduction of fluid pressure; isolation of air bubbles from water and formation of fleet complexes; separation of flotation complexes from water with the formation of foam on the surface of the liquid; removal of foam from the surface of the liquid. In the practice of wastewater treatment, pressure flotation units are common both with the saturation of the entire flow of purified wastewater with air (Fig. 18, a) and with the saturation of part of the purified water (20-50%) with air and mixing it with wastewater entering the treatment, i.e. with the recirculation of part of the purified liquid (Fig. 18, b). The latter scheme is used in the intensification of flotation treatment by pre-treatment of water with coagulants.

During flotation thickening of activated sludge, at least partial subutilization of the substrate occurs. To intensify biochemical processes in the cells of microorganisms of the fleeted activated sludge, an additional amount of air is introduced into the foam layer. As a result, not only an additional amount of oxygen is supplied, but also coalescence of air bubbles occurs, contributing to a change in the multiplicity of the foam. This ultimately reduces its volume and thins the layers of liquid between the air bubbles in the foam layer. Regeneration of activated sludge under foam layer conditions is particularly effective in flotation with ozone or an air mixture enriched with oxygen. In this case, the driving force of mass transfer increases, which also allows to intensify the additionalization of the substrate absorbed by the cells of the microorganisms of the activated sludge.

Biological treatment facilities in natural conditions are divided into filtration fields and biological ponds. In filtration fields, wastewater passes through a layer of soil containing a large number of aerobic bacteria that receive oxygen from the air. In the process of filtration through the soil layer, organic contaminants of wastewater are retained in it. This forms a biological film with a large number of microorganisms of various species. Organic substances detained on biofilm are oxidized by aerobic microorganisms to mineral compounds. These processes occur most intensively in the soil at a depth of approximately 0.1... 0.4 m. As a result of biochemical processes, carbon of organic substances is converted into carbon dioxide, and nitrogen of ammonium salts is converted into nitrates and nitrites.

In artificial conditions, aeration tanks are most often used, as well as biofilters. Usually, an aeration tank is a large reservoir of rectangular cross-section, through which wastewater slowly flows along with active sludge. With the help of pneumatic or mechanical devices, a mixture of water and activated sludge is bubbled with air, saturating it with oxygen. All this ensures intensive oxidation of organic substances. The process of wastewater treatment in an aeration tank can be divided into three stages:

- at the first stage, adsorption of contaminants and their oxidation occurs;
- in the second step, hard-to-oxidize contaminants are oxidized;
- In the third stage, the process of bottling wastewater takes place.

The speed of movement is selected on the basis of the time of stay of wastewater in the aeration tank of about 6 - 30 hours, depending on the required degree of treatment. The process of wastewater treatment in an aeration tank can be divided into three stages. After mixing wastewater with activated sludge on the surface of its microorganisms, the adsorption of contaminants and their oxidation occurs. In the first stage for 1... 3 hours biological oxygen consumption (BOD) of wastewater is reduced by 50... 75%. In the second step, hard-to-oxidize contaminants are oxidized. The rate of oxygen consumption at this stage is less than at the first.

The purified water from the aeration tanks is sent to a secondary sump, so called because before the aeration tank, the water is purified in the primary sump. In the secondary settling tank, the active sludge is separated from the water due to the precipitation of its microorganisms in the form of flakes. It should be noted that in the process of oxidation of organic substances, aerobic microorganisms multiply, and the biomass of activated sludge (or, as it is sometimes called, microbial biomass) increases. Therefore, part of the activated sludge is returned to the aeration tank (circulating active sludge), and part (excess active sludge) is sent for dehydration. It would seem that a simple matter is to remove water from the biomass of activated sludge. However, this technological step is currently not fully resolved, although there are several ways to dehydrate the sludge sludge.

Of interest is the process of bubbling wastewater. When aerating water in large-volume structures, this is very important: it is necessary to disperse the air to the smallest bubbles and that the bubble is evenly carried out throughout the volume of the liquid, and it is possible to supply a sufficiently large amount of air through porous pipes or other devices serving for this.

Consider the mechanism of starting the aeration tank. It is filled with water, which is bubbled with air through the devices discussed earlier. Next, a certain amount of activated sludge is added to the water. In this case, you can use ready-made active sludge from normally working aeration tanks, and you can get active sludge from river or pond silt that is not contaminated with oil products. This sludge is freed from heavy mineral impurities by settling before use in the aeration tank, then aerated and sent to the aeration tank.

In a normally working aeration tank, active sludge includes, in addition to zooglean accumulations of bacteria, in a small amount of infusoria, rotifers, worms. In violation of the normal operating conditions of the aeration tank, filamentous bacteria, branching zooglea, aquatic fungi, etc. Microorganisms cause the so-called swelling of active sludge, which is why the sludge settles very poorly when settling.

The causes of sludge swelling are overloading of aeration tanks with pollution, the presence of a large amount of carbohydrates in the initial wastewater, insufficient air supply, low pH of water in the aeration tank. To combat this phenomenon, reduce the load of pollutants on the aeration tank or increase the amount of air supplied, or temporarily increase the pH to 8.5¸ 9.5 and use other technological techniques.

In the initial period of development of the use of biological methods, the requirements for the quality of wastewater treatment were reduced to achieving a concentration of BOD$_{\text{full}}$ and suspended substances (EXPLOSIVE) at the outlet of treatment facilities in the range of 15-20 mg / l, as well as a certain degree of disinfection. Currently, the requirements for the quality of treatment have increased dramatically. Since the treated wastewater somehow enters the water body, which in the conditions of Russia is almost always interpreted as fishery, the values of BOD$_{\text{N}}$ and BB should be at a level of no more than 3 mg / l. In addition, there were quite strict requirements for the concentration of biogenic elements: ammonium nitrogen, nitrogen of nitrites and nitrates, as well as for the concentration of phosphorus. In addition to these basic indicators, certain requirements for the concentration of petroleum products, synthetic surfactants, heavy metals, etc.

To achieve the indicators of the requirements of fishery reservoirs, it is necessary to separate post-treatment in the composition of granular filters and adsorber filters, which significantly increases the capital and operating costs of treatment facilities and the area occupied by them with high wastewater consumption. In addition, when used as a device for separating the silt mixture of the settling tank, there is a significant removal of activated sludge from the aeration tank and even further from the settling tank. To eliminate the mentioned shortcomings of traditional circuits, the use of membrane microfilters as the final stage of purification is promising.

Initially, the use of membranes in wastewater treatment schemes was limited to post-treatment. Ultrafiltration, microfiltration or reverse osmosis plants were used under very strict discharge requirements or when direct water reuse was necessary. High capital and operating costs and insufficient knowledge of membrane applications in water treatment have been the predominant factors in limiting the scope of these technologies. However, with the advent of less expensive and more efficient membrane modules and the tightening of requirements for the discharge of purified water, interest in membrane systems has increased.

The development of membrane technologies has come from their use exclusively for tertiary wastewater treatment to direct integration into systems with activated sludge - membrane bioreactors (ICBMs). In Fig. Figure 2.39 illustrates the evolution of the incorporation of membrane technologies into biological treatment processes.

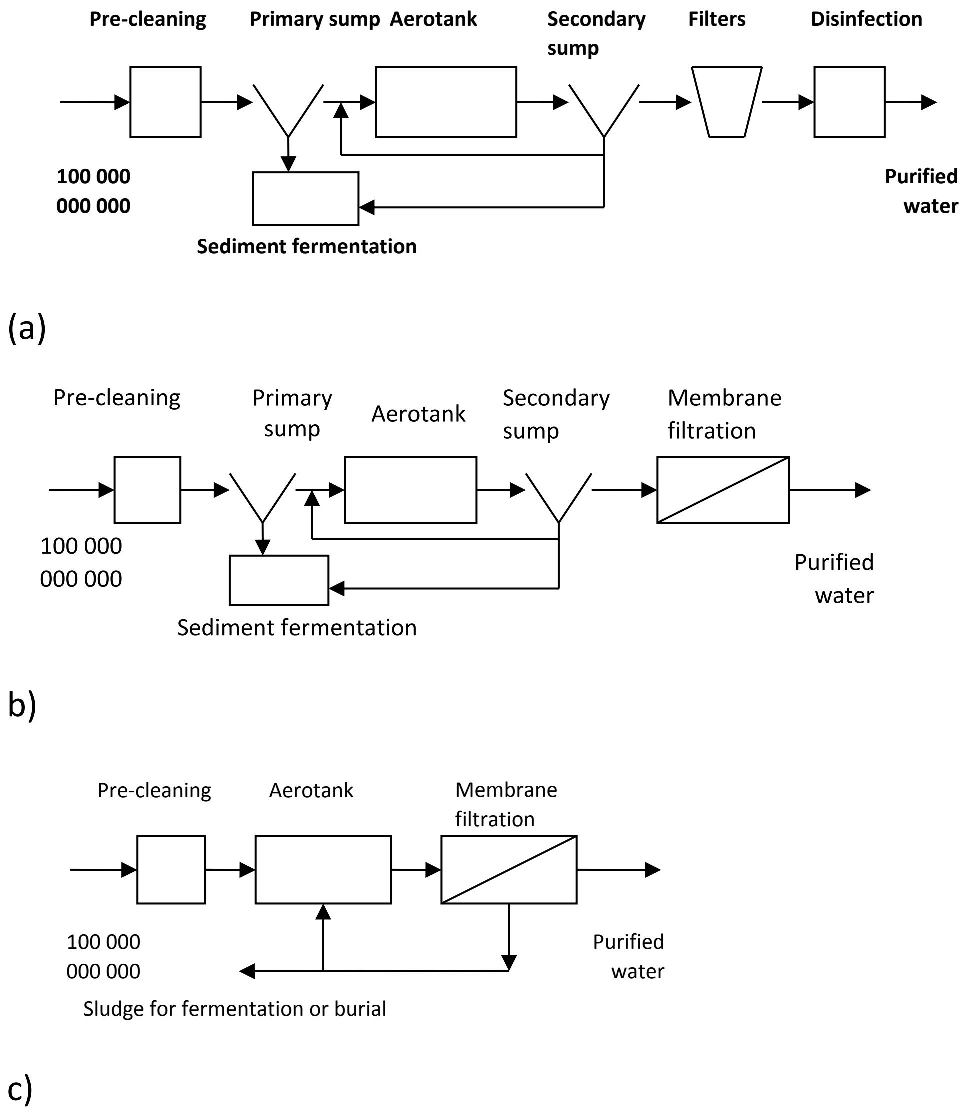


Fig. 2.39. Evolution of the introduction of membrane technologies in the processes of biological purification.

In Fig. Fig. 2.39, and the traditional scheme of biological wastewater treatment is presented. At the first stage (Fig. 2.39, b), the membranes were used as an element of post-treatment of wastewater after the secondary settling tank. Depending on the type of membranes used, they ensured the removal of suspended solids and part of the colloidal compounds from the water. At the same time, they did not exert any influence on the parameters of the biological reactor.

At the present stage (Fig. 2.39, c), membrane separation is integrated directly into the biological treatment process instead of secondary sedimentation tanks, being a direct element of the purification technology and significantly affecting the parameters and conditions of the biocenosis.

Membrane bioreactors have a number of advantages that make them a serious alternative to other cleaning methods. First of all, it is the retention of all suspended substances and part of the soluble components of wastewater in the bioreactor, which ensures a very high quality of purified water, meeting the most stringent requirements for discharge or directly for reuse. The ability to apprehend bacteria and viruses ensures the relative sterility of the outgoing water, the simplification of final disinfection systems and the elimination of related hazards associated with the by-products of decontamination. The retention of suspended particles of the source water in the bioreactor makes it possible to prolong the contact of organic contaminants, including hard-to-oxidize ones, with microorganisms until they are completely subjected to biological destruction. In traditional schemes, these particles are leached out of the bioreactor along with part of the activated sludge.

Hybrid systems using ICBM are highly resistant to fluctuations in source water concentrations due to the good adaptation of biocenoses. The disadvantages of hybrid membrane systems were mainly due to economic reasons. The system was characterized by high capital costs due to the high cost of membranes and energy costs to overcome the pressure gradient. Concentration polarization and other membrane contamination problems can lead to frequent membrane cleaning, which stops work and requires clean water and reagents. Because ICBM trap all suspended solids and a significant portion of soluble organic matter, excess active sludge can have poor precipitation and filterability. In addition, when working with a large age of activated sludge, the inorganic components accumulating in the bioreactor can reach concentration levels that can have a negative effect on the microbial population or on membrane structures. These problems are widely covered in the literature, but there is no consensus on the degree of their influence on the parameters of the IDB.

In membrane installations, microfiltration membranes with a pore size of 0.075-0.3 µm are mainly used, which makes it possible to separate suspended substances larger than 0.45 µm, bacteria, cysts, etc. According to a number of developers, including ours, these installations will become widespread in practice by achieving high cleaning efficiency.

3.1.5 Wastewater treatment using immobilized microorganisms

Technological possibilities for improving the efficiency of biological treatment plants are rather limited. In this regard, the development of methods for intensifying purification processes based on the use of highly efficient microorganisms-destructors is of paramount importance. The development of microbiological bases for the treatment of industrial wastewater confirmed the idea of the possibility of replacing activated sludge and biofilm of treatment facilities with clean cultures not only in the laboratory, but also in production conditions.

To ensure thorough and reliable purification of treated water at a significant flow rate, it is necessary to retain a significant biomass of destructor microorganisms in the treatment plant, and this can be achieved by immobilizing microorganisms on the carrier (Table 2.15).

Attached organisms are more resistant to the action of toxicants, multiply faster than in suspension, and are characterized by increased metabolic activity.

Table 2.15 - Possibilities of wastewater treatment with immobilized destructor microorganisms

Contaminants	Microorganism	Carrier
Hexamethyleneamine	Bacilius subtilis	Fiberglass, clay minerals
Dyes	Pseudomonas sp.	Charcoal, mussel flaps, sea sand
Aromatic hydrocarbons, heterocyclic amines, phenol-containing effluents of metallurgical plants	Pseudomonas sp., Trichosporon cutaneum., активный ил	Fiberglass ruffs, glass beads
Surfactants, dyes, morpholine-containing effluents	Pseudomonas sp., Bacilius subtilis	Fiberglass ruffs, natural materials fiber

Ethylketone, ethyl acetate, propionic aldehyde, crotonaldehyde, acetaldehyde, styrene	Pseudomonas fuorescens, Bacilius subtilis	Activated carbon Foam rubber, fiberglass, glass beads, glass flares
Caprolactam	Achromobacter guttatus	Inclusion in PAAG, collagen
Fatty acids	Alkaligenes sp.	Zeolite
Naphthalene-2-sulfonate	Pseudomonas sp.	Sand
Phenol	Candida tropicalis	Inclusion in Ca-alginate, polystyrene-based gels, PAAG, adsorption on activated carbon
Benzene	Pseudomonas putida	Inclusion in PAAG, Sa-alginate
B-Methylstyrol	P. aerugenosa	Sa-alginat
Crotonaldehyde, acetaldehyde, ethanol, butanol, ethyl acetate, vinyl butyl ether	B. coagulans, B. alcaligens	Cell flocks (flocculant - latex of divinylstyrene type)

The biomass of the destructor microorganisms is grown in advance and the highly concentrated suspension is put into contact with the inert material so that immobilization occurs. As an organic substance for the nutrition of microorganisms, you can use a xenobiotic that has undergone decomposition, but more often growth on such a substrate is slow, therefore, for the rapid accumulation of biomass, media with an easily accessible source of carbon are used.

The use of bioreactors with highly active destructor bacteria fixed on the carrier makes it possible to effectively purify industrial wastewater characterized by a different composition and concentration of pollutants. Here, the most acceptable is immobilization by the method of adsorption and aggregation. Organic and inorganic carriers can be used as adsorbents - various polymers, ceramics, clay and others, large-porous carriers have attracted special attention in recent years.

Microbiological treatment is economical, does not require large capital and operating costs, local treatment plants occupy small areas, are simple and reliable to maintain.

A crucial step in ensuring the operation of the reactor with fixed microorganisms is the choice of the carrier. The carrier for immobilization should be easily permeable and able to protect microorganisms from mechanical, aero- and hydrodynamic influences, sudden changes in pH, temperature, concentration of pollutants. In the practice of microbial water purification, nozzles of the "via" type and glassmakers have found wide application as carriers of microorganisms. Recently, new polymer carriers of microorganisms have been developed. Among them, of particular interest are materials in the form of form-resistant fibrous non-woven elements, which are made by pneumatic spraying melts of thermoplastic polymers.

Wastewater treatment from petroleum products.

Microorganisms capable of consuming diesel fuel as the only source of carbon are widespread in the environment. Strains of Acinetobacter sp. HB-1 and Mycobacterium sp. MCC B 65-B oxidize 55% and 4506% of diesel fuel (1%) for 14 days, respectively, and Mycobacterium flavescens EX-91 - 45% for 7 days. The maximum oxidation state of diesel fuel (1%), equal to 95%, reaching the strains Arthrobacter oxydans As-1838D and Pseudomonas B-2443 on the fourth day. Cultures Arthrobacter globiformis VKPM S-1551 and Rhodococcus eritropolis VKPM S 1550 utilize diesel fuel (0.5%) by 99% at a flow rate of 0.29 - 0.33 $^{h-1}$. The ability of cells of the Rhodococcus opacus 31 KR strain to adsorb on a capron carrier and a fibrous polymeric material has also been studied. Rodococcus is well sorbed on the surface of both carriers. However, the fibrous polymeric material is seeded with microorganisms preferably than the kapron carrier "viya". This is A significant advantage of the fibrous polymer material over the carrier of "via" is that the structure of the fibrous polymer material, along with the significant porosity and specific surface area present to it, provides immobilized cells of microorganisms with protection from hydro- and aerodynamic loads. This is due to the liquid of a fibrous polymeric material consisting of fibers cohesively fastened together at the points of contact.

It was found that water contaminated with diesel fuel, in conditions of intensive air supply, is purified by immobilized microorganisms-destructors at a dilution rate of 0.30 $^{h-1}$ with a COD purification efficiency of 76.9% (Table 2.16). Diesel fuel is oxidized by 98%. With an increase in the flow rate of model wastewater to 0.45 and 0.8 l / h, the oxidation efficiency of the pollutant decreases to 91.4% and 78.1%, respectively.

Table 2.16 - Oxidation of diesel fuel in water by destructor microorganisms immobilized on a fibrous polymer material

Diesel fuel concentration, mg/l	COD, mgO_2/l	Flow rate, l/h	Dilution rate, $^{h-1}$	Efficiency of oxidation of diesel fuel, %	COD cleaning efficiency, %			
Source water	Purified water	Source water	Purified water					
1625	32,5	511,0	118,0	0,28	0,30	98,0	76,9	
	140,0		165,0	0,45	0,45	91,4	67,7	
	355,0		212,0	0,80	0,80	78,1	58,5	

One way to remove hydrocarbons from wastewater is to use microorganisms that can use oil and petroleum products as a source of carbon and energy. Among the methods of biological purification of oil-contaminated waters, preference is given to microbial associations (biocenoses) or specialized, adapted to a certain composition of chemical contaminants, cultures of microorganisms. The efficiency of water purification from oil and petroleum products increases with the immobilization of microorganisms. Accumulative cultures of microorganisms consist of 3-4 types of bacteria. Most of the isolated monocultures on media with oil, paraffins and hexadecan are less active in using these substrates compared to the associations from which monocultures were isolated.

An important and essential factor for the immobilization of cells in the cultivation of strains is the formation of a homogeneous cell suspension. But often conglomerates of cells can form, partial or complete flotation can be observed.

Strains of A. calcoaceticus K-4, N. vaceinii K-8, R. erythropolis EK-1 are able to grow and multiply in the presence of ceramsite. At the same time, there is both an increase in the maximum specific rate of bacterial growth and an increase in the level of biomass. After growing bacteria in the presence of claydite, the amount of residual oil in wastewater is 20−35%, and without claydite – 40−55%. At the same time, the level of biomass does not change much. The decrease in the oil content in versions with ceramsite is due to the adsorption of oil on it.

The use of bacterial cultures to clean up oil contaminants is often effective only when mineral food sources are added. Thus, when nitrogen, phosphorus and potassium are introduced into the places of oil pollution, the process of oil biodegradation is accelerated. Additional application of phosphates is accompanied by a significant increase in oil consumption. Adding 0.1% of diammonium phosphate to oil-contaminated water results in a decrease in the oil content after purification. At the same time, the cleaning efficiency is 99.5%.

With an increase in the initial oil content in the water from 100 to 250 mg / l, the purification efficiency of the N. vaceinii K-8 strain immobilized on claydite decreases and is no more than 90%, while for the R. erythropolis strain EC-1 practically does not change and remains at the level of 99.5% (at a high water supply rate of 0.68 l / min. and under low aeration conditions - up to 0.1 liters of air per 1 liter of water per min.) [5].

All microorganisms are able to extract 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.

3.2. Examples of the functioning of modern biological treatment facilities

3.2.1 Wastewater treatment plants in Moscow

Lyuberets treatment facilities (LTF) with a capacity of **3 millionm^3 / day**, which are the largest in Europe, provide reception and treatment of household and industrial wastewater of the North-Western, North-Eastern and Eastern districts of the city of Moscow, as well as the cities of the forest park zone: Khimki, Dolgoprudny, Mytishchi, Balashikha, Reutovo, Zheleznodorozhny, Lyubertsy.

Lyuberets treatment plants operate according to the traditional technological scheme of complete biological treatment: the first stage is mechanical purification, including filtering water on grates, capturing mineral impurities in sand traps and settling water in primary sedimentation tanks; the second stage is biological water purification in aeration tanks and secondary sedimentation tanks (Fig. 2.40). The processes occurring here are similar to the processes of self-purification in natural reservoirs - rivers and lakes, but the speed of the processes is greatly increased thanks to specially developed technologies.

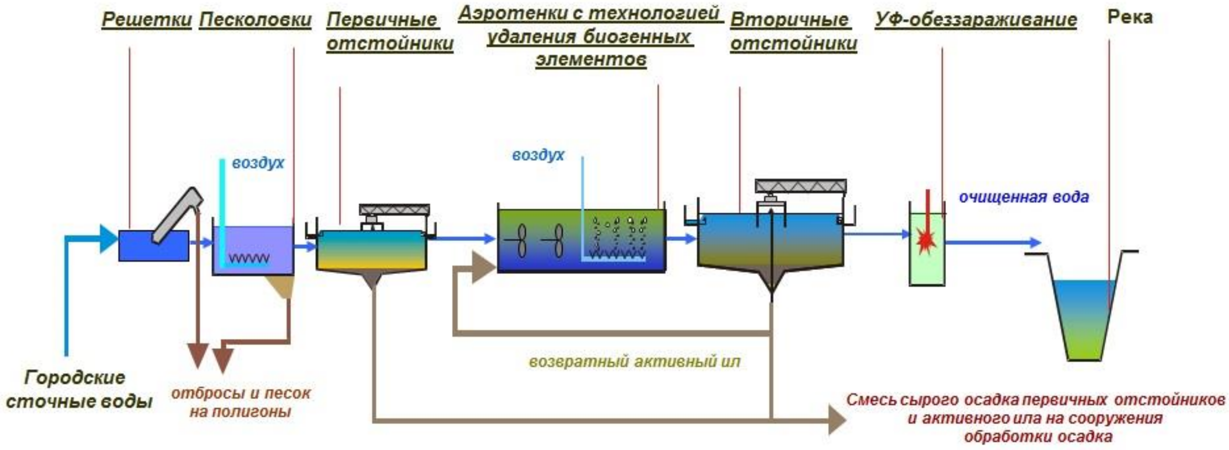


Fig. 2.40 - Scheme of wastewater treatment at Lyuberets wastewater treatment plants

The LTF complex includes 3 independently functioning wastewater treatment units: the Staraya Station (LTF station) with a design capacity of 1.50 million^{m3} per day, the I block of the Novolyuberetsky wastewater treatment facilities (NWTF-1) - 1 million m3 per day and the II block of the Novolyuberetsky treatment facilities (NWTF-2) - 500 thousand m3 per day.

A feature of the VOC is the biogenic element removal unit commissioned in 2006, where nitrogen and phosphorus are deeply removed. In addition, in 2007, ultraviolet disinfection facilities with a capacity of 1 million^{m3} / day of treated wastewater were put into operation.

With wastewater, a large number of different types of garbage enter the LTF: household items of citizens, garbage of food production, plastic containers and plastic bags, as well as construction and other garbage. To remove them on LTF, two types of mechanized lattices with gaps of 5 and 6 mm are used.

The second stage of mechanical wastewater treatment is sand traps - structures that serve to remove mineral impurities contained in the incoming water. Mineral contaminants in wastewater include: sand, clay particles, solutions of mineral salts, mineral oils.

After passing the first two stages of mechanical treatment, wastewater enters the primary sedimentation tanks designed for the deposition of undissolved impurities from wastewater. Structurally, all primary sedimentation tanks on LTF of open type and have a radial shape, with different diameters - 40 and 54 m.

Clarified wastewater after the primary sedimentation tanks is subjected to complete biological treatment in aeration tanks. Aeration tanks **are** open reinforced concrete structures of rectangular shape, 2, 4 corridor type. Biological wastewater treatment is carried out with the help of activated sludge with forced air supply.

The silt mixture from the aeration tanks enters the secondary sedimentation tanks, where the process of separation of the activated sludge from the purified water takes place. Secondary sumps are structurally similar to primary sumps. Sediments formed at various stages of wastewater treatment are delivered to a single sludge treatment complex.

A mixture of raw sediment of primary sedimentation tanks and compacted activated sludge enters the methane tanks, where it is stabilized and neutralized in thermophilic mode at a temperature of 50-55 ° C. The fermented sludge is then washed and compacted in radial sludge compactors. Further, the washed and dehydrated sediment enters the chamber membrane filter presses and centrifuges for dewatering the sludge using flocculants. The formed sediment - "kek" with a humidity of 73% by road is taken to landfills.

3.2.2 Use of membranes in biological wastewater treatment processes

The use of membrane technologies can reduce the area of treatment facilities by 70%, while the efficiency of cleaning increases significantly. With the use of membrane filtration and the abandonment of secondary settling tanks, problems such as floating substances and sludge removal disappear. Existing primary and secondary sedimentation tanks can be converted into buffer tanks.

Thanks to the purification on the membranes, all bacteria and almost all viruses are removed from the effluents, and the quality of the purified filtrate allows the purified water to be reused as industrial water (for example, for irrigation). By retrofitting subsequent purification steps, the filtrate can be purified to the quality of drinking water.

For the first time, ICBM technology was discovered by Dorr-Oliver Inc. (today Eimco Water Technologies Pty Ltd.), which in 1966 was the first to produce flat-frame membrane modules located outside the bioreactor.

The membrane bioreactor combines biological treatment with activated sludge with mechanical membrane filtration (Figure 2.41). The membrane module is used to separate the sludge mixture and is an alternative to the widely used method of deposition of activated sludge in secondary sedimentation tanks, used in traditional biological treatment systems in aeration tanks.

There are two types of bioreactors:

1. with the internal location of the membrane: membranes immersed in purified water are an integral part of the biological reactor;
2. external arrangement of membranes: the membranes are separated from the process tanks and require the installation of intermediate pumps.

The action of the bioreactor is based on the synthesis of biotechnology and technology for the separation of aqueous suspensions on ultrafiltration polymer membranes.

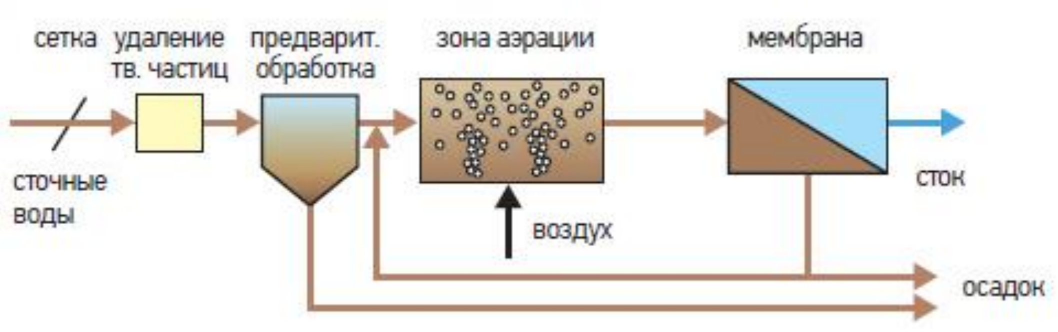


Fig.2.41 - Scheme of wastewater treatment using a membrane reactor

The membrane bioreactor system consists of an aeration tank and a membrane module equipped with hollow-fiber ultrafiltration or microfiltration membranes. Treated wastewater enters the aeration tank. The sludge mixture in the aeration tank circulates through the membrane module. Ultrafiltration membranes are used for treated wastewater. Aerotank in the membrane bioreactor system works with a high concentration of activated sludge, so its dimensions are 2-3 times smaller than the size of a classic flowing aeration tank.

The membrane module consists of 10-20 cassettes with membranes. Each cassette contains from 5 to 15 bundles of membrane fibers. The hollow fiber membrane is a hollow filament with an outer diameter of about 2 mm and a length of up to 2 m. The surface of the filament is an ultrafiltration membrane with a pore size of 0.03–0.1 μm.

Each bundle consists of 100–1000 membrane fibers and is equipped with a common filtrate outlet branch pipe (Fig. 2.42). Such a small pore size is a physical barrier to the penetration of activated sludge organisms having a size of more than 0.5 μm, which makes it possible to completely separate the active sludge from the wastewater and reduce the concentration of suspended solids in the purified water to 1 mg / l or less.

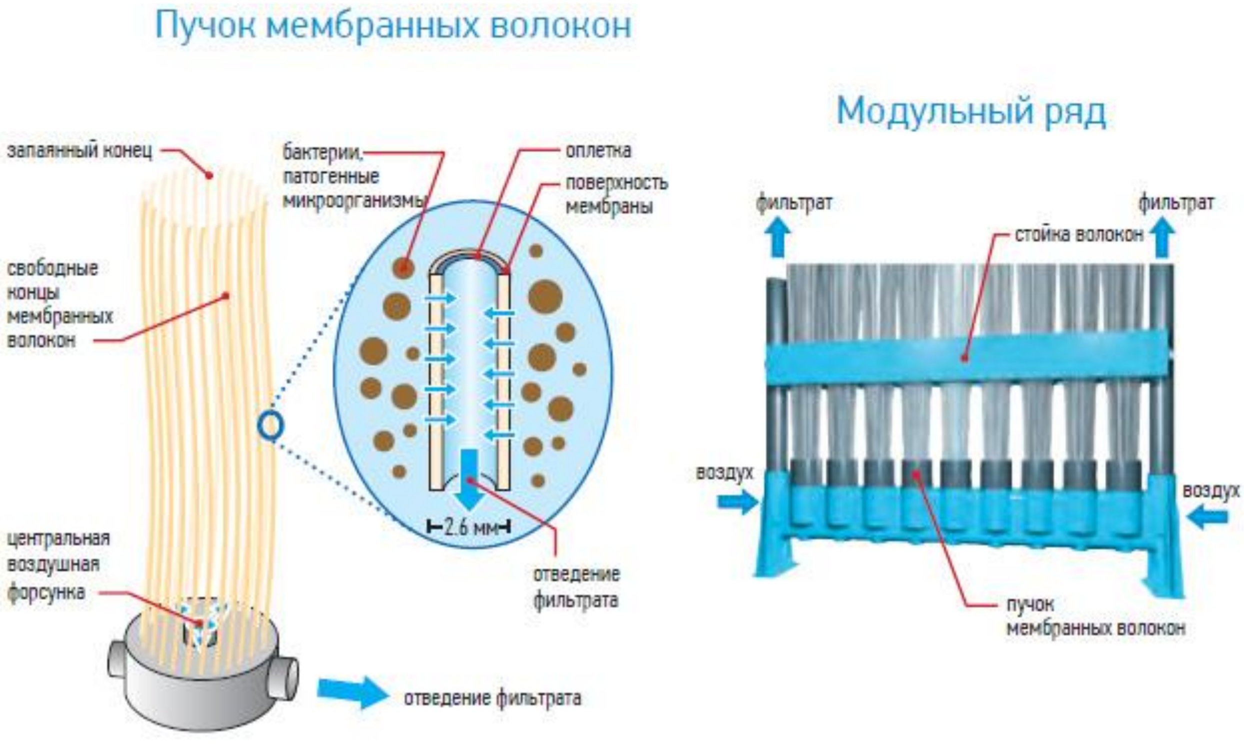


Figure 2.42 – Membrane fiber bundle

Filtration takes place under the action of vacuum created on the inner surface of the membrane fiber by a self-priming filtration pump. To organize filtration between the inner cavity of the membranes and the space of the membrane unit, a pressure difference (0.01 ~ 0.06 MPa) is created. In this case, the mixture of wastewater and activated sludge is filtered through the surface of the membranes from the outside to the inside. As a result of the separation of solid and colloidal particles on the hollow fiber membranes, the concentration of activated sludge in the membrane biorector block and in the aeration tank increases, which contributes to deep biological wastewater treatment and reduces the volume of the aeration tank by 2-3 times.

The purified water enters through pressure pipelines for disinfection, and the active sludge remains in the membrane tank and is maintained in suspension by an aeration system built into the membrane module.

Aeration is carried out by compressed air using aeration systems (blowers). Depending on the required performance, the membrane modules are combined into a membrane block. The number of membrane modules in the unit can be increased if it is necessary to improve the performance of the system.

The tangent filtration of the silt mixture used in membrane bioreactor systems prevents its clogging, i.e. the accumulation of deposits (bacteria). Such movement of the sludge mixture is provided by a circulation pump with a capacity significantly higher than the flow rate of the wastewater to be treated. The ability to regulate the flow and pressure in the circulation circuit allows you to establish full control of the membrane filtering process with maximum efficiency. In addition, the implementation of the tangential filtering regime has positive consequences for the biology of the entire system. Constant washing of membranes disperses cleansing bacteria that no longer form dense floccules, and therefore the possibility of their direct contact with contaminants and oxygen is significantly increased. It follows that the ratio of active bacteria to oxidizable contaminants is greater in an ICBM system than is usually found in a classical active sludge system.

Activated sludge microorganisms are not removed from the ICBM system, so the bioreactor works in conditions of high concentration of biomass of considerable age. In addition, constant circulation leads to mechanical effects on the membranes of bacteria. That is why the main energy consumed by bacteria is not used for reproduction (as it happens in classical biotechnologies), but is consumed to maintain vital activity, which leads to a decrease in the growth of excess active biomass.

Advantages of membrane bioreactor technology

1. The ability to produce, without including additional units in the technological scheme, deep treatment of wastewater from pollutants to indicators that meet the

requirements for the discharge of treated effluents into natural reservoirs of all categories.

2. The possibility of obtaining "gray" waters, the use of which significantly reduces the load created by the building on the environment.

3. Increasing the resistance of the bioreactor to volley discharges of bioresestive substances characteristic of industrial facilities of local water disposal.

1. The ability to increase or decrease productivity without changing the technological process.

2. Reduction by 20-40% of the weight and size characteristics of capacitive structures, because the required amount of activated sludge is in a smaller volume at a higher concentration.

3. Obtaining a small amount of excess activated sludge, which significantly affects the cost of its mechanical dewatering and disposal.

4. Reduction by 30-70% of the area occupied by the equipment (due to the absence of secondary sedimentation tanks, post-treatment units, silt sites).

5. Ensuring high microbiological safety of treated effluents.

6. The removal of activated sludge from the system to the tank with purified water is excluded.

Various membrane modules are used in ICBM technology, in particular hollow-fiber, flat-frame, tubular (Fig. 2.43).

The largest suppliers of ICBM equipment are:

1. GE Water & Process Technologies;
2. Kubota;
3. Mitsubishi-Rayon;
4. Siemens Water Technologies;
5. Toray Industries Inc;
6. Huber Technology.

a – hollow fiber; b – flat-frame; B – tubular

Fig. 2.43 -- Membrane modules used in ICBM technology

HUBER has been producing membrane technology for more than a decade. During this time, huber VRM® submersible membrane units with rotating flat vacuum membrane membranes designed for large treatment plants have been repeatedly modernized and adapted to the growing market requirements (Figures 2.44 – 2.45).

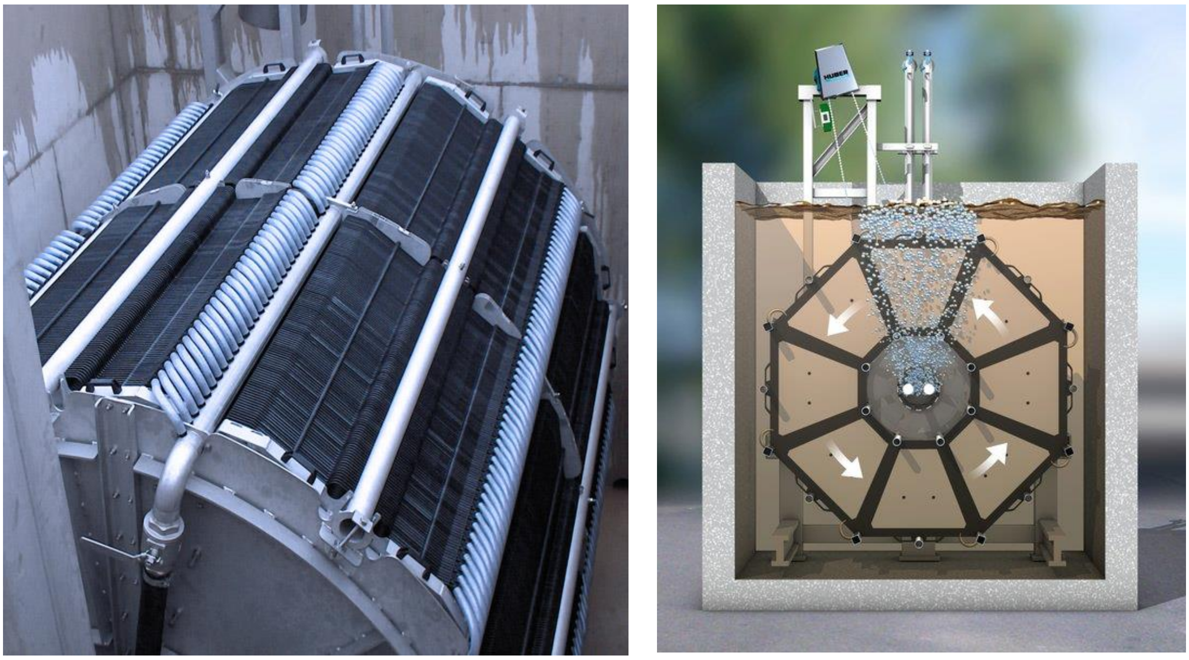
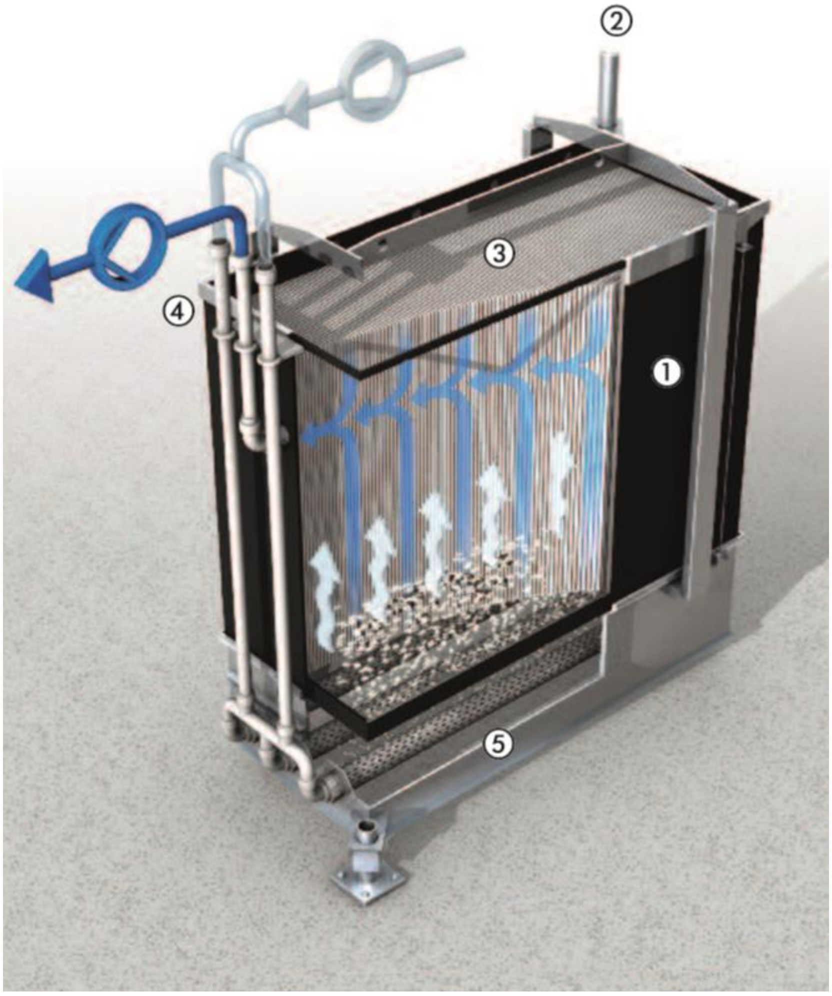


Figure 2.44 - Membrane unit HUBER VRM®

These units offer increased productivity (over 100^{m3}/h per unit) combined with low energy consumption. Due to the fact that the membranes rotate, the unit has many advantages. Periodic cleaning of the membrane surface is carried out with air with a flow rate of 150 - 250 l / (m^2 * h) supplied from the middle of the filter drum. Due to the fact that air must be supplied only from half the required depth, a better degree of membrane cleaning is achieved at significantly lower energy consumption, and the interval between chemical cleaning of membranes increases.

For decentralised cleaning, submersible units with fixed flat membranes HUBER BioMem® are used.



1 – ultrafiltration membrane modules; 2 – guide rod; 3 – membrane; 4 – removal of clarified water; 5 – air tubes

Fig. 2.45- Membrane unit HUBER BioMem®

The HUBER 1 ultrafiltration membrane modules are mounted directly in the aeration tanks or mounted on guide rods 2 in separate filtration chambers. Clarified water (filtrate) is pumped through the membrane 3 by means of a pump and discharged at the top of the membrane module 4. To prevent sludge deposition on the surface of membranes, as well as clogging and biological fouling, the membranes are cleaned by air under pressure supplied through air tubes from below 5.

Mitsubishi Rayon is developing STERAPORE fiber membranes for wastewater treatment (Figure 2.46). The advantages of these membranes are the absence of the need for washing (air purification), hollow fiber, has a high resistance to chlorine.

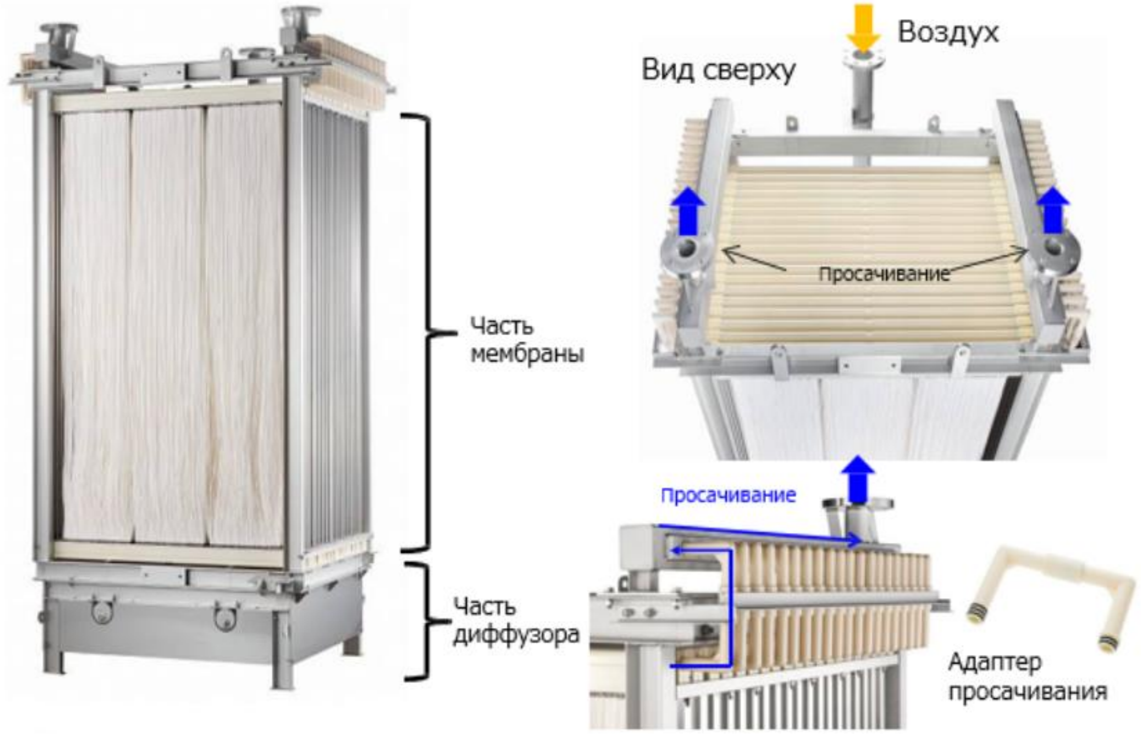


Fig. 2.46 – SterapORE Mitsubishi Rayon Membrane Module

3.2.3 Modern technologies for the removal of nutrients

Achieving the requirements for the quality of wastewater treatment, including nutrients, at the level of MPC for fishery purposes is a strict economic necessity today. At the same time, most of the treatment facilities in our country are designed only for the oxidation of organic pollution, built 35-45 years ago and are still operating today. In this regard, for enterprises operating sewage treatment plants, the reconstruction is due to the fulfillment of the requirements of the Government of the Russian Federation and the need to minimize environmental payments. Responsibility for the choice of the technological scheme of reconstruction and the correctness of the calculation of treatment facilities, that is, for the technical solutions for reconstruction proposed by design organizations, ultimately falls on local water utilities or companies operating treatment facilities. In such a situation (taking into account the serious amount of capital costs required for the reconstruction of facilities), operating organizations are considering a large number of proposals from various companies, and the issue of final Reconstruction of treatment facilities for nitrogen and phosphorus removal technologies - myths and the reality of decision-making, in this regard, is delayed for many months. Unfortunately, it is not always chosen a solution that will really provide the required quality of wastewater treatment. The main reason and problem - specialists with experience in the development, design, implementation and operation of wastewater treatment facilities in our country - a few and in modern conditions of the operating organization it is quite difficult to understand the effectiveness of the proposed solutions. The problem is further complicated by the fact that the time between the approval of a convincingly and beautifully formulated theoretical solution, and the launch of the treatment facilities reconstructed according to this decision, is relatively long; at the stage of design, approval, reconstruction and subsequent operation, responsibility is blurred. Ultimately, it is the operating organization that is responsible for the results of the cleaning quality, which may not reach the originally required ones.

To meet modern requirements for the quality of treated water discharged into water bodies, ammonium nitrogen 0.39 mg / l, nitrite nitrogen - 0.02 mg / l, nitrate nitrogen 9.1 mg / l and phosphate phosphorus 0.2 mg / l at treatment facilities, it is necessary to implement modern technologies at the level of BAT removal of nitrogen and phosphorus from wastewater. Achieving the required standards in the real operating conditions of urban wastewater treatment plants does not seem to be a problem with their correct design. To perform the correct design of wastewater treatment facilities from nitrogen and phosphorus, it is necessary:

• Assess the dynamics of consumption and concentrations of wastewater contaminants entering biological treatment and determine from the data set the values of wastewater consumption and concentrations included in the calculation;

- choose the optimal technological scheme for the implementation of nitrogen and phosphorus removal processes, taking into account the real qualitative and quantitative parameters of wastewater entering biological treatment and the requirements for the quality of purified water;
- to calculate the volumes of the anaerobic, anoxid and aerobic zones of aerotanks, taking into account not only the concentrations of contaminants entering the wastewater treatment, but also taking into account the speed characteristics of biochemical processes (kinetic characteristics of wastewater) characteristic of these wastewater;
- calculate the aeration system in such a way that the specific aeration system provides the required oxygen regime of the structure, taking into account the quality of the wastewater;
- calculate the values of the return activated sludge cycle and internal recycles in such a way as to ensure the specified efficiency of nitrate removal. Biological wastewater treatment facilities from nitrogen and phosphorus are more sensitive to fluctuations in incoming contaminants than aeration tanks that work only to oxidize organic pollutants, and therefore, the choice of design values of wastewater quality indicators from the array of real data that are used to calculate structures is one of the determining factors in the correctness of the results obtained.

The biological method of deep removal of nutrients (nitrogen and phosphorus) from wastewater with a combination of aerobic, oxid and anaerobic stages of purification allows real biological treatment facilities to achieve a total phosphorus content in purified waters of 1.0... 1.5 mg/dm3, and the total nitrogen content is 8... 10 mg/dm3 (including protein, ammonium, nitrite and nitrate). In world practice, there are several traditional schemes for combining anaerobic and aerobic stages proposed for the deep removal of biogenic elements from wastewater of different compositions, some of which are presented in Fig. 2.47 – 2.55.

1. A/O (anaerobic-oxide) process

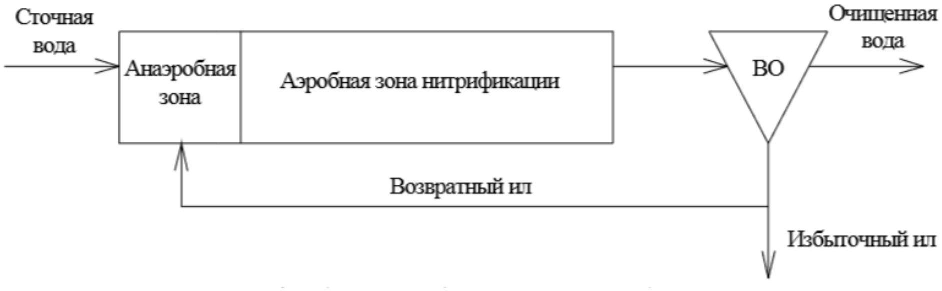


Fig. 2.47 - Schematic diagram of the A/O (anaerobno-oxide) nitrogen and phosphorus removal process

According to the scheme presented in Figure 1, the return sludge is mixed with the incoming wastewater and fed into the anaerobic reactor, then the wastewater is aerobically treated and entered secondary sedimentation tanks. This is the simplest and cheapest scheme for removing nitrogen and phosphorus compounds, but its use is possible only for wastewater of industrial composition with high loads on active sludge for carbon-containing organic matter, moderate nitrification and with the content of high concentrations of phosphorus-containing compounds. For low-load structures, an additional oxid stage is arranged in order to more effectively remove nitrogen nitrates and nitrites.

2. A2/O – process (anaerobic/anoxic/oxic)

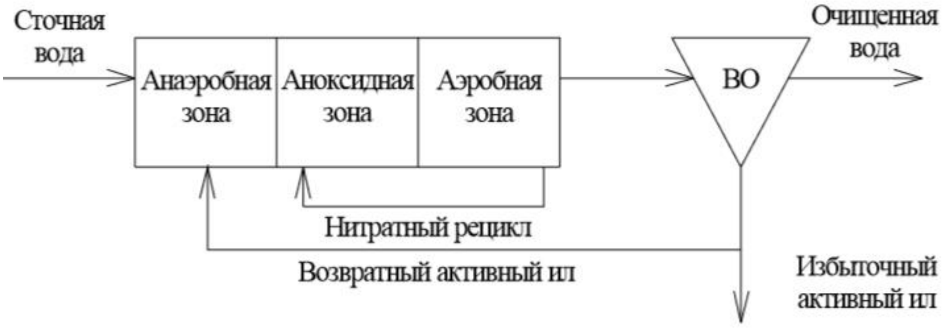


Fig. 2.48 - Schematic diagram A2/O of nitrogen and phosphorus removal process

Process A2/O (Anaerobic/Anoxic/Oxic) for the removal of nitrogen and phosphorus. This process is a sequence of anaerobic, oxid and aerobic zones. In the A2/O process, the anaerobic, oxid and aerobic zones are divided into several compartments of perfect mixing.

3. The UCT UCT process (University of Cape Town) was proposed at the University of Cape Town in 1984 and represents a modification of previous processes with three recycling streams, (rather than two as in previous processes).

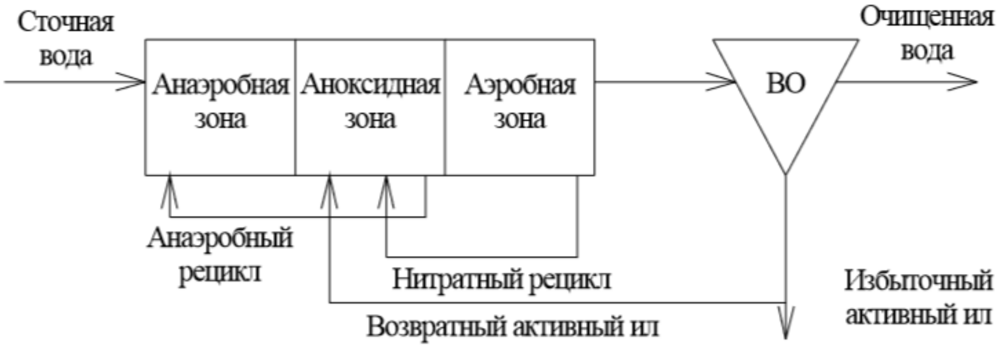


Fig. 2.49 -. Circuit diagram of the UCT process

This scheme allows to minimize the amount of nitrates entering the anaerobic zone of the structure, thereby increasing the efficiency of biological removal of phosphorus. In contrast to the schemes discussed above, in this process, the recycling of recurrent activated sludge and the nitrate recycle are fed into the anoxid zone.

4. Process Modified UCT (University of Cape Town)

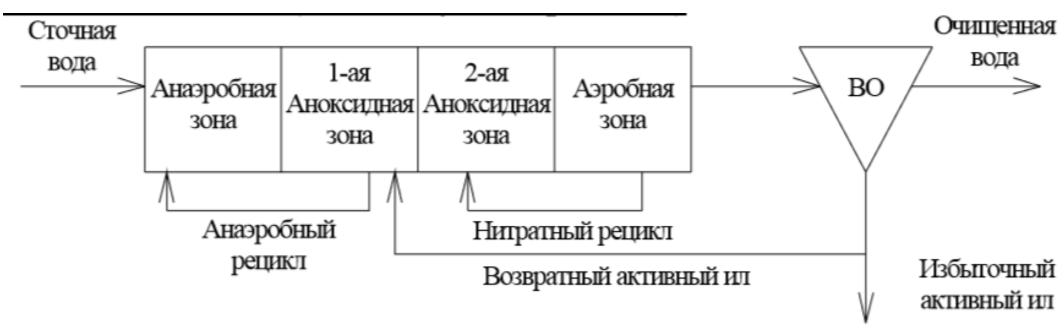


Fig. 2.50 - Schematic diagram of the Modified UCT process

The process is a sequence of anaerobic, two oxid and aerobic zones. In this process, the first oxid zone is designed to remove nitrate nitrogen from the return activated sludge, the second oxid zone is designed to remove nitrates formed during the nitrification process in the aerobic zone to ensure the required quality of the treated water according to N-NO3. The main factors affecting the effectiveness of the process of biological removal of phosphorus: the time of stay of wastewater in the anaerobic zone, the time spent in the anocyclid and aerobic zones, the amount of easily oxidized organic compounds, the age of activated sludge, the concentration of nitrates in the anaerobic zone.

5. The Bardenpho process. The most famous, widely used in Europe, purification scheme, which allows you to effectively remove nitrogen and phosphorus compounds on low-load structures, was named (Vag - in honor of the developer Barnard, den - denitrification, pho - phosphorus extraction).

Fig. 2.51 - Schematic diagram of the Bardenpho process

In this scheme, wastewater treatment begins with the anoxid stage, in which denitrification is carried out. This zone is supplied with wastewater used for denitrification as a source of carbon, and a sludge mixture after the nitrification, which contains nitrites and nitrates. This is followed by the aerobic stage, where there is a decrease in the content of organic pollutants in the treated wastewater and nitrification. A mixture of sludge from this zone containing nitrates is fed into the next anoxid denitrification zone and simultaneously to the previous anoxid denitrification zone. The process ends in the aerobic zone, in which nitrification and partial defosfotation are carried out.

6. Process Modified Bardenpho

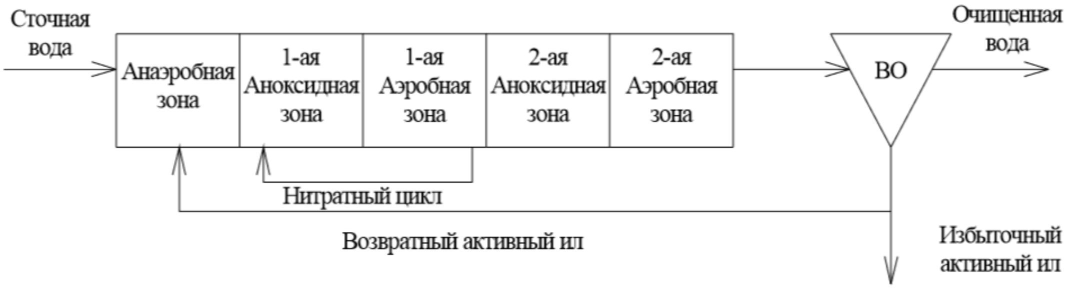


Fig. 2.52 - Schematic diagram of the Modified Bardenpho process

The process has one anaerobic zone, two oxid and two aerobic zones with silt and nitrate recycle. Incoming wastewater and return active sludge are fed into the anaerobic zone, where fermentation reactions, consumption of easily oxidizable FAO organic matter and phosphorus release take place. In the nitrification zone (1st aerobic zone), pre-oxidation of organic compounds, oxidation of ammonium nitrogen and consumption of phosphorus occur. In the 1st oxid zone, the process of denitrification takes place - the oxidation of organic compounds with oxygen-bound nitrates coming from the return active sludge. In the 2nd oxid zone, nitrates formed during the nitrification process in the 1st aerobic zone are restored. The last aerobic zone serves for aeration of the silt mixture to reduce anaerobic conditions in the secondary settling tank. 7. JHB Process Johannesburg process.

Fig. 2.53 - Schematic diagram of the JHB process

This process is a sequence of the auxidal zone (where denitrification occurs), the anaerobic zone (a decrease in phosphorus concentration), the second auxidal zone (removal of nitrate and nitrite nitrogen) and the aerobic zone (in which ammonia oxidation occurs). 8. Modified JHB process

Fig. 2.54 - Schematic diagram of the modified JHB process

The modified JHB process has a repeat cycle, from the end of the anaerobic zone to the beginning of the previous anoxid zone, to provide residual easily biodegradable compounds to the denitrification process. 9. Virginia Initiative Process Abroad, VIP processes are spreading for the simultaneous removal of organic substances, nitrogen and phosphorus compounds. The VIP and UCT processes are very similar. The supply of nitrate recycle and return sludge in them is provided to the anoxid zone, from the exit of which the sludge mixture is pumped to the entrance of the anaerobic zone by an oxidized recycle. Naturally, the presence of nitrates should not be allowed in the anoxid recycle

Fig. 2.55 - VIP Process Concept

However, the methods of biological dephosphotation used make it possible to remove total phosphorus during biological treatment of domestic wastewater only up to a concentration of 1 mg / l. Deeper removal of phosphorus is achieved by using chemical coagulants (Degremont, 2007).

For deeper biological removal of phosphorus and nitrogen from the solution, the process of fermentation (acidification) of the sediment at the PLCA and the process of their accumulation are carried out jointly in the "ripening" zones (UCTK technology - University of Cape Town - Kell). (Kell, 2010; patent)

Today, various schemes are used in practice, combining the biological process and chemical deposition. Such a combination of processes allows to achieve a higher quality of the purified water than when using one of them.

At the Sestroretsk station - SKS, the removal of phosphorus from household wastewater is carried out by a combined method - biological and chemical. For biological disposal, UCT (University of Cape Town) technology is used. Chemical removal is also used - ferrous sulfate Ferix-3, (10% aqueous solution). At the same time, the dose of the reagent is on average 35 g /^{m3}. (Belyaev et al. 2008).

The choice of a specific scheme for the removal of nitrogen and phosphorus compounds from wastewater for sale in industrial aeration tanks depends, first of all, on the qualitative composition of wastewater entering biological treatment and the requirements for the quality of treated water.

The most common in Russia and abroad are standard configurations of processes for the biological removal of nitrogen and phosphorus in aeration tanks with recirculation of silt mixture flows and a certain sequence of alternation of treatment zones.

A comparative evaluation of these process diagrams shows that almost all of the described processes contain internal recirculation circuits. The aerobic and oxidal zones are related. Since they contain dissolved oxygen, although in different forms: aerobic - in direct form, oxid - in the bound form of NO_2 or NO_3.

Thus, the recirculation circuits of the nitrogen removal step can be implemented and used in practice using carousel recycling. In this process, simultaneous denitrification takes place in the same reactor simultaneously with a change in the phases of aeration (in the aerobic zone) and mixing (in the anoxid zone).

It should be noted that there is a positive experience in the application of the carousel principle at domestic treatment facilities.

The aeration tanks of the biogenic element removal unit of the Lyuberets treatment facilities consist of 4 corridors, divided into zones (Figure 2.56).

1 corridor - anaerobic zone (without forced oxygen supply), in which phosphorus is released;

Corridor 2 – anoxid zone (mixing zone), in which the denitrification process takes place;

Corridor 3 – aerobic zone (forced aeration + mixing, in which the nitrification process takes place;

Corridor 4 – aerobic zone (forced aeration), in which the process of nitrification takes place.

Corridors 3 and 4 are interconnected by an endless circular corridor of the "carousel" type, which makes it possible to provide the conditions necessary for the process of nitri-denitrification. Separation of treated wastewater and activated sludge is carried out in radial sumps.

At the biogenic element removal unit, a consistently high quality of wastewater treatment is achieved in terms of the main indicators and biogenic elements (Table 2.17).

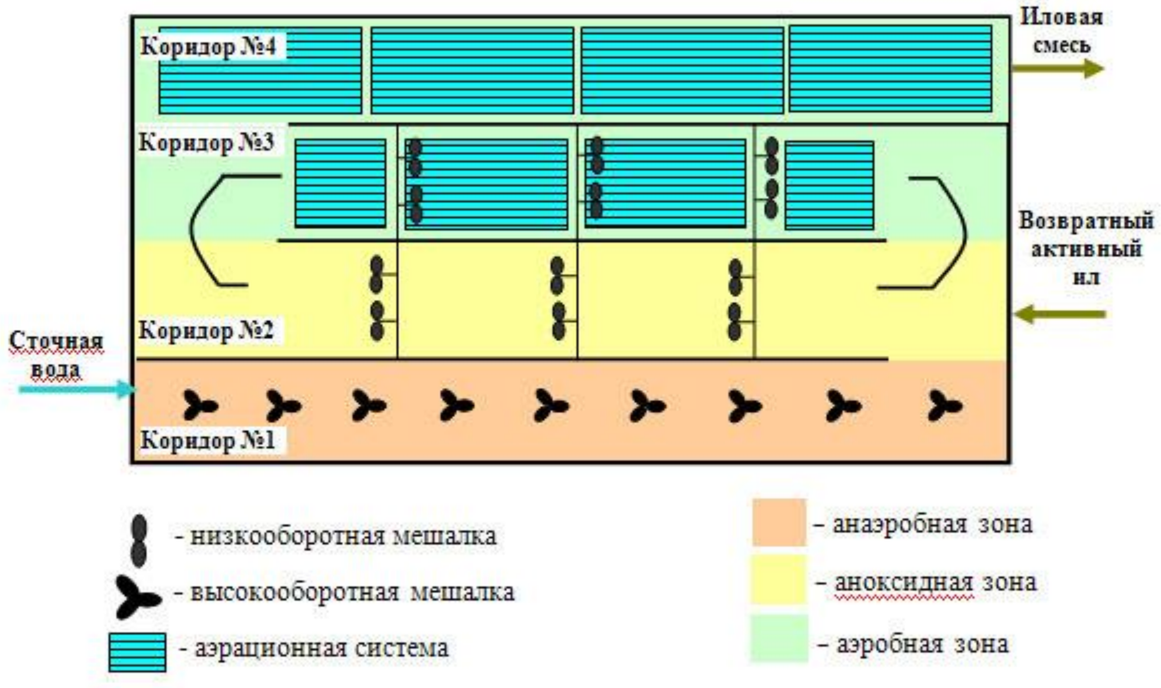


Fig. 2.56 - Diagram of the aeration tank of the biogenic element removal unit

Table 2.17 - Efficiency of nutrient removal in aeration tanks (Figure 2.56)

Name of indicators	Unit	Average value for 2013	Project significance	EU Regulations
Suspended solids	mg/l	6,4	8,0	35
BOD_5	mg/l	2,1	4,0	25
Ammonium nitrogen	mg/l	0,5	1,0	10 (total nitrogen)
Nitrite nitrogen	mg/l	0,02	-	
Nitrate nitrogen	mg/l	8,62	9,1	
Phosphorus phosphates	mg/l	0,58	0,9	1 (total phosphorus)

Modern requirements for the quality of treated water, and primarily for biogenic elements, require the implementation of nitri-denitrification and phosphorus removal (chemical or biological) technologies in biological wastewater treatment facilities. Competently selected, for specific conditions, technological scheme and its technical implementation, with correctly carried out calculations, allow to ensure the specified quality of cleaning. However, it should be noted that the volumes of facilities in which nutrient removal technologies are implemented are 2-4 times greater (depending on the quality characteristics of incoming wastewater, treatment quality requirements and minimum design temperatures) than the volumes of aeration tanks designed only for the oxidation of organic compounds. An alternative to the construction of new volumes when reconstructing existing structures or reducing the construction volumes during new construction is to increase the oxidative capacity of aerotanks. One of the most proven and reliable solutions to increase the oxidative power of aerotanks (bioreactors) is the implementation of technologies with an increased amount of biomass. The use of membrane bioreactor (MBR) technologies makes it possible to maintain an operating dose of activated sludge up to 8.0-12.0 g / l, which reduces, with the introduction of technologies for the removal of biogenic elements, the total volume of ICBMs by 3-5 times, compared to the volumes of classical structures (aerotank + secondary settling tank). In addition, using for sludge separation not gravitational methods, which are used in secondary sedimentation tanks, but membrane ultrafiltration, ICBMs are a system of practically ideal sludge separation. This allows not only to reliably and stably meet the most stringent requirements for suspended solids, BPS, forms of nitrogen and phosphorus, but also to avoid such problems that arise during operation, such as the removal of activated sludge during the development of foaming and swelling processes, disruption of the aerobic age of activated sludge and, as a result, the nitrification process, during periods of increased (or volley) loads on organic compounds, ammoniation of activated sludge in secondary sedimentation tanks, etc.

Modern requirements for the quality of treated wastewater require the implementation of technologies for the removal of nutrient elements at sewage treatment plants. For operating organizations, the issue of choosing reliable technological and technical solutions that consistently ensure the required quality of purification, including nitrogen and phosphorus, is paramount. Of particular importance are the correctness of the choice of the technological scheme, its technical implementation and the reliability of the calculations of structures performed for each specific case, taking into account the real fluctuations in the incoming load for pollutants and costs. The specified quality of treated water must be ensured under any design regimes both in terms of costs and quality of incoming wastewater, taking into account their minimum temperature. In addition, the implemented technological and technical solutions for the biological treatment of wastewater from biogenic elements should ensure a stable required quality of purified water in real conditions of instability of the incoming load.

To ensure modern standards for the discharge of treated water, in the course of biological wastewater treatment, it is necessary to organize such biochemical processes as oxidation of organic compounds, nitrification, denitrification and phosphorus removal (by chemical, biological or biological-chemical method). It is obvious that the implementation in the facilities, in addition to the processes of aerobic oxidation of organic compounds, also the processes of nitrification, denitrification, phosphorus removal, requires an increase in the volume of aeration tanks compared to the old existing technologies for treating wastewater only from organic compounds.

An alternative to the construction of new volumes during the reconstruction of existing structures or the reduction of construction volumes during new construction is the implementation of solutions to increase the oxidative capacity of aerotanks (bioreactors). One of the most proven and reliable methods of increasing the oxidative power of aerotanks (bioreactors) is the use of membrane bioreactor (MBR) technologies. In MBR, the working dose of activated sludge in the bioreactor is maintained at a level of up to 8.0-12.0 g / l due to the use of not the gravity-free method of sludge separation, as in the secondary settling tank, but ultrafiltration. Ultrafiltration membranes, which are an almost ideal filter for activated sludge, provide a concentration of suspended solids in purified water of 3 mg / l or less (below the detection limit of 3 mg / l for suspended water). Membrane bioreactors combine biological wastewater treatment processes with free-floating biomass, sludge separation processes and tertiary water purification. The use of ICBMs does not limit the dose of activated sludge in biological reactors, since the efficiency of silt separation using membranes does not depend on the dose of activated sludge (in the operating range of biomass concentration up to 8 - 12 g / l). The working dose of activated sludge in membrane bioreactors exceeds the same parameter in traditional aeration tanks by 3-5 times, which, in turn, allows to proportionally reduce the required volumes of structures.

During the operation of facilities operating on the aerotank + secondary settling tank technology, after secondary settling tanks, the quality of purified water for BPCC, ammonium nitrogen and nitrite nitrogen, in most cases, deteriorates compared to the quality of the settled sample taken at the outlet of aeration tanks. The deterioration of the quality of purified water after secondary settling tanks compared to the quality of purified water in the settled sample at the outlet of the aeration tank worsens for the following reasons:

The minimum concentrations of suspended solids at the outlet of secondary settling tanks are 6-12 mg / l, which, accordingly, gives the BPKpol at the output of secondary sedimentation tanks 6-15 mg / l. In this case, in order to achieve the required value of

BPCpols that meet the requirements for discharge into the reservoir, it is necessary to additionally arrange a filtration system (tertiary purification).

The development of the processes of swelling and foaming, which is typical not only for industrial (although for industrial effluents this problem is the most urgent), but also for municipal wastewater, leads to an increased removal of suspended substances (and with deep-onset processes - to complete non-precipitation of activated sludge in secondary sedimentation tanks), which leads to both the excess of the content of suspended substances and BPS fillings in the treated water above the required values. At the same time, with the development of the processes of foaming and swelling of activated sludge, the installed after-treatment filters not only do not cope with high concentrations of suspended substances, but can also fail.

When settled sludge is found in secondary sedimentation tanks in cylindrical conditions, the processes of ammoniation of activated sludge develop and, as a result, the concentration of ammonium nitrogen can increase in secondary sedimentation tanks by 0.5-5.0 (or more) mg / l. At the same time, partial nitrification is realized in the upper oxygen layers of the secondary sedimentation tank and. as a result, the concentration of nitrites increases to 1.0 mg / l. The indicated concentrations of ammonium nitrogen and nitrite nitrogen will be concentrations. relevant substances in purified water.

When implementing technologies for biological removal of phosphorus, phosphorus-accumulating microorganisms of activated sludge, located in secondary sedimentation tanks under oxygen-free conditions, release phosphorus into the external environment, as a result of which, the concentration of phosphorus phosphates can increase by 1.0-6.0 mg / l, which is the concentration of phosphorus in purified water.

Obviously, with perfectly working secondary settling tanks and scrupulous operation of the operating services, the above problems 3 and 4 can be avoided, but it is not possible to ensure the required quality of purified water at the outlet of secondary sedimentation tanks according to BPCC, at a suspended substance concentration of 6-12 mg / l, not to mention situations with foaming and swelling. The main causes of swelling and foaming are as follows:

increased concentration of petroleum products in the wastewater entering the biological treatment;

the presence of toxic substances in wastewater;

a sharp change in the temperature of incoming wastewater;

abrupt changes in the composition of incoming wastewater;

low load on active sludge on organic compounds;

The pH value of the medium is less than 6;

low concentration of dissolved oxygen in aeration tanks.

If the last three causes can be excluded by technological and technical measures, then it is almost impossible to influence the first three causes.

The use of membrane technologies in biological wastewater treatment (MBR) allows to completely avoid the above problems with the deterioration of the quality of treated water after secondary settling tanks compared to the quality of purified water. MDBMs are currently the world's most rapidly developing wastewater treatment and post-treatment technology. The use of membrane biorectors allows, in addition to reducing the volume of bioreactors themselves, to exclude from the wastewater treatment scheme such structures as secondary sedimentation tanks and post-treatment filters (Figure 2.57).

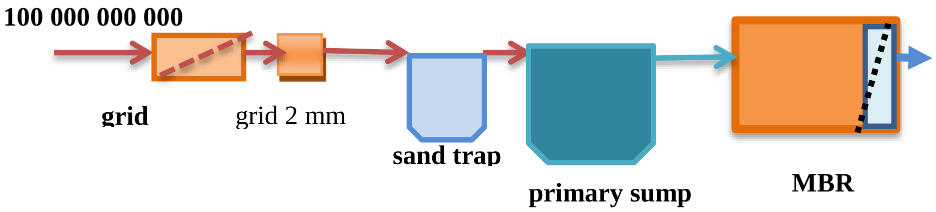


Fig. 2.57 – Scheme of biotreatment with MBR

The use of membrane bioreactors for wastewater treatment can significantly reduce the volume of facilities for biological treatment and subsequent post-treatment of wastewater, while ensuring a stable quality of treated water at the level of MPC for fishery reservoirs, or increase the productivity of treatment facilities several times in existing volumes.

Thus, the use of MBR technologies makes it possible to achieve the required quality of purification, including nitrogen and phosphorus, when using nitri-denitrification and phosphorus removal technologies (chemical and biological), while the volumes of ICBM bioreactors are 3.1 (with biological removal of phosphorus) and 4.4 times (with chemical removal of phosphorus) less than the volumes of aeration tanks, where nitrogen and phosphorus removal processes are also implemented, that is, when reconstructing existing aeration tanks and secondary sedimentation tanks for nitri-denitrification and phosphorus removal technologies when using ICBMs, it does not require volume entrainment.

4.Disposal of sewage sludge and excess activated sludge

4.1. Treatment of sewage sludge

One of the most effective methods of conditioning wastewater sediments is their treatment with reagents, in particular iron salts, aluminum, mineral acids, alkalis, lime, polymeric 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.

Given the wide variety of reagents, it is important to choose the right coagulants and flocculants. Knowledge of the mechanism of coagulation and flocculation is of paramount importance.

According to one view, the most likely cause of instability in dispersed systems is the formation of bridge bonds between dispersed phase particles through adsorbed polymer microions. The contribution of moticulation is assumed to be dominant even during destabilization by low-molecular cation-active flocculants with a high density of positive charge.

Other researchers tend to believe that the flocculation of charged particles of the dispersed phase by cationically active 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.

The experience of experimental study of polymeric flocculants suggests their use at certain stages of conditioning of sewage sludge (Fig. 2.58).

Fig. 2.58 - Methods and processes used in the treatment, disposal and disposal of sewage sludge

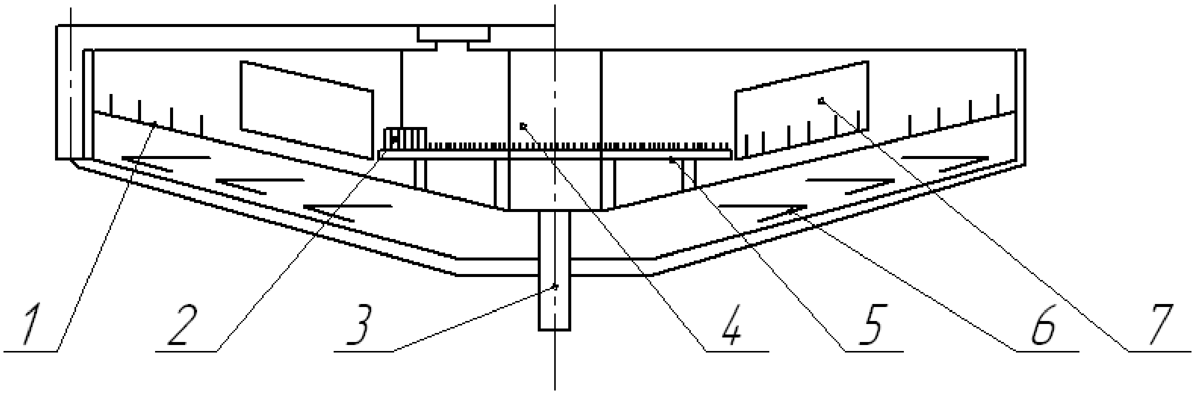
For the most effective thickening of sewage sludge, as a rule, not one type of physical and chemical treatment is used, but several. It is quite easy to dehydrate a suspension of activated sludge with a sediment of primary sedimentation tanks containing a significant amount of mineral impurities, with preliminary reagent treatment with iron and lime. Dehydration in this case is carried out on rotating vacuum filters.

For conditioning excess activated sludge, a method involving heating it and adding reagents is effective. In this case, a sharp decrease in the viscosity of the sludge is achieved due to an increase in temperature, and an intensive process of aggregation takes place under the complex effect of temperature and reagents. The latter leads to the formation of aggregates with a size of at least 1.0 - 5.0 mm and the intensification of the dehydration process.

Sludge of activated sludge belongs to hard-to-thicken systems, which is explained by the weak water transfer of activated sludge biomass. In this case, the thickening process is hampered by the presence of a large number of abrasive impurities. According to the authors, in the absence of these impurities and with the use of fresh biomass of activated sludge, the problem of thickening of activated sludge was solved in the same way as for most suspensions of various industrial microorganisms. As studies have shown, the suspension of fresh activated sludge with pre-heat treatment thickens well, for example, on COC 501 T-2 separators. 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.

The simplest devices for compacting sludge in the form of gravity-type sedimentation tanks have not undergone significant changes in recent years. Design improvements are limited to a variety of attempts to increase the deposition surface while reducing the total area of the settling tank. These shallow sedimentation plants use closely planted inclined tubes or parallel plates to provide a larger deposition surface while reducing the area for particle deposition. A slowly upward flow of wastewater passes through pipes or between plates, particles are deposited on the surface and slowly enter the silt collection bin, while the light of the clarified liquid comes up and is released through the drain device. Usually, for more successful operation of settling tanks, pre-treatment of the suspension with coagulants such as polyelectrolytes is used. This makes it possible to obtain clarified water with a suspension content of 10 - 15 million-1 and to ensure the concentration of silt up to 1-5%.

However, this concentration of sludge is still insufficient to ensure good dehydration, in subsequent stages it is necessary to increase the concentration of sludge to 5 - 10% or more. Figure 2.59 shows a diagram of a radial-type rotary sludge compactor that can significantly intensify the deposition process.

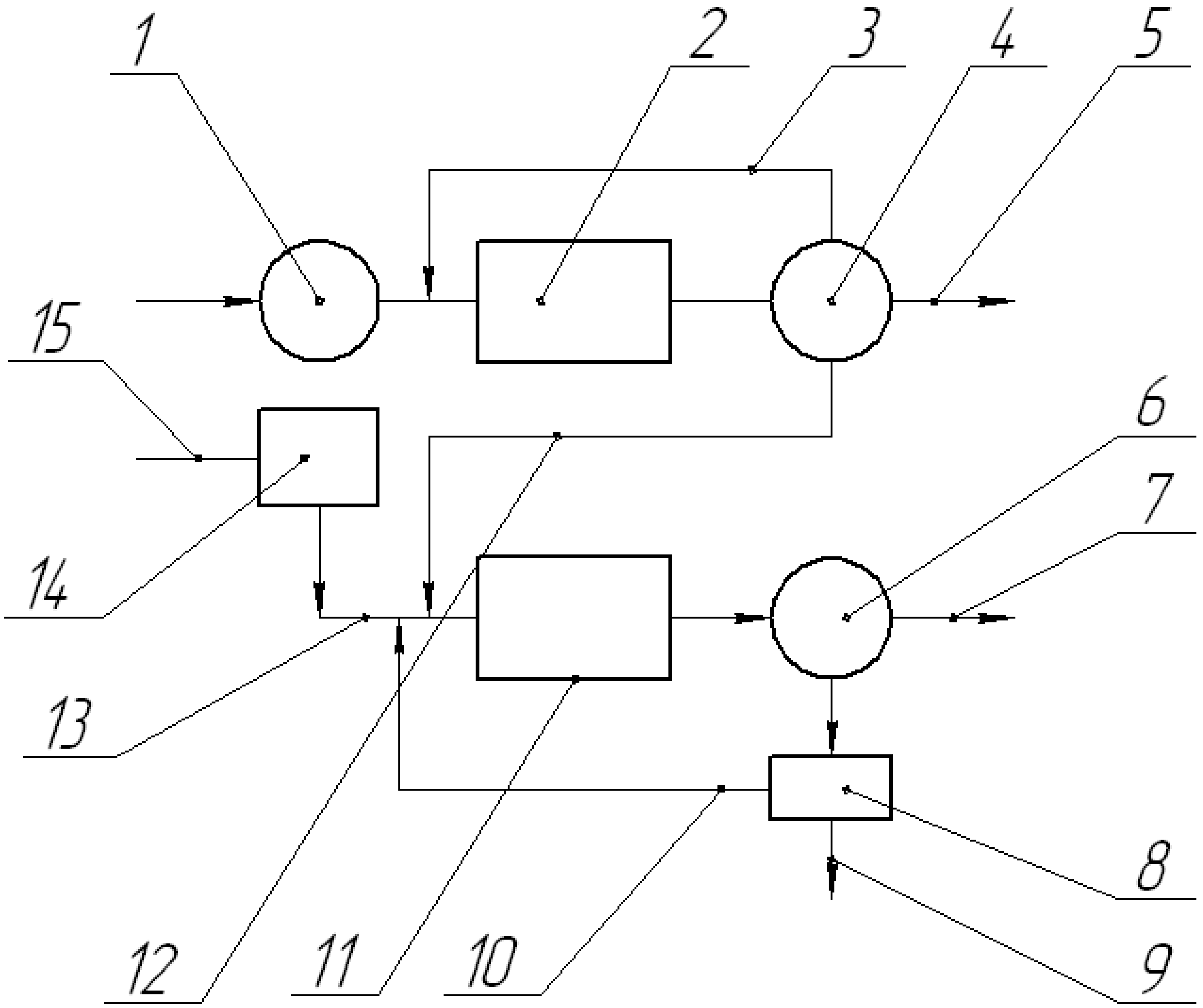


1 - pin agitator; 2 - side drive; 3 - sludge supply pipeline; 4 - intake device: 5 - chain transmission; 6 - scraper mechanism; 7 - shelf blocks.

Fig. 2.59. Rotating shelf sludge compactor of radial type

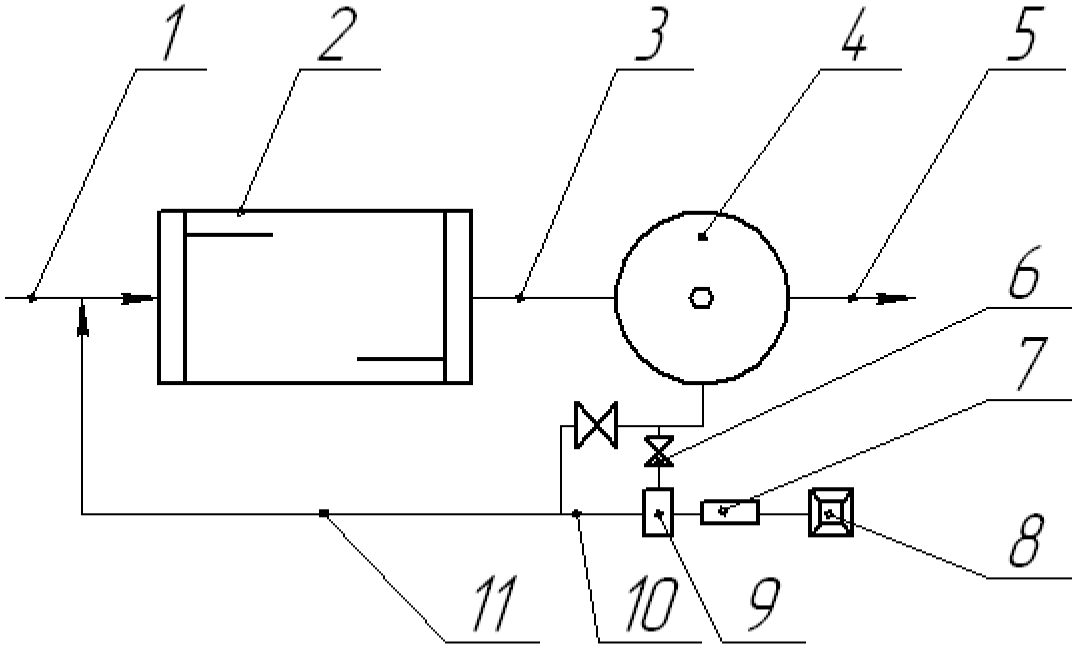
In our country, various designs of shelf sludge compactors are used for the primary compaction of excess activated sludge. Rotating shelf sludge compactor of radial type, shown in Fig. 36 is a design in which the shelf units 7 and the whip agitator 1 are linked to a scraper 6 and an intake device 4. The rotation of the entire system is carried out by a fixed drive 8, installed on the service site, rotational speed 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. 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 sludge with low humidity (approximately with a residual humidity of 60-70%), require relatively low costs for processing the sludge. Recently, high-performance centrifuges have become more commonly used. Centrifuges operate continuously and do not require manual labor when unloading condensed sludge. The use of hydrocyclones with self-pulsating sand nozzles is also promising. A distinctive feature of such a hydrocyclone is the use of a sand nozzle made of elastic material, such as 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. Recently, instead of centrifuges and filters, hydrocyclones have been used to wash the solid phase of the suspension. Battery hydrocyclones with a diameter of a single cell of 60 and 100 mm and a total capacity of 120 - 150 m^3 / h for thickening and washing of the urea complex with paraffin for installation according to the countercurrent washing scheme instead of OGSH-120 centrifuges have been developed. The battery hydrocyclone is rationally arranged from single elements along the perimeter of the circle, in the process of operation each element can be disconnected. Single hydrocyclones are equipped with circulation tubes, as a result, stagnant zones in the branch pipes are excluded during battery operation with partially switched off cells.

Technological schemes of centrifugal dewatering of sedimentation of primary sedimentation tanks and activated sludge are given in Figures 2.60 and 2.61, respectively. Compared to other methods, the method of centrifugal treatment of precipitation 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).



1 - primary settling tanks; 2 - aerotank; 3 - supply of circulating activated sludge to aeration tanks; 4 - secondary settling tanks; 5 - purified wastewater; 6 — sludge compactor; 7 - discharge of the drain fluid from the seal into the primary sedimentation tanks; 8, 12 - centrifuges; 9, 15 - 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 fugate to the mineralizer

Fig. 2.60 - Scheme of sludge dewatering of primary sedimentation tanks:



1 - supply of waste liquid to aeration tanks; 2 - aerotheics; 3 - entry of the sludge mixture into the secondary settling tanks; 4 - secondary settling tanks; 5 - discharge of treated waste liquid; 6 - supply of activated sludge to centrifuges; 7 - heat treatment of dehydrated sludge; 8 - treated sludge bunker; 9 - centrifuges; 10 - centrifuge; 11 - supply of a mixture of centrate with circulating activated sludge to aeration tanks

Fig. 2.61. Activated sludge centrifugation scheme

Technological schemes of centrifugal dewatering of sedimentation of primary sedimentation tanks and activated sludge are given respectively in Fig. 2.58, 2.59. Compared to other methods, the method of centrifugal treatment of precipitation 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).

Filters are also used to thicken sewage sludge 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.

The original compact device of the filter of the bag type is also used, in which the filter bag is wound on a perforated rotating drum, and the filter is squeezed by a special clamping roller device that allows you to work at different thicknesses of the sediment entering the bag filter.

For many years, when dewatering wastewater sludge, filter presses have been used, 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 considerable size and heavy associated devices, the use of such filter presses is unprofitable in small and medium-sized treatment plants.

Pressure filtration is a cyclic process in which the operations of filling and pressing the sludge are sequentially repeated with simultaneous precipitation of squeezes. Technological simplification associated with the use of belt filters and belt filters

First, water is removed from the sludge, and then 60 - 80% of it is removed from the tape with a scraper. It falls on the pressing tape.

After reaching the required consistency and moisture content, the sludge is sent for final dewatering at high pressure.

4.2. Drying of sewage sludge and activated sludge

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

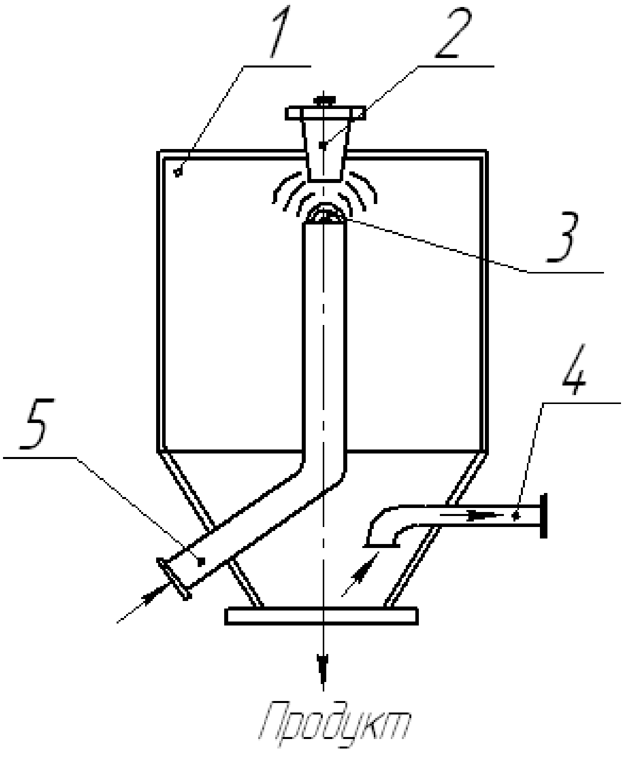
The advantage of spray dryers is a very short residence time of the dried material in the chamber, usually not exceeding I min, which is very important for such heat-sensitive materials as biomass of microorganisms, including active sludge.

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 slurry slurry, 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 (ACB), and after evaporation 7 -10% of the DIA.Achieving higher values of the concentration of biomass 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 drying process by spraying.

After plasmolysis or evaporation, the sludge of activated sludge is dried in spray dryers, such as the SRP type (Figure 2.62).



1 — drying chamber; *2* — centrifugal spraying mechanism; 3 — guide apparatus;
4 — gas outlet; 5 — gas pipeline

Fig. 2.62 - Scheme of spray dryer type SRP

Sludge is supplied through a spraying mechanism 2 in 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 - 1

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

Poparяemoé vlage..... 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, m^3...... 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 possibilities 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. Other methods for producing biomass of microorganisms in granular form are also known, which can be used to obtain biomass of activated sludge.

Many interesting and promising designs of devices with a fluidized bed for simultaneous drying and granulation were created by specialists of domestic research institutes. 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 in some cases for the utilization of activated sludge biomass.

4.3. Directions of disposal of sewage sludge and excess activated sludge

4.3.1. Use of sewage sludge and excess activated sludge as fertilizers

The properties of precipitation 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 precipitation as a fertilizer, since fluctuations in the composition of precipitation, in particular the content of nutrients phosphorus, nitrogen, potassium in them, vary greatly depending on the type and origin of precipitation.

When sewage sludge is fermented, there is a significant decrease in the nutrient content of the solid component of the sludge. The nitrogen content, for example, can be reduced by 40 to 50% 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 precipitation.

In Table. Figure 2.18 provides approximate characteristics of the composition of certain types of sediments.

Table 2.18. Approximate composition of some types of sewage sludge

Type of sediment	Nitrogen, %	Phosphorus, %, P2O5	Potassium, %, K2O
Primary	2,1-2,8	1,2-1,7	-
Precipitate on filter substrates	2,7	2,6	-
Activated sludge	3,1-5,3	2,6-7,1	0,59
Precipitate after fermentation, mixed	1,6-5,6	1,1-3,6	0,17-0,45

The presence of heavy metals in sediments makes it difficult to use them as fertilizer.

Heavy metals can not only cause intoxication of bacteria in the process of sediment stabilization, but also have a toxic effect.

Waste of microbiological production (wastewater, sewage sludge, sludge from the preparation of salts, activated sludge and products of its biological processing) contain in its composition the main biogenic elements - nitrogen, magnesium, potassium, phosphorus, calcium, which can be used in the composition of organic fertilizers.

In agriculture, a common technique is the natural use of sewage sludge, for example, to form the soil, restore its structure on waste lands, increase the content of nutrients in the soil.

The use of salt sludge and sewage sludge necessitates stricter compliance with sanitary standards for soil composition control.

A number of economically developed countries have developed environmental and sanitary conditions for the use of sewage sludge in agriculture.

The general principles of salt sludge selection, precipitation and soil composition control are based on the identification of the elemental composition of the mineral part of sediments by the content of citational, toxic and neutral elements in them.

Mineral nutrients in precipitation include mainly nitrogen, phosphorus, potassium, calcium, magnesium, manganese, iron, sulfur, boron, zinc, copper, molybdenum, cobalt; to toxic - cadmium, mercury, lead, chromium and in excessive quantities - zinc, copper, cobalt, boron" molybdenum.

Neutral elementsare represented mainly by silicon and aluminum.

An essential criterion in assessing the suitability of wastewater and its sediments for natural, mainly agricultural use, is the content of heavy metals in it.

In order to ensure the safety of the use of sewage sludge when it is applied to the soil, for example, the EEC rules do not allow grazing of livestock on pastures for 6 weeks from the moment of introduction of fermented sewage sludge into the grass stands. It is recommended to make it during the period of maximum growth of grass, fermented sediment can not be used if the pH of the soil exceeds 6, since at acidic pH the assimilation of metals is more intense.

The use of sediment significantly increases the yield of grass, legumes, corn, cabbage, cereals. Wastewater and its sediments can be used, for example, in forestry.

When wastewater sludge is used as fertilizer on pasture lands, there may be a risk of contamination of meat and dairy products. The concentration of persistent organic compounds in milk can reach 0.5 µg/L for every 1.0 µg/L of their initial concentration in the dry sludge mass, unless a 30-day break is observed between the time of grazing and the time of the beginning of grazing in it. In order to prevent contamination of food with persistent toxic organic compounds of sewage sludge, it is not recommended to use them in places of continuous grazing of livestock.

These information indicate the need for strict sanitary control by special control services over the use of sewage sludge as a fertilizer.

The main requirement in the production of peat-silt 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-silt 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.

Screw and screw pumps should be used to pump dehydrated sediments to a humidity of 88 - 92%. Centrifugal pumps work satisfactorily at a sludge humidity of more than 92%.

Dehydration is carried out in mechanical centrifuges, vacuum filters or by sedimentation of suspended particles. The essence of the scheme is the use of dehydrated sludge up to 88 -92% directly from the cards. –

There are two ways to compost:

1. Composting in piles is a natural way of bio-oxidation. In this case, a small amount of sludge is processed.

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.

The energy consumption for the preparation of 1 ton of the product is 20 -190 kW.

Of greatest interest are technologies that create conditions for the rapid development of microrganisms, which release biogenic substances (phytolins) that suppress the development of other microorganisms.

The process of biofermentation of peat-silt mixtures into fertilizer consists in the rapid development under favorable conditions of first mesophilic microorganisms (tmin = 10 - I5 ° C, tmax = 35 - 47 ° C, topt = 30 - 45 ° C), and then thermophilic microorganisms (tmin = 40 - 45 ° C, tmax = 80 ° C, topt = 55 - 75 ° C). When composting under conditions of forced aeration, it is possible to create conditions for the predominant development of actinomycetes that secrete the antibiotic Aetinomyces Streptomycine, which 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 - 8months of eggs.

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 massas the process attenuates or by an enhanced aeration device. Selective cultures of microorganisms can be used to intensify the process. For example, the culture of thermophilic actinomycetes is grown in the laboratory on a Kosmachev medium: per 1 liter of tap water (g): KNO_3 - 1, $(NH_4)_2SO_4$ – 1, Na_2HPO_4 – 1, $MgSO_4$ – 0.5 $FeSO_4$ –

1,chalk – 4, starch – 20, agar – 20, pH of the medium 7,2 – 7,5 and introduced into the laid shoulder, where: the height of the shoulder is 2.5 - 3,0 m, the width is not less than 4 and, the length is arbitrary, the minimum weight of the shoulder is 200 t. perforated pipes through which air is driven by 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-silt mixture): moisture content 70%; the proportion of phosphorus on the DIA is not less than 0.5%; the angle of the natural slope of the shoulder is 36 - 43°. In order for the compostable mass not to freeze in winter, each stack is laid for as short a time as possible (1-2 days) and covered with a layer of peat 30 cm thick. 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. In the process of composting, it is necessary to constantly monitor the process.

4.3.2. Possibilities of using biomass of excess activated sludge

The biomass of excess activated sludge under certain conditions can be used as a protein-vitamin supplement when performing strict sanitary control. 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 using activated sludge biomass as a feed additive gives positive results in some cases.

At the same time, the conditions for obtaining a protein preparation from activated sludge are also known. The most appropriate mode of protein separation from the biomass of activated sludge is the heat treatment temperature of 130 - 135 ° C, the heat treatment time is 20 - 30 minutes, the pH is 9.0, under which the protein yield is about 65%. Such a protein preparation under certain conditions can be recommended as a feed additive.

A more significant process 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 trend towards the expansion of 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 efficiency of biogas production increases with the simultaneous solution of several tasks. Thus, near the Czechoslovak resort town of Třeboň, treatment facilities have been built, which, in addition to livestock waste, process urban wastewater on their basis with the help of anaerobic digestion produces biogas and high-quality fertilizers. The treatment facilities of this city produce 5800 - 6000^{m3} / day of biogas or 2.2 - 2.3 million m3 per year, which is 1800 - 1900 tons of equivalent fuel.

biogas 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/m^3 /61/

The fertilizers obtained along with biogas contain a dry residue of 31%, nitrogen 0.6%, phosphorus 0.6%.The annual capacity of the plant is 4700 tons of organomineral fertilizers. At the same time, from I kg of processed raw materials containing 81 - 82% of organic substances, 0.8 - 1.2 m3 of biogas are obtained.

The use of activated sludge as a flocculant to thicken suspensions is a new way to dispose of activated sludge. The essence of this method is as follows. Excess active sludge formed during biological wastewater treatment, in native form or with pre-treatment with an electromagnetic field, is fed to the condensation stage of the suspension of the main production, for example, suspension of phosphorite concentrate.

Favorable, from the point of view of aggregation of part of the solid phase of the condensed suspension, the hydrodynamic regime is created in the suspended layer of the sediment, which is easy to implement in a special mixer.

The use of activated sludge allows not only to dispose of excess activated sludge, but also to reduce the loss of thickened slurry.

In the case of thickening of the suspension of phosphorite concentrate, there is a decrease in the loss of the solid phase with the clarified liquid by 20% or more. When drying phosphorite concentrate, the organic part of the biomass of activated sludge is burned, and in the finished product of the phosphorite concentrate there is a small amount of mineral compounds that make up 10 - 15% of the mass of the active sludge biomass.

Experimental studies have shown that fresh active sludge with a low ash content, usually not exceeding 16 - 25%, has effective flocculating properties. In the case of using rotten biomass of activated sludge, its flocculation properties are practically not manifested.

It should also be noted the strong influence on the flocculation of cells of microorganisms of the specific growth rate. Of great interest are the results obtained to establish the relationship between the flocculating properties of torulopsis glabrata yeast cultured on wastewater on their specific growth rate. It was found that the value of the specific growth rate of μ for pronounced flocculation and subsequent sedimentation of yeast cells is 0.14 - 0.17 $^{h-1}$. This fact is of great practical importance for the thickening of the suspension of microorganisms, including activated sludge.

The influence of cultivation conditions on the production of activated sludge biomass used as a flocculant is of great importance. In the case of using native activated sludge as a flocculant, it must be aerated before use. In this case, there is no decay of the biomass and, in addition, the flocculation properties are improved.

An important intensifying factor in the flocculation process using activated sludge biomass is its preliminary acidification or direct supply of a mineral acid solution to the mixing zone of activated sludge with a clarified finely dispersed suspension or wastewater. Reducing the pH to 3.0 - 4.0 units increases the degree of flocculation of particles of the solid phase of the clarified suspension and, in addition, this leads to the practical cessation of the process of decay of the biomass of activated sludge, and, consequently, the release of explosive gases, such as hydrogen sulfide, methane, which contributes to the safety of work using activated sludge.

The biomass of activated sludge can be used in various technological processes as a feedstock, for example, in construction for the preparation of concrete, cement mortars, etc. In this regard, it is advisable to consider individual examples of this method of utilization of activated sludge biomass.

An important aspect of the disposal of sewage sludge and excess activated sludge biomass, when they cannot be disposed of as raw materials in technological processes for any reason, is their use as energy sources. The burning of sewage sludge, for example in Western Europe, is a very common way to dispose of sewage sludge. The equipment design of this method of wastewater sludge disposal includes, as a rule, a receiving hopper, a supply system, a furnace, a heat recovery boiler, a device for cleaning the gases formed during combustion.

Incineration can significantly reduce the volume of sludge and improve its further disposal, for example, with the use of building materials in production, as well as as a road-building material, etc.

The considered methods of utilization of excess silt biomass and sewage sludge do not exhaust all possible areas of use of these wastes for technical purposes. Other methods have been developed, in particular the production of oil and coal from activated sludge. The search for greater use of sewage sludge and activated sludge continues through their processing and the isolation of valuable components from them.

4.3.3. Example of the possibility of using excess activated sludge in biotechnological production

In a number of biotechnological industries, including plants for the production of fodder yeast, it is possible to create low-waste biotechnological production through the use of activated sludge as an additional source of substrate or auxiliary product.

Based on preliminary studies, several ways of using activated sludge have been outlined. One of the simplest in terms of technical solution is the supply of native activated sludge from treatment facilities to the stage of growing fodder yeast. However, as tests have shown, this method can be considered as temporary, since the quality of activated sludge is constantly changing, and this can lead to a deterioration in the technological performance of yeast cultivation. In this regard, it was concluded that activated sludge needed to be dehydrated and microbial biomass obtained as a finished product.

Taking into account the fact that the thickening of the suspension of fodder yeast is carried out using the separation method, it becomes expedient to apply this method at such an enterprise to dehydrate the activated sludge.

Studies have shown that the most effective method of thickening activated sludge is separation with pre-reactive treatment.

Figure 2.63 shows a scheme of pilot tests of the activated sludge condensation technology.

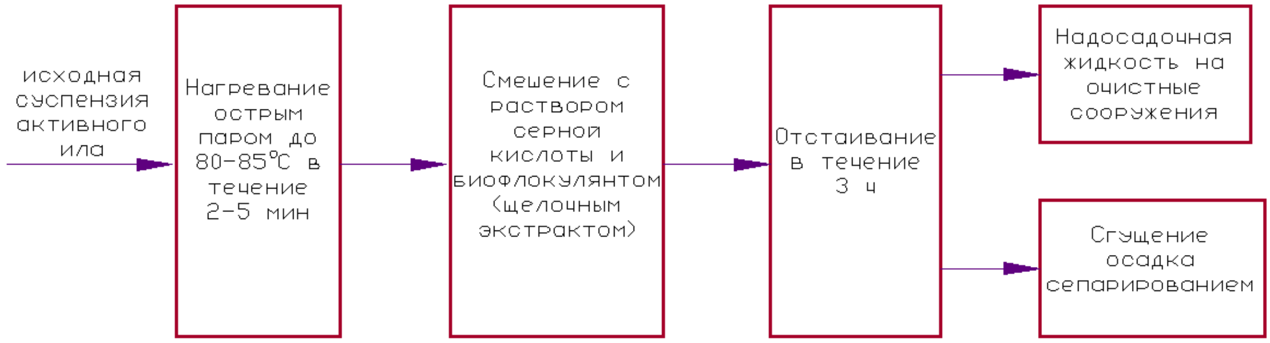


Fig. 2.63 - Schematic diagram of pilot tests of thickening of activated sludge suspension

According to this condensation scheme (Fig. 42), a suspension of excess activated sludge with a concentration of 0.8-1.2% of the DIA is fed for heat treatment (85°C) to intensify the flocculation process that occurs under the combined effect 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 as a flocculant a soluble protein obtained by extraction treatment of the yeast suspension, 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% DIA, 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 slurry 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: DIA 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% DIA suspension is sent for separation, and clarified liquid is sent to fermenters or discharged into the sewer.

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

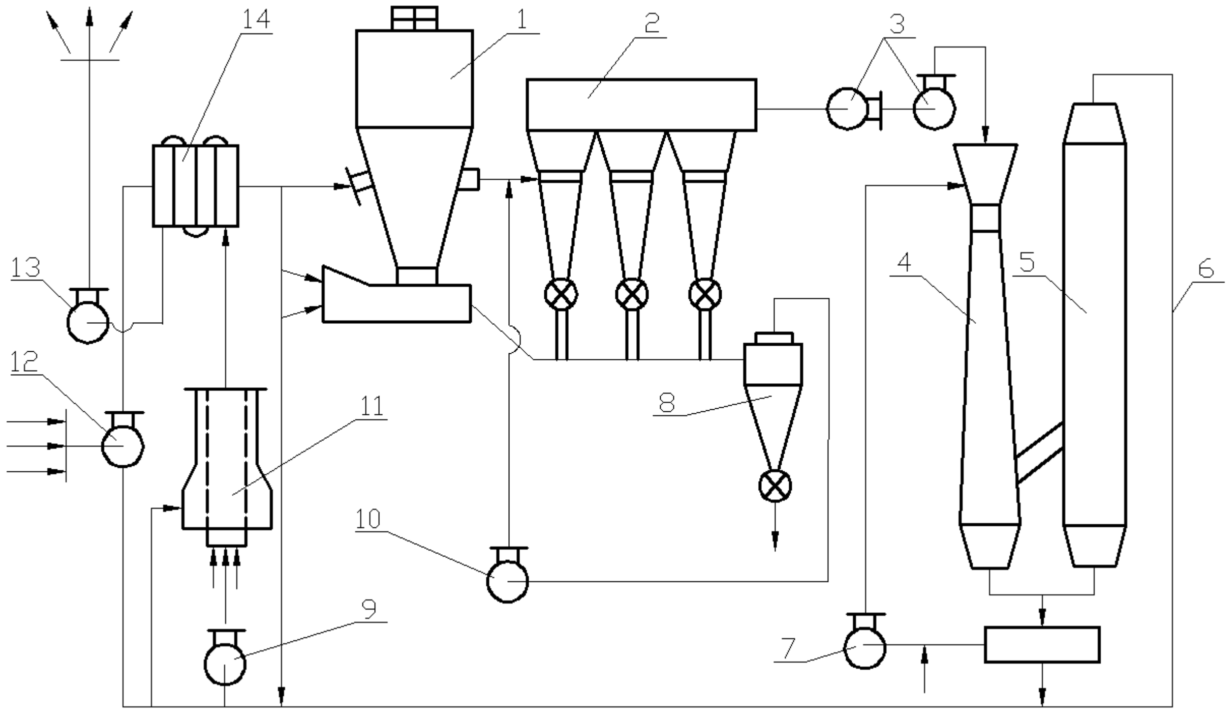
85	5,6	Waste culture fluid up to pH 5.6	3,0	0,98	2,6	0,5	7,6	0,26

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.

Another example of low waste and environmental friendliness of the process is the reduction of exhaust gas-air emissions into the atmosphere.

It is known that at the stage of obtaining yeast biomass, a sufficiently large amount of exhaust gases is formed. At the same time, the efficiency of wet cleaning for fermenters and separators is 97.3-99.8%; for dryers – 99.5-99.8%.

We will consider the technological scheme for cleaning gas-air emissions of drying plants (Fig. 2.64). The steam-air mixture from the cyclone battery is fed by two smoke exhausters to the wet cleaning system consisting of a Venturi pipe and two drop breakers, and enters the recirculating gas duct with condensate separators. From the gas duct, the main part of the steam-air flow by a fan, together with atmospheric air, is directed to the air heater and then as a coolant to the drying chamber. The remainder of the flow is burned in a cyclone furnace, then the air heater passes and is ejected through a chimney 120 m high. Only the part of the steam-air flow that has passed through the heat treatment system is ejected from the system.



1 – drying chamber; 2 – cyclone battery; 3 – smoke exhausters; 4 – Venturi pipe; 5 – drop breaker; 6 – gas duct; 7 – pump; 8 – cyclone; 9 – fan; 10 – blower; 11 – firebox; 12 – fan; 13 – smoke exhauster; 14 - air heater

Fig. 2.64 – Scheme of purification of gas-air emissions of the drying plant

Thermal afterburning systems significantly reduce the dust content in gas-air emissions of fodder yeast production.

Another type of exhaust gas-air emissions is associated with the functioning of fermentation equipment. A wet system for cleaning such emissions from the fermenter involves the use of a venturi pipe. At the same time, the specific water consumption for irrigation of Venturi pipes is 0.4-0.6 l /^{m3} of gas-air emissions, which leads to an increase in the liquid flow to the treatment facilities.

To reduce the additional load on the treatment facilities, the possibility of creating a circulation circuit in this gas purification system was investigated. Tests have shown that 11-fold circulation of water flow does not impair the purification of gas-air emissions. This made it possible to drastically reduce the discharge of wastewater from the wet gas treatment system. In addition, the circulating water supplied for irrigation to the wet gas purification systems was completely replaced by biologically purified water.

Wet cleaning systems for gas-air emissions can reduce air pollution by microbial cells or dust of the finished product by 97.3-99.8%.

Due to the use of various technological techniques that contribute to the introduction of low-waste technology, the technical and economic production of fodder yeast has been significantly improved (Table ...).

For all types of products, the cost price has been significantly reduced. The growth of labor productivity indicates that the achieved indicators are not a consequence of the growth in the number of employees, but relate to qualitative changes in the work of the plant.

This is confirmed by the figures of consumption of raw materials and chemicals per 1 ton of products in the hydrolysis production and the production of BVK (Table 2.20)

Table 2.20. Specific consumption of raw materials and chemicals per 1 ton of fodder yeast (kg)

Raw materials and chemicals	Before implementation	After implementation	Decrease, %
Paraffin	1219,5	1076,2	11,75
Ammonia water	490,1	444,1	9,39
Ammophos	87,1	76,9	11,7
Ammonium sulfate	48,3	35,0	27,5
Potassium chloride or sulfate	44,4	40,8	8,1
Epsomite	19,7	18,4	6,6
Iron sulfate	3,3	0,5	84,8
Copperas	5,3	9,0	-
Zinc sulphate	2,4	2,3	4,2
Manganese sulfate	1,3	0,9	30,8

Given in Table. 37. The data are an illustration of evidence of an increase in the efficiency of technological processes on the example of the production of fodder yeast through the introduction of low-waste technology.

Even more significant results can be achieved with the use, for example, of closed water use, which confirms the need for continuous improvement of technology and equipment, as well as the application of new achievements of science and technology.

4.3.4. Use of activated sludge biomass for technical purposes

The production of microrganism biomass for feed purposes has raised a number of criticisms related to its possible toxicity. However, the use of such biomass for technical purposes does not give rise to any objections and is determined only by economic and technical feasibility.

One such way is to use activated sludge biomass as a substitute for the carboxymethylcellulose used to prepare drilling fluids.

Microorganisms capable of synthesizing exopolysaccharides can be found among representatives of almost all classes of groups.

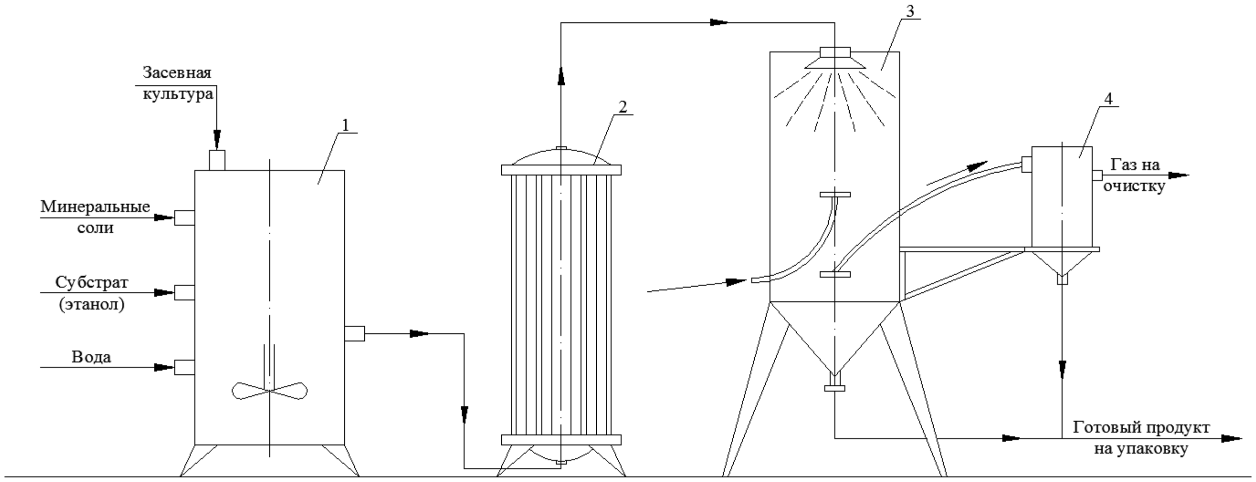
The most accessible is the biomass of activated sludge. Taking advantage of the opportunity to develop active biomass using the technology adopted for the production of fodder yeast, several tens of tons of microbial biomass were obtained. A pilot batch of such microbial biomass was sent to the Torukhansk 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. 2.65).



1 – column-type aeration tank; 2 – combined apparatus for biomass extraction; 3 – spray dryer; 4 - Cyclone

Fig. 2.65 – 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.

The experience of St. Petersburg in the disposal of sewage sludge is of interest. According to the own statements of SUE "Vodokanal of St. Petersburg", an important area for improvement, to which Vodokanal pays great attention, is the treatment and disposal of sewage sludge. This is a complex process that spans many stages. And the introduction of new developments at each stage allows you to improve the process as a whole. The fact is that as a result of wastewater treatment, a precipitate is formed containing pollution extracted from the effluents. Previously, sediment from St. Petersburg was exported to landfills, where it was stored. This created serious environmental problems. Today, three wastewater sludge incineration plants have been built and are operating in the city - at the Central Aeration Station, the Northern Aeration Station and the South-Western Treatment Facilities.

The introduction of plants has become a necessary, but insufficient condition for the disposal of precipitation in the conditions of such a metropolis as St.

Petersburg. It was also necessary to ensure the disposal of sewage sludge from the treatment facilities of the suburbs, where, due to their low productivity, the construction of sludge incineration plants is economically impractical.

Therefore, today Vodokanal has implemented a concept confirmed by the patent of the Russian Federation "Wastewater Disposal System of the Metropolis". In accordance with the new development in the suburbs, wastewater sludge is compacted, mechanically dehydrated, collected in storage tanks, and then transported by road to sludge incineration plants.

Vodokanal also introduced an innovative system for the treatment of sewage sludge, which is confirmed by the patent of the Russian Federation "Sewage Sludge Dewatering System", as a result of which low-humidity sludge is obtained. Undirected sludge is supplied to the sludge treatment and utilization complex with the help of non-clogging pumps developed at SUE Vodokanal of St. Petersburg, as part of the patented "Method of pumping wastewater sludge from primary sedimentation tanks".

Recall that the systematic approach of SUE "Vodokanal of St. Petersburg" to the development of a smart economy is that it covers the entire cycle of introducing innovations at the enterprise: search, testing, evaluation and application in production activities. Today, Vodokanal has 92 valid patents for inventions and utility models and three trademarks. Patent activity at the enterprise has been conducted since 1997. During this period, more than 200 patents were obtained, 70% of them were introduced into production.

The systematic introduction of innovative technologies in the field of water disposal and sludge disposal has significantly reduced the environmental burden on the environment, reduced the discharge of pollutants, including nitrogen and phosphorus, into the Gulf of Finland, and also implemented all the recommendations of HELCOM.

5. Surface wastewater treatment

5.1. Use of best available technologies in surface wastewater treatment practices

In connection with the tightening of environmental standards and the introduction of measures to stimulate the introduction of the best available technologies (BAT), introduced in the Russian Federation since 2015, first at the stage of development, and since 2019 - through the introduction of such technologies, control over air emissions and wastewater discharges of industrial enterprises is significantly increased (statement by Minister S.E. Donskoy at a working meeting with Russian President Vladimir Putin of December 30, 2014) [1].

One of the options for BAT for surface wastewater treatment is the technology developed by us, the basis of which was previously worked out at electric power facilities [2]. After the beginning of the introduction of this technology at the first facilities of the electric power industry, its improvement was carried out in relation to objects of an intersectoral nature.

The essence of the proposed technology is as follows.

Surface wastewater generated, for example, in the production area of an enterprise as a result of heavy rainfall and melting snow, enters the treatment plant (Figure 2.66). These include the following main components: storage tank-settling tank 1; flotation machine 2; intermediate tank 3; post-treatment filters 4, 5, 6; ultraviolet sterilizer 7; reservoir for accumulation of purified water 8; reagent treatment unit 10.

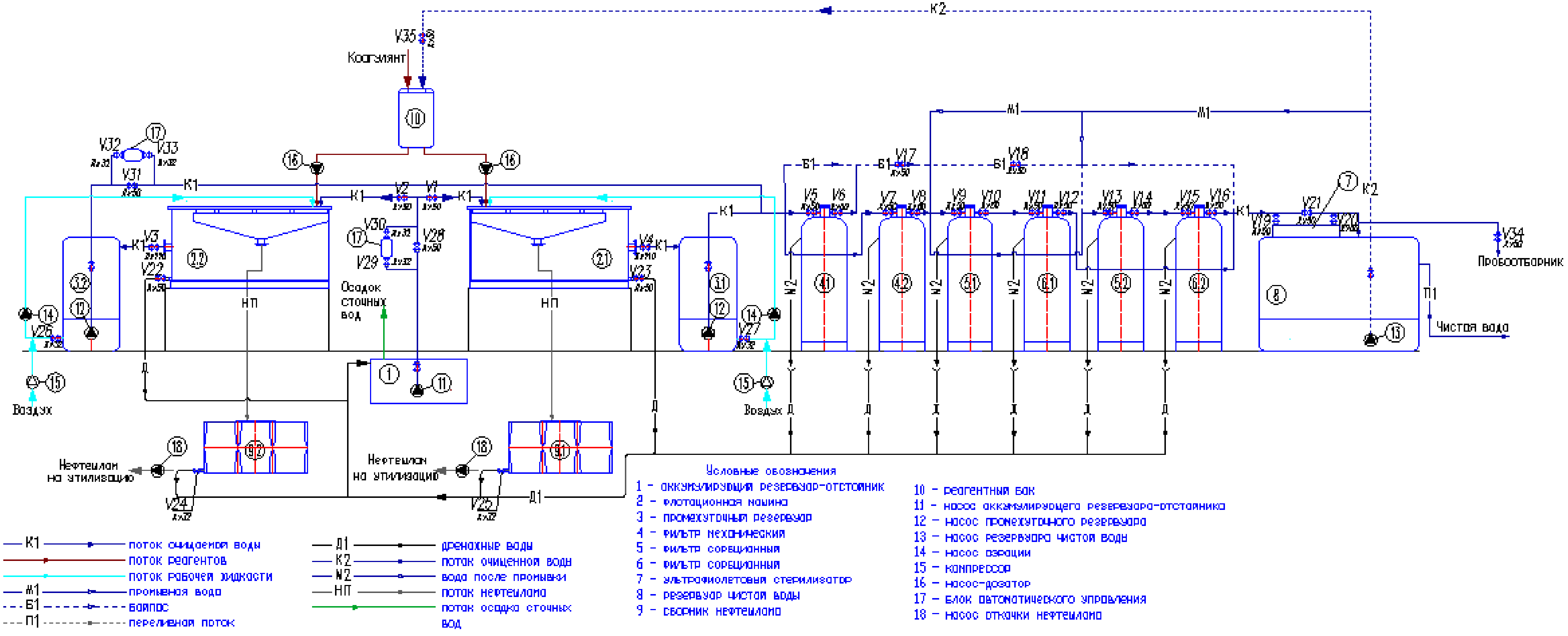


Fig. 2.66 – Schematic technological scheme of surface wastewater treatment plants

Surface wastewater enters the storage tank-settling tank 1, where the treatment of suspended substances takes place. As a result of pre-treatment of wastewater in the accumulating tank-settling tank 1, a precipitate is formed, which is periodically removed from it by a sludge-sucking special vehicle and taken out for disposal. The storage tank-settling tank 1 is equipped with an automatic self-priming pump 11 with a float level sensor. When the water level in the storage tank 1 reaches its maximum value, the pump 11 turns on and feeds the effluents to the inlet chambers of flotation machines 2.1, 2.2, which operate in parallel. Also, a solution of the coagulant aqua-aurate 30 is supplied to the entrance chambers of flotation machines 2.1, 2.2 by means of dosing pumps 16, which is prepared in tanks 10. The introduction of a solution of aqua-aurat 30 into wastewater containing finely dispersed particles of contaminants causes coagulation of contaminant particles. The use of a coagulant allows you to intensify the process of flotation water purification.

To carry out the flotation cleaning process, a working fluid (water-air mixture) is fed into the inlet chambers of flotation machines. It is prepared by means of aeration pumps 14, which take water from intermediate tanks 3.1, 3.2. Air supply to the working fluid is carried out by the compressor 15 into the suction line of the aeration pump. The amount of air should not exceed 5% of the flow rate of the water-air mixture.

As a result of the treatment of wastewater from petroleum products in the flotomachine, oil sludge is formed, which is periodically discharged into the foam collector, and then into the oil sludge collection tank 9, from where it is periodically removed and sent for disposal.

After cleaning in the flotation machine, the wastewater is supplied by gravity to intermediate tanks 3.1, 3.2, from where the submersible pump 12 is supplied to the post-treatment stage, including filtration on stage I and II filters.

At Stage I , water is fed to mechanical granular filters. At this stage, two filters 4.1 and 4.2 are installed, which are tied in parallel. As a load of mechanical filters, a granular load in the form of an AC sorbent is used.

Flushing of filters is carried out with purified water from the tank 8.

Water that has been purified on the filters of the first stage enters the sorption post-treatment flowing on the filters of the second stage. Sorption filters are tied in two parallel lines: line 1 – pos. 5.1 and 6.1, line 2 - 5.2 and 6.2. Sorption filters of the same line are connected in series. Activated carbon AG-3 is selected as the filter load. Activated carbon grade AG-3 is a universal adsorbent of various polluting compounds from liquid and gas media.

The system provides for backwashing of carbon filters in case of replacement of loading and for prevention. Washing is carried out with purified water, washing water is discharged into the accumulating tank-sedimentation tank 1.

After the sorption filters, the water passes through the ultraviolet sterilizer 7, where the water is disinfected, and it is collected in a reservoir of clean water 8, from where it is discharged by gravity into the city storm drain.

The sludge formed in the accumulation tank-sedimentation tank 1 is periodically removed from it by a sludge-sucking special vehicle and taken out for disposal. Oil sludge is collected in oil sludge collection tanks 9.1, 9.2, from where it is periodically removed and sent for disposal. The sediment formed in the flotilla is removed from it during its maintenance, and drained into the accumulating tank-sedimentation tank 1. The spent filter material is handed over for disposal to a specialized Organization.

After the regeneration of the filters, the washing water is sent to the beginning of the treatment facilities - the accumulating tank-settling tank 1, after which they are re-purified.

When the effluents in the storage tank-settling tank 1 are exhausted, the units of the installation are turned off.

The results of tests of this technology at one of the energy enterprises are given in Table 2.21.

Table 2.21 – Test Results of Surface Wastewater Treatment Technology

Defined	Normative document on MVI	Measurement result*, mg/dm^3		Measurement accuracy**, mg/dm^3		Note
		Sump	After filters	Sump	After filters	
Suspended solids	PNDF 14.1:2110-97	114,6 120,1 112,4 116,6 117,8	11,3 11,1 11,2 10,8 10,5	For all 10.0	For all 2.0	Norm +0,75 to the background
Petroleum products	PNDF 14:1:2:4.128-98	4,99	0,02	1,25	0,01	
		1,48	0,02	0,37	0,01	
		1,42	0,03	0,36	0,015	
		1,49	0,04	0,37	0,02	
		1,16	0,02	0,29	0,02	

*The result is obtained as an arithmetic mean of two parallel definitions.

** This error is obtained in the laboratory and is provided by the results of monitoring the accuracy of measurements.

The experimental data shown in Table 1 show that the main indicators (concentration of petroleum products and suspended substances) meet the requirements for the quality of treated wastewater discharged into open water bodies.

At the same time, specific energy costs are 0.5 - 0.7 kWh /^{m3}, and in the case of using known technologies (analogues) - 1 - 2 kWh / m^3 [3].

Thus, the developed technology of surface wastewater treatment makes it possible to obtain treated wastewater that meets all the requirements for its discharge into an open water body, and can be considered as one of the options for BAT.

5. 2. Water disposal of surface runoff in modern conditions

5.2.1.Emerging issues related to global warming

The problems of flooding and flooding of residential areas are largely due to the solution of the problems of water disposal of surface runoff. It should be noted that these problems are becoming more and more relevant every year. This is confirmed by numerous data from different regions of the world on emergency situations related to flooding and flooding of residential areas caused by flood phenomena from frequent and heavy rains. One of the main reasons for these negative phenomena is, apparently, the emerging global warming. The new Paris Treaty, signed by most countries of the world, may contribute to slowing the rate of global warming by reducing emissions of so-called greenhouse gases into the atmosphere. However, despite these measures taken, the phenomena associated with heavy rainfall tend to be frequent, with an increase in simultaneous precipitation, usually commensurate with the monthly rainfall. All this indicates that in order to avoid flooding and flooding of residential areas in these cases, it is necessary to create more powerful systems for removing surface runoff compared to existing ones.

Consideration of the above problems is very relevant at the present stage, as this leads to frequent and severe flooding of residential areas. In this regard, there is a need to implement various measures that help reduce the negative impact of possible flooding and flooding of residential areas.

5.2.2. Comparison of methods for calculating the surface runoff of residential areas

According to the latest information, the number of floods and flooding of territories is increasing every year. The events of 2013, when russia experienced large-scale flooding of the territories around the Amur River, and the events of 2014, when there was a large-scale flooding of territories in the Altai Territory and adjacent territories, as well as severe flooding in Bulgaria near the city of Varna confirm the urgent need to develop preventive measures to eliminate the manifestation of such negative natural phenomena or reduce their scale of damage.

Existing methods for calculating surface runoff do not fully take into account the basic conditions for the formation of this type of water flow.

The approach proposed by us is to analyze the existing residential areas, taking into account the relief and structures of surface runoff drainage in the event of heavy rains and melting of the snow cover.

To reduce the risk of flooding and flooding of territories, new construction should be carried out only in elevated places, and taking into account the necessary calculations when at least a monthly rainfall falls per day. In addition, it is necessary to conduct comparative estimates on the amount of formation of surface runoff during heavy rainfall and melting of the snow cover. After comparison, use for the calculation the maximum amount of runoff generated during heavy rainfall or melting of the snow cover.

In the case of drainage of surface runoff of residential areas, it is necessary to calculate the maximum amount of surface runoff formed during heavy rainfall or melting of the snow cover.

The well-known method of surface runoff removal is carried out in the following sequence.

The annual volume of surface wastewater generated in residential areas and sites of enterprises, Q_a, is determined by the formula:

$Q_a=Q_{rain} + Q_m + Q_i,$

where Q_{rain}, Q_m, Q_i is the average annual volume of rain, meltwater and irrigation water flowing from residential areas and industrial sites, m^3.

$Q_m=10h_m \psi_m F,$

where F is the total area of runoff, ha;

h_m - rainfall for the cold period of the year, mm;

ψ_m - the total coefficient of meltwater runoff from residential areas and sites of enterprises, taking into account snow removal and water loss due to partial absorption by permeable surfaces during thaws, can be taken within 0.5 ... 0,7.

The total annual volume of irrigated water flowing from the runoff area is determined by the formula:

$Q_i=10mkF_i \psi_i,$

where m is the specific water consumption for washing road surfaces, l/m2 (1.2-1.5 l/m2 per sink is accepted);

k - the average number of car washes per year (for the central part of Russia is about 150);

F_i – area of hard surfaces to be washed, ha;

ψ_i is the coefficient of runoff for irrigation waters (taken to be equal to 0.5).

$Q_{rain}=10h_{rain}\ \psi_{rain}\ F$,

where F is the total area of runoff, ha;

h_{rain} - precipitation for the warm period of the year, mm;

ψ_{rain} the total coefficient of rainwater runoff from residential areas and sites of enterprises.

Also, the consumption of rainwater in the collectors of rainwater drainage, which drains wastewater from the territories, is determined.

$$Q_r = \psi_{mid} \cdot A \cdot F / t_r{}^n \qquad ,$$

where is the average constant flow coefficient; ψ_{mid}

A, n – parameters characterizing the intensity and duration of rain for a particular area;

F – estimated area of runoff (catchment);

t_r – the estimated duration of rain, equal to the duration of the flow of surface water on the surface and pipes to the design site.

$$A = q_{20} \cdot 20^n \cdot (1 + lgP/lgm_r)^\gamma \qquad ,$$

where is the intensity of rain for a given area lasting 20 minutes at P = 1; q_{20}

n – degree indicator;

m_r – the average amount of rain per year;

P – the period of a single excess of the calculated intensity of rain;

γ - Degree indicator.

Formulas for determining Q_{rain} and Q_r have a number of drawbacks: they take into account only the average intensity of rainfall, average the flow coefficient and do not take into account the structure of soils and the degree of their desolation.

Taking into account these shortcomings, it is proposed to determine the consumption of rainwater of different probabilities of excess, taking into account the maximum intensity of precipitation and the structure of soils, determined by the formula $Q_{rd}, \frac{m^3}{c}$

$$Q_{rd} = 16{,}7 a_c \alpha_c \, F \varphi K_J K_\Phi,$$

where a_p is the calculated precipitation intensity corresponding to the required probability of exceedance (RP) for flow as determined from Tables P-2-1 and P-2.2 (Annex 2);

α_c - The calculated coefficient of slope runoff as determined by tables P-2.3 to P-2.6 (Annex 2);

F - Catchment area, km^2;

φ - The reduction factor of the maximum rainwater runoff depending on the size of the catchment area. As defined in Table P-2.7 (Annex 2);

K_J - The coefficient of consideration of the impact of the steepness of the catchment area and determined from Table P-2.8 (annex 2);

K_Φ - A coefficient taking into account the catchment formula and determined by (14) and Table P-2.9 (Annex 2).

The calculated intensity of precipitation of different probabilities of exceedance is determined by the following formula:

$$a_p = a_{hour} \cdot K_t,$$

Where a_{hour} is the maximum hourly rain intensity of the required VP. Determined from Table P-2.1 (Annex 2) for a given stormwater area (Figure 2.67), mm/min.

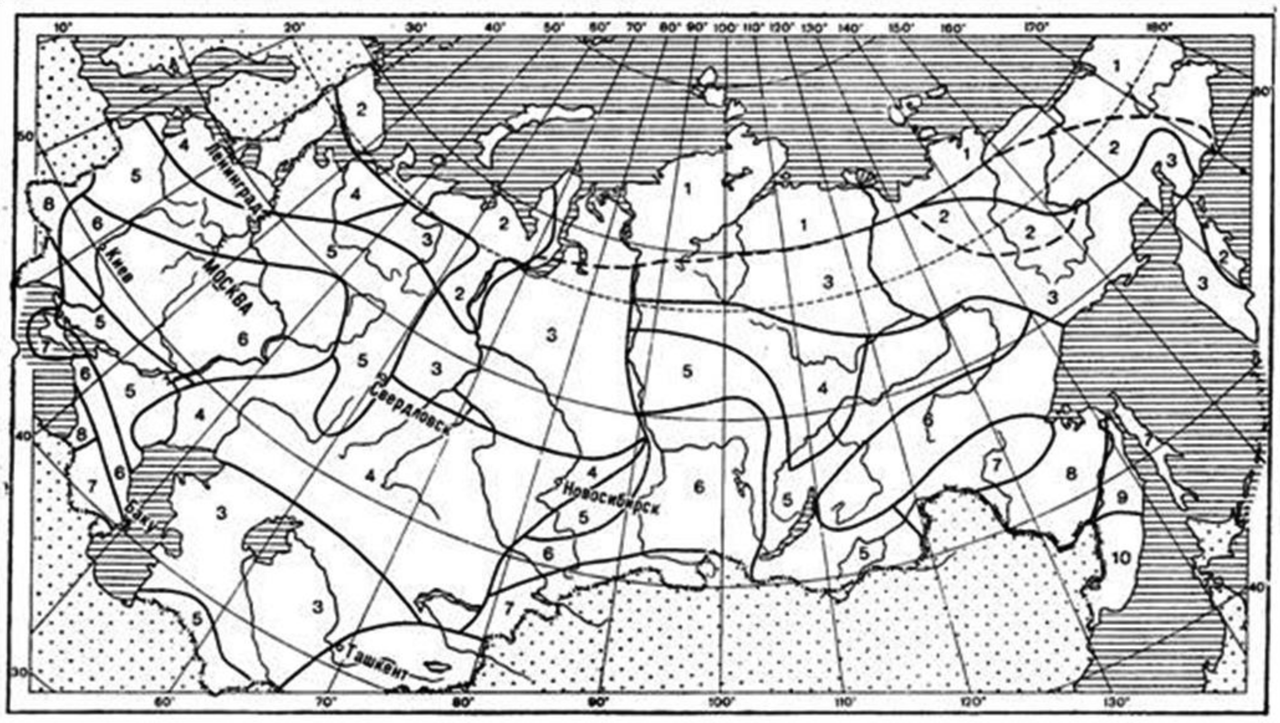


Fig. 2.67 - Map-scheme of storm regions of Russia [4]

For catchments whose areas are located in several stormy areas, the estimated hourly rain intensity is defined as a weighted average by area.

K_t - The coefficient of reduction of the hourly intensity of precipitation depending on the time of formation of the maximum costs in small catchments. Determined from Table P-2.2 (Annex 2).

The calculated coefficient of slope runoff is determined by the formula:

$$\alpha_c = \alpha_0 \cdot \delta_n, \qquad (5.9)$$

Where α_0 is the coefficient of slope runoff at full saturation of the soil with water, as taken from Table P-2.3 (Annex 2).

δ_n - A coefficient that takes into account the natural accumulation of rainwater runoff on the surface of catchments, depending on the different deposits and soils.

The value of the coefficient on catchments, the area of which is characterized by continuous silage or homogeneous soils throughout the basin is determined by the formulaδ_e

$$\delta_n = 1 - \gamma_d \beta P \qquad ,$$

where γ_d is the coefficient taking into account the different permeability of the soils on the slopes of the catchments under the design conditions and determined from Table P-2.4 (Annex 2).

β - A coefficient taking into account the condition of the soils at the beginning of the formation of the calculated flood, determined from Table P-2.5 (Annex 2).

Π- Correction factor for reducing the permeability of soils with an increase in the catchment area. Determined from Table P-2.6 (Annex 2).

With partial silage and sharp differences in soils in the catchments, in these cases, the following formula is used for this purpose. коэффициента δ_e

$$\delta_\text{e} = 1 - (\gamma_{dl} \cdot f_l + \gamma_{dg} \cdot f_g)\beta\Pi \qquad ,$$

Where γ_{dl}, γ_{dg}, are the coefficients taking into account the permeability of the soils in the individual parts of the catchment, different in degree of desolation and soils, are determined according to Table P-2.4 (Annex 2);

f_l, f_g - coefficients characterizing the values of individual parts of the catchment, different in the degree of desolation and soils and determined respectively by the formulas:

$$f_l = \frac{F_l}{F}; \; f_g = \frac{F_g}{F}$$

Where F_l, F_g, are the areas of individual parts of the catchment occupied by various soils and vegetation (Figure 2.68).

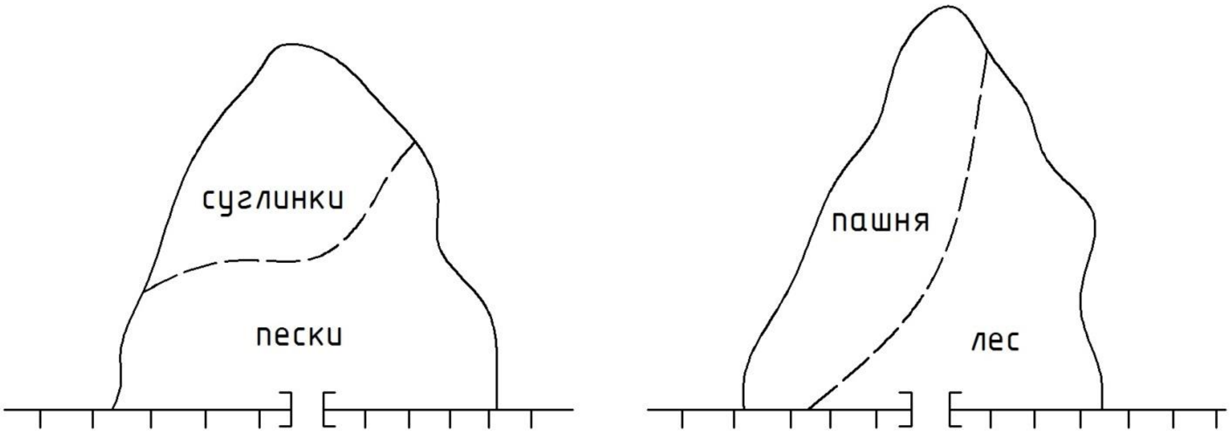


Fig. 2.68 – Diagram explaining the heterogeneous conditions of runoff loss on the slopes of catchments

For large and medium-sized watercourses located in the zone of excessive moisture, as well as in the forest-steppe and steppe parts of the European territory of Russia, the formula of D.L. Sokolovsky is recommended:

$$\delta_{\mathrm{e}} = 1 - \gamma_d \lg\left(f_p + 1\right),$$

where - is defined from Table P-2.4 (Annex 2);γ_d

f_p - the area of permeable soils as a percentage of the total area of the basin.

Recommendations for determining the calculated slope of the main log in order to establish the steepness coefficient of the catchment area K_J in Table P-2.8 (Annex 2).

1. In a flat area, the calculated slope of the main log in small catchments (J) may be taken to be equal to the slope of the log at the structure.

2. On very small watersheds with an area of up to 1.0$^{\mathrm{km}2}$, as well as on single-slope catchments, with an unchanged, unambiguous slope of the drainage surface (Fig. 2.69a), the slope between the watershed point along the main log and the lowered point of the living section in the alignment of the transition can be taken as the calculated slope of the main log.

3. In case of a sharp change in the slopes of the drainage surface on various parts of the slopes along the entire length of single-slope and small catchments (Fig. 2.69b), as well as on medium catchments, the calculated slope of the main channel will be determined as a weighted average at the distance from the upper watershed point to the alignment of the transition.

4. On large and medium watercourses, in the presence of a well-defined channel, the slope of the river in the main channel shall be taken as the calculated slope of the main log, characterizing the average slope along its greater length upwards from the alignment of the transition.

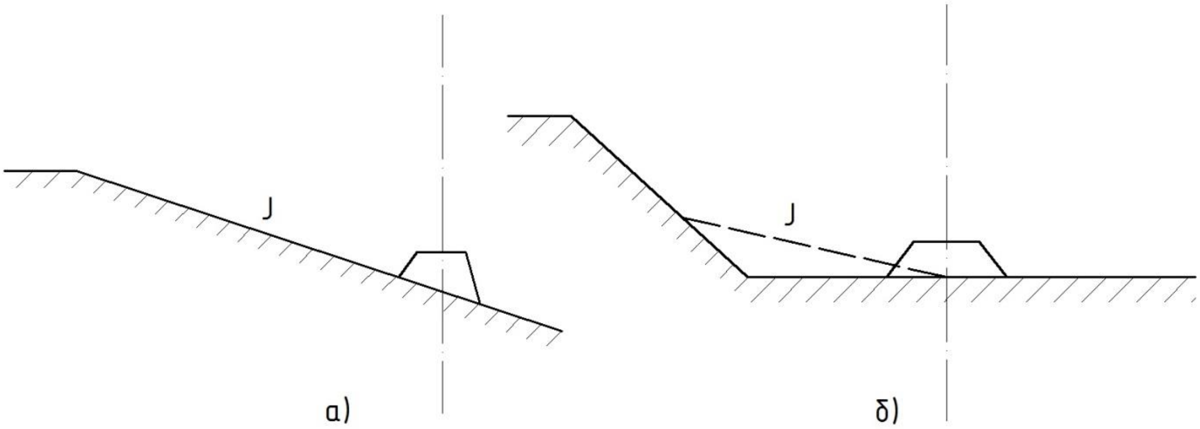


Fig. 2.69 - Scheme for determining the calculated slope of the main channel

The coefficient $K_{ф}$, taking into account the shape of the catchment area, is determined by the formula:

$$K_{ф} = ф + (1 - ф)c \qquad ,$$

where ф, are the coefficients that takes into account the shape of the catchments and determined from the graphs (Figure 2.70).

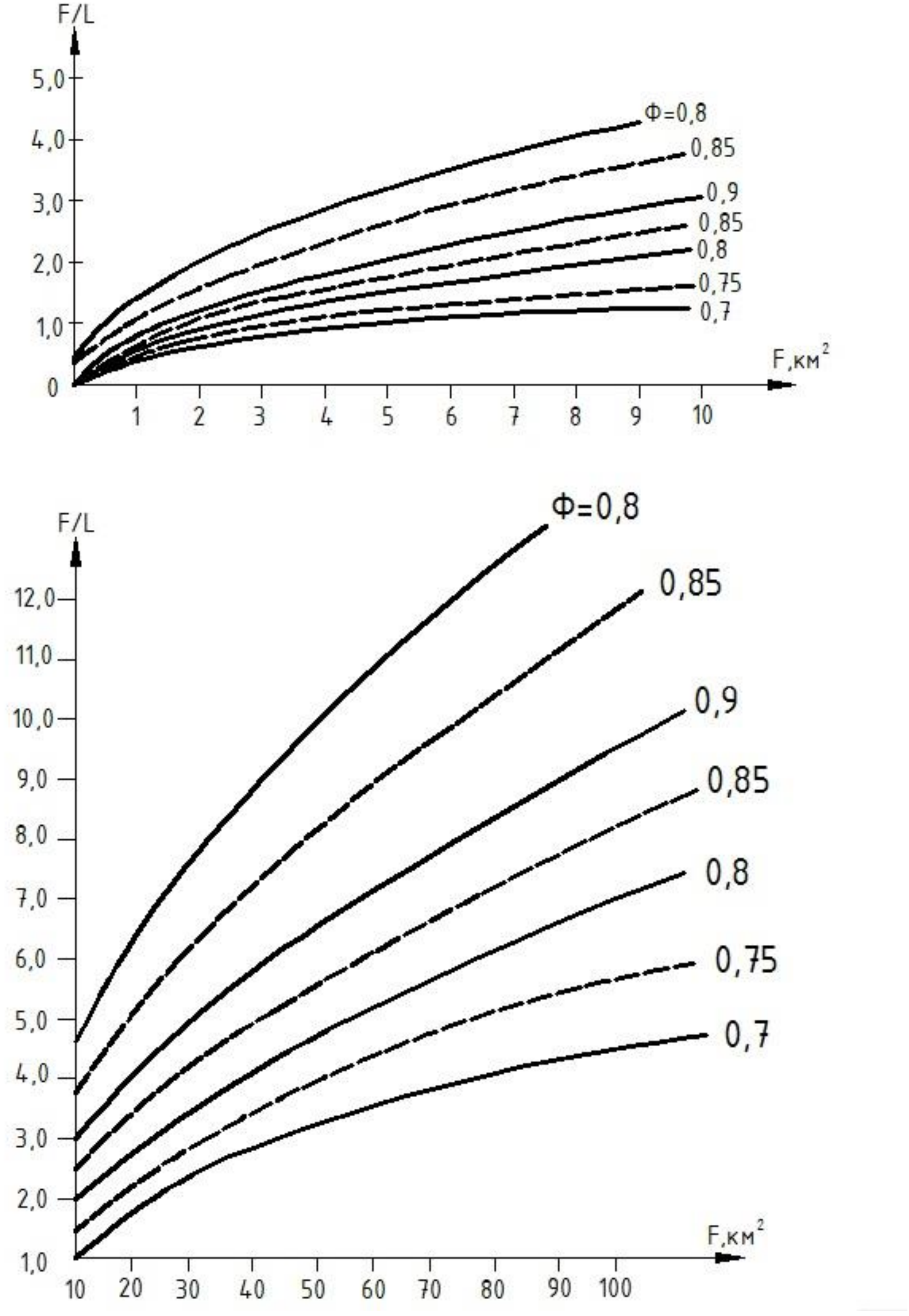


Fig. 2.70 - Graph for parameter definition ϕ

c - A coefficient taking into account the reduction in the effect of the catchment shape on the maximum calculated flow rate and determined from Table P-2.9 (Annex 2).

The length of the main log on small catchments is determined from the highest watershed point located in the direction of the main log.

When the territory is located in several stormwater areas or in the immediate vicinity of their border, the calculated storm characteristics in the areas adjacent to the border of a particular area are determined by the formula:

$$a'_{hour} = \frac{a_N + a_{N+1}}{2},$$

where a'_{hour} is the estimated intensity of the hourly rain for the transition section, which is 25 km long in each direction of the boundary of the storm water area in the direction of the road, mm/min;

a_N, a_{N+1} - Hourly rain intensities as defined in Table 1 and Fig. 1 for two adjacent districts.

Example

As an example, consider a production site located in the Moscow region:

- roof area of buildings and structures – 0.37 hectares;
- asphalt pavements – 0.34 hectares;
- open ground areas – 0.25 hectares;
- green spaces and lawns - 0.3 hectares, of which 0.15 hectares - clay soils: and 0.15 hectares - sandy loam and sandy soils at natural humidity, all are covered.

$$F_{gen} = 0{,}37 + 0{,}34 + 0{,}25 + 0{,}3 = 1{,}26 \text{ га}$$

The flow of rainwater in rainwater collectors that drain wastewater from the territories should be determined by the formula

$$Q_r = \psi_{mid} \cdot q_{20} \cdot 20^n \cdot (1 + lgP/lgm_r)^\gamma \cdot F/{t_r}^n$$

According to the proposed methodology, the calculation of costs from rainwater, taking into account the maximum intensity, different structure of soils and different probabilities of excess, $Q_{rd}, \frac{m^3}{s}$ should be carried out according to the formula: $Q_{rd} = 16{,}7 a_p \alpha_p \, F \varphi K_J K_\Phi,$

According to the existing method, the intensity of rain lasting 20 minutes at P = 1 is taken according to [4]. For Moscow region

$$q_{20} = 80\frac{l}{s \cdot ha} = 80\frac{l}{s \cdot ha} \cdot 1{,}26\ ha \cdot \frac{3600}{1000} = 362{,}9\frac{m^3}{h}$$

According to the proposed methodology, the intensity of precipitation is determined by the formula (8) at $a_{hour} = 0{,}46\ mm/min$ and $K_t = 2{,}12$ for the selected area.

$$a_p = a_{hour} \cdot K_t = 0{,}46 \cdot 2{,}12 = 0{,}97\frac{mm}{min} \cdot \frac{60}{1000} = 0{,}058\frac{m}{h} \cdot 12600\ m^2$$
$$= 733\ \frac{m^3}{h}$$

As a result of the calculation, the difference in the values of precipitation intensities by 2 times is visible. This is due to the use in the proposed technique of the maximum hourly intensity of rain and the reduction coefficient K_t in contrast to the existing method, where average values of precipitation intensity are used.

The flow coefficient ψ_{mid} according to the existing methodology is calculated as a weighted average for different types of surface

$$\psi_{mid} = \frac{\sum \psi_i F_i}{F} = \frac{0{,}6 \cdot 0{,}37 + 0{,}6 \cdot 0{,}34 + 0{,}2 \cdot 0{,}25 + 0{,}1 \cdot 0{,}3}{1{,}26} = 0{,}401$$

According to the proposed methodology, the coefficient of slope runoff for this case $\alpha_0 = 0{,}7$. At the same time, according to the proposed technique for sod clay soils $\gamma_{dg1} = 0{,}04$, for sod sandy loam and sandy soils at natural humidity $\gamma_{dg2} = 0{,}15$; $\beta = 1{,}1$; for The Moscow Region P= 1,0.

Herewith

$$f_{\text{г}1} = \frac{F_{\text{г}1}}{F} = \frac{0{,}15}{0{,}3} = 0{,}5;\ f_{\text{г}2} = \frac{F_{\text{г}2}}{F} = \frac{0{,}15}{0{,}3} = 0{,}5$$

$$\delta_{\text{e}} = 1 - (0{,}04 \cdot 0{,}5 + 0{,}15 \cdot 0{,}5) \cdot 1{,}1 \cdot 1{,}0 = 0{,}8955$$

and then we get

$$\alpha_p = 0{,}7 \cdot 0{,}8955 = 0{,}62.$$

From the calculation it can be seen that the effluent coefficients for different calculation methods differ by 1.5 times. This is due to the fact that the existing methodology does not take into account the composition of soils and their forestation. The proposed technique eliminates these shortcomings with the help of special coefficients that take into account the natural accumulation of rainwater runoff on the surface of watersheds, depending on various deposits and soils.

Thus, according to the main parameters, namely the calculated intensity of precipitation (a_p) and the coefficient of slope runoff (α_p) according to the new method of calculating the values of these parameters, about 2 and 1.5 times, respectively, higher than similar values calculated by the known method.

The data obtained indicate that when designing a storm sewerage system based on the results of the calculation according to the existing methodology, when storm precipitation falls in the amount of a monthly norm or more, the storm sewer system will not cope with such a consumption of storm wastewater, and as a result of which it will overflow and flood the adjacent territories.

These data indicate the need to introduce these provisions into regulatory documents relating to the formation and discharge of surface runoff.

1. Opportunities to use wastewater treatment technologies to capture and dispose of carbon dioxide

It is known that the solution to the problems of global warming is partly due to the increase in greenhouse gases in the atmosphere, including carbon dioxide and methane. Various methods and devices are known for cleaning gas emissions from gaseous contaminants, including carbon dioxide. One option is a method for cleaning gas emissions on the principle of sorption - desorption of carbon dioxide in water [1]

In the simplest version, this method includes an absorber operating at increased pressure, and a beret desor, in which, due to a decrease in pressure, carbon dioxide is released from the water.

The main advantages of such water purification on the principle of absorption - desorption: this is the simplicity of the method and design of the installation, the absence of heat exchangers and boilers; the absence of heat consumption; the cheapness of the solvent; the absence of vapors of an expensive or toxic solvent passing into the gas phase.

The mainshortcomings of the process of water purification on the principle of sorption - desorption: this is a low degree of purification, large gas losses at high pressure due to a significant increase in its solubility; lowabsorption capacity of water for carbon dioxide.

A method [2] is known, the essence of which is that the purification of gases from carbon dioxideis carried out by sorption of carbon dioxide by an absorber with subsequent desorption under reduced pressure and when heated, and sulfone is used as an absorber.

A significant drawback of the known method is the low degree of purification of gas emissions from carbon dioxide, as well as the high cost of the absorber. The task in this case isto develop a new method that will increase the efficiency of cleaning gas emissions from carbon dioxide and reduce the cost of the absorber.

The task and the specified technical result are achieved by the fact that the method of purification of gases from carbon dioxide hafor [3] by sorption by the absorber followed by desorptionunder reduced pressure during heating is reversed , and a distinctive feature is that at the stage of washing an aqueous alkaline solution with a pH of 7-9 is used as an absorber. , and in the desorption stage, an acidic aqueous solution with a pH of 1-5, and the change in pH from an alkaline to an acidicvalue occurs within 1-5 minutes when exposed to an aqueous solution of a magnetic field with a strength ranging from 500 to 5000 oersted and a magnetic field gradient of 10 to 200 ørsted / m.

The method proposed by the author for cleaning gasemissions from carbon dioxide ha for [3] is carried out by sorption by an absorber with increased pressure, followed by desorbenceunder reduced pressure and when heated, ifat the sorption stage, the process pressure is in the range of 0.3-2.9 MPa, and as an absorberuses an aqueous alkaline solution with a pH of 7-9 , and at the stage of desorption, an acidic aqueous solution with a pH of 1-5, and the change in pH from alkaline to acidicvalue occurs within 1-3 minutes when exposed to a magnetic field with a strength ranging from 300 to 5000 oersteds with a field gradient from 10 to 200 ørsted / m. At the same time, at the sorption stage, a regime with increased pressure of 0.3 - 2.9 MPa and low temperatures up to 1-$10^{0\text{ is}}$ used. C, and at the desorption stage, the pressure limits are 0.01-0.1 MPa, and the temperature is 20-90^{0}C.

The implementation of the proposed method is carried out by passing gas emissions at an increased pressure of 0.3-2.9 MPand through a layer of an aqueous alkaline solution having a pH of 7-9 and a temperature of 1-100C, and then within 1-3 minutes the pH is lowered to values of 1-5 in the zone of action of the magnetic field with a field strength of 300-5000 oersted with a field gradient ranging from 10 to 200 oersted / m. The use of a magnetic field with these parameters, as our research has shown, allows, when the pH changes in almost a fraction of a minute, to bring the state of the aqueous solution to an equilibrium one, which can then be effectively used in the stages of sorption-desorption.

At the same time, sorption is carried out in a mode with an increased pressure of 0.3 - 2.9 MPa and low temperatures up to 1-10^{0}C, and desorbation of carbon dioxide from an acidic aqueous solution with a pH of 1-5 is carried out at a reduced pressure in the range of 0.01 - 0.1 MPa and an elevated temperature of 20-90 0 C. The selected parameters of the absorption and desorption modes were justified at a reduced pressure in the range of 0.01 - 0.1 MPa and an increased temperature of 20-90 0 C. The selected parameters of the absorption and desorption modes were justified at a reduced pressure of 0.01 - 0.1 MPa. conducting experimental studies. With parameter values exceeding the declared intervals, the degree of purification fell markedly and in this regard, it was necessary to repeat the technological operation of cleaning gas emissions, and, consequently, to increase operating costs.

Carbon dioxide dissolved in water can be used to produce various products, including soda, dry ice, etc. In Fig. 2.71 schematically shows that in the production process, the main product (P_1) from the main step 2 is received to the final stage of completion 3 and then sent to the customer, the generated waste after pre-treatment in step 1 is sent for use as raw materials at step 5, where the products P_2 are obtained.

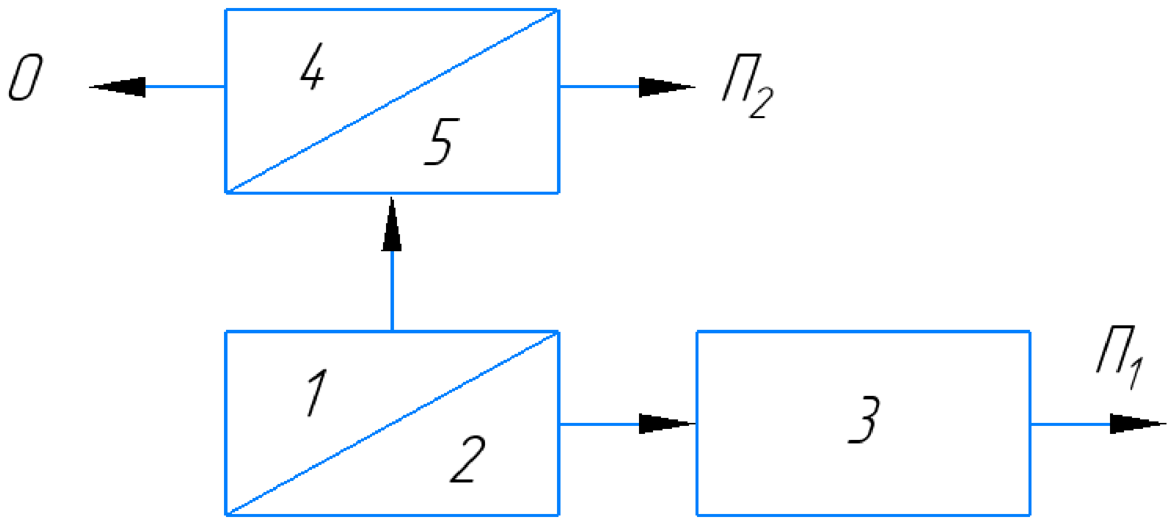


Fig. 2.71. Scheme of production with associated production of carbon dioxide products

Another option for capturing and using carbon dioxide can be implemented using water purification technologies. Earlier, we developed and implemented in the early 90s of the last century a method of pressure flotation with two working fluids, one of which was a saturated solution of carbon dioxide [4].

The process can be intensified by pressure flotation using reagent treatment. Coagulants, flocculants, surfactants are used. This allows you to increase the size of the units, increase their hydrophobicity. The disadvantages of reagent treatment include an increase in the amount of foam, which entails the difficulties of dehydration and disposal of precipitation.

This problem can be partially solved by structural methods, for example, by installing a thin-layer sedimentation or filter after the unit. Secondary saturation of the flotable medium with larger gas bubbles can be carried out. Often saturation is carried out by bubbling. But with this method, in addition to coalescence of bubbles, the destruction of flotation units 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 and several working fluids with gases of different solubility.

This idea was first expressed by B.S. Ksenofontov in 1989 and is studied in detail in a numberof his articles and especially in the monograph [5], and in the broad aspect of possible application is protected by a patent [6].

According to Ksenofontov B.S., with the introduction of one working fluid saturated with air, a bubble of 0.01-0.05 mm on average 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 bubble of carbon dioxide (easily soluble gas). And a bubble of carbon dioxide coalesces through the bubble of air.

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 vehicles are reduced by 1.8 times. There is also a compaction of the foam layer, which is considered in detail in the work. The process of pressure flotation can be intensified by introducing a second working fluid [4]. The introduction of a second working solution - a solution of an easily soluble gas leads to a repetition of the formation of the second phase - gaseous. To form a bubble of an easily soluble gas, it is also necessary to spend energy, and more than when releasing an air bubble, due to the good solubility of the gas, so the release of the second gas also requires the centers of origination. Since instantly, a hard-to-dissolve gas was released from the solution - air, its bubbles and 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 flotological 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 2-3 mm.

Flotation extraction of activated sludge flakes can be described using Ksenofontov's multi-stage model. The flotation extraction process has three states: A, B, C.

State A - the flakes of activated sludge and bubbles in the liquid volume are not connected and do not contact. In the first stage, cotton contacts the gas bubble. In the process of adhesion, a flotation complex of cotton-bubble (state B) is formed, 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. With this approach to the study of flotation extraction and division of the entire process into three states, in general, the whole 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 C_A, C_B, C are the concentrations of activated sludge, respectively, in states A, B, C;

k_1, k_2 are the constants of the rate of transition from state A to state B and vice versa;

k_3, k_4 are the constants of the rate of transition from state B to state C and vice versa;

k_5, k_6 are the constants of the rate of transition from state C to state A and vice versa.

Determining the kinetic constants of the flotation process $k_1 – k_6$ is quite a difficult task, but they allow for detailed studies and scientifically based calculations of devices.

For all constants except k_1, expressions were proposed by B.S. Ksenofontov to calculate them.

Reliable adhesion of flotable particles with air bubbles is ensured by the fact that during pressure flotation the bubble size is minimal and is released directly on the extracted particle.

Experimental studies aimed at intensifying the pressure flotation process by introducing a second working solution (formed by an easily soluble gas) have shown that the average size of gas bubbles in flotation complexes is about 2 mm. For a flotation complex, the size of the bubble in which is ~2 mm, the lifting speedreaches up to 5 cm / s. However, at the same time, the turbulent component of the process also increases significantly, leading to the destruction of complexes and particle precipitation. According to the pilot tests conducted by Ksenofontov B.S., it was found that the flotation process using a solution of $_{CO2}$ as a second working solution) is accelerated by 2 ... 2.5 times [4].

Another use case for water treatment technologies is associated with the use of microalgae using carbon dioxide as a substrate [7]. At the same time, almost twice the mass of carbon dioxide per unit biomass of microalgae is required, or rather this indicator is 1.8. It is also important that microalgae utilize residual nutrients, including nitrogen and phosphorus. This option of growing microalgae at the final stage of wastewater treatment helps to increase the efficiency of wastewater treatment, and makes this technology more competitive.

A similar technological scheme (Fig. 2.72), as a rule, includes the source of carbon dioxide formation (Fig. 2.72). 2.72, pos. 1), carbon dioxide sorption with an aqueous solution (pos. 2), cultivation of microalgae (pos. 3), separation of microalgae biomass 4 and water purification node 5.

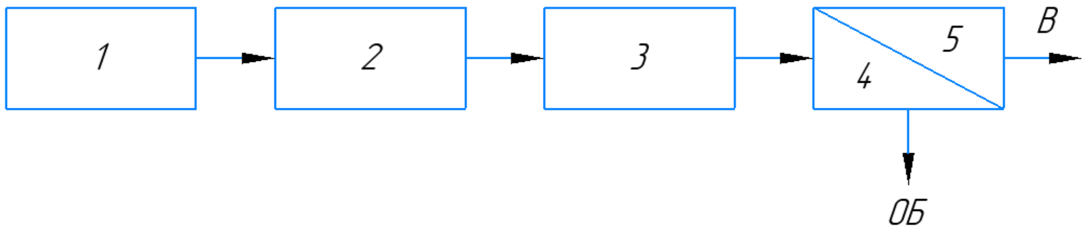


Fig. 2.72 Schematic diagram of carbon dioxide capture and utilization:

1 - the source of carbon dioxide formation, 2 - the sorption of carbon dioxide with an aqueous solution, 3 - the cultivation of microalgae, 4 - the release of microalgae biomass, 5 - the water purification unit, B - purified water, OB - separated biomass.

Eco-energy combains are quite effective equipment for the utilization of greenhouse gases, including carbon dioxide and methane [7].

Methane tanks are known on the basis of wastewater sludge digestion technology [9-12]. The biogas formed in them can be used to generate heat and electricity.

It should be noted that known electric generators include the use of methane tanks with a biogas purification system and an electrical and thermal energy generator.

The disadvantage of well-known eco-energy combains is the low yield of biogas during the fermentation of sewage sludge, as well as the lack of compactness of equipment placement.

An eco-energy combine is known, which includes components in the form of a methane tank with a biogas purification system and an electric and thermal energy generator with electricand thermal energy recovery units.

The disadvantage of the well-known eco-energy combain is the low yield of biogas during the fermentation of sewage sludge.

Such a task is to develop a new design of an eco-energy combain that provides a higher yield of biogas. The technical result is an increase in the efficiency of the process of fermentation of sediment with a higher yield of biogas.

The task and the specified technical result are achieved by the fact that the eco-energy combine [8] includes a cylindrical type methane tank with a biogas purification system and a generator with electric and thermal energy recovery units, and a distinctive feature of which is that all components are located in a single housing made of heat-insulating composite material and a filter for capturing carbon dioxide is placed on top of the housing, and the methane tank used is made with a height exceeding its diameter from 3 to 10 times, respectively, and the electrical and thermal energy recovery units are made of dielectric material.

Figure 2.73 shows the scheme of the eco-energy combain

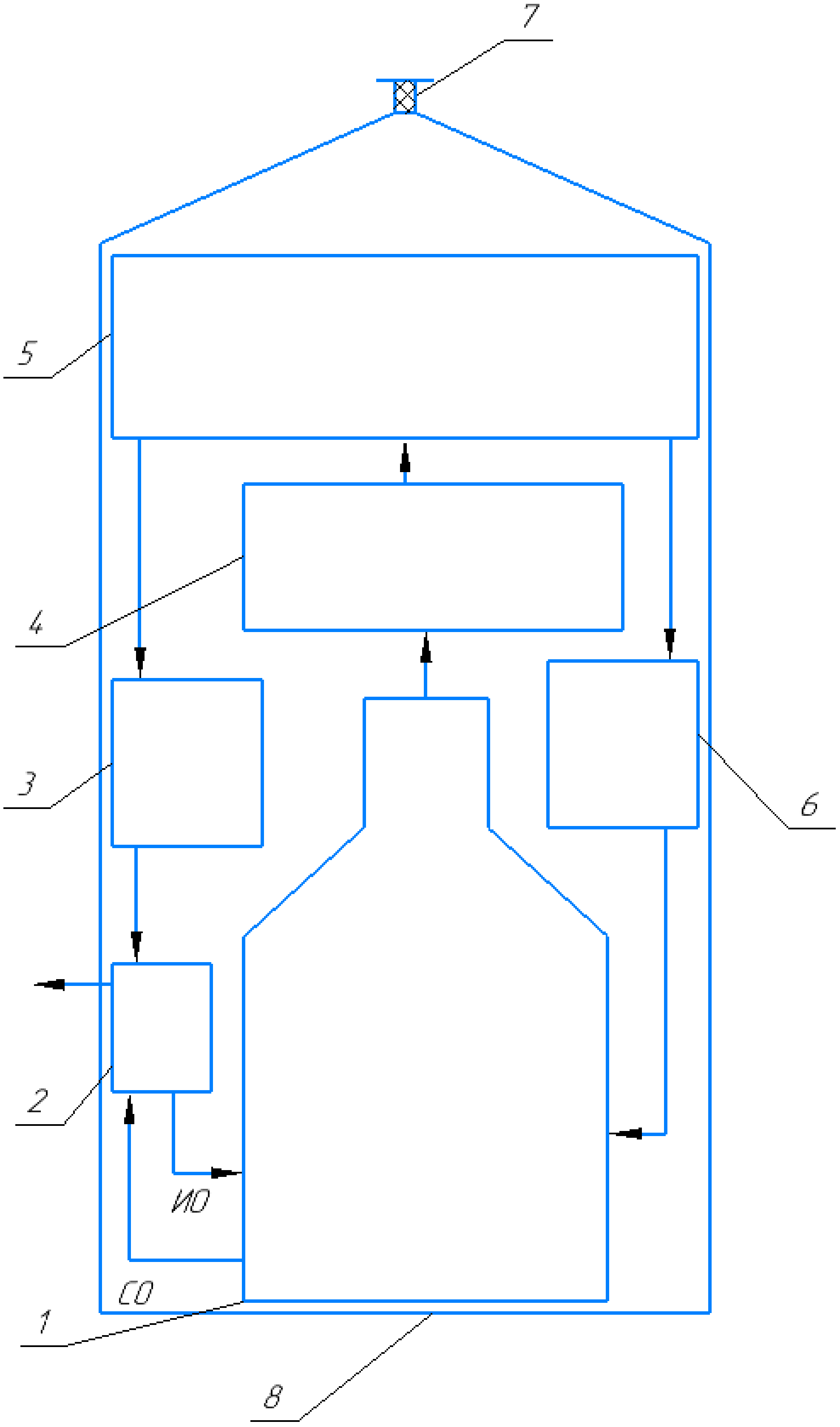


Fig. 2.73. Scheme of eco-power combine

Theproposed eco-energy combine (Figure 2.73) includes a housing 8, in which inside the bottom there is a methane tank of 1 cylindrical type, with a biogas purification system 4 and with a supply and sediment removal unit 2, a gas purification unit, a generator 5 with electric energy recovery units 3 and thermal 6 made of dielectric material, and at the same time at the top of the housing 8 there is a filter for capturing carbon dioxide 7. the height of which is greater than its diameter from 3 to 10 times, and all the components of the eco-energy combain are located in a single case made of heat-shielding composite material.

The principle of operation of the eco-energy combain proposed by the author [8] is as follows. The initial sediment (IO) of wastewater is fed into the methane tank 1 for fermentation. To heat the sludge, a coolant from heat recovery unit 6 of thermal energy is supplied to the methane tank 1. The biogas formed during sludge fermentation is purified in the biogas purification system 4. The purified biogas is further fed into the generator of electrical and thermal energy 5. Generator 5 feeds generated electricity in the recuperator 3, and thermal energy in the recuperator 6, which are sources of further use of electrical and thermal energy. Excess gases are released into the atmosphere through a carbon capture filter 7. Fermented precipitate (CO) is removed from the methane tank for disposal.

The use of the proposed eco-energy combine makes it possible to obtain a biogas yield of about 10-15% more than in the case of the use of known installations, and also that the area occupied by the eco-energy combine is 5-10 times smaller than the area of known installations of the same capacity.

On the basis of the foregoing, the following conclusions can be drawn.

1. For the first time, integrated solutions for the capture and utilization of carbon dioxide using wastewater treatment technologies are proposed.
2. For the first time, a comprehensive hardware design of the process for capturing and utilizing carbon dioxide using eco-energy combines has been proposed.

Control questions for the course "Basics of water treatment and sanitation"

Water treatment

1. Abnormal properties of water.
2. Water quality indicators.
3. SaNPiN "Drinking water" General information.
4. Water intakes are surface and underground.
5. Separation of phytoplankton from water. Prospects for the application of flotation technology.
6. Reagent treatment of natural water.
7. Sedimentation of natural water. Types of sumps.
8. Filtration of natural water. Types of filters.

9. Two-stage scheme of natural water purification.
10. Scheme of water purification at the South-Western water supply station of Moscow.
11. Scheme of deironing water using aeration of water with air and subsequent settling. Description of the principle of operation of the installation, operating according to the above scheme.
12. Scheme of deironing water using catalysts. Describes how an installation operates according to this scheme.
13. The concept of water hardness.
14. Methods of water softening
15. Reagent method of water softening.
16. Use of a vortex reactor for reagent softening of water.
17. Use of ion exchange method for water softening.
18. General information about water degassing.
19. Chemical methods of degassing.
20. Physical methods of degassing.
21. Decribernation of water.
22. Methods of water disinfection.
23. Chlorination of water.
24. Ozonation of water.
25. Ultraviolet water treatment.

Wastewater

1. General information about wastewater disposal systems.
2. Types of wastewater.

3. Approximate composition of municipal wastewater.
4. Approximate composition of surface wastewater.
5. Properties of municipal and industrial wastewater (viscosity, electrical conductivity, etc.)
6. Indicators characterizing the quality of wastewater

(suspended solids, BOD_5 , BOD_{20} , $BOD_{complete}$, COD, permanganate oxidizability, etc.)

7. Ensuring the necessary quality of industrial wastewater before discharge into the city sewerage. Decree of the Government of the Russian Federation No. 644 of July 29, 2013 with comments and additions (list the name of the main indicators and the total number of indicators.
8. What is the reason for the rather stringent requirements of the indicators specified in Resolution No. 644.
9. Wastewater disposal systems for urban and surface waters.
10. All-alloy, separate and semi-separate wastewater sewerage systems. Define and point out the differences.
11. Briefly describe the wastewater disposal systems in Moscow and St. Petersburg.
12. What types of wastewater disposal systems will be used in the Russian Federation in the future?
13. Basics of mechanical wastewater treatment.
14. Grill. Types of grids.
15. Sand traps. Types of sand traps.
16. Recommended parameters when selecting and operating grates.
17. Formulation and solution of the problem of determining the length of horizontal sand traps.
18. Aerated sand traps. Explain the need to use aeration systems in sand traps. Types of aeration systems used in sand traps.
19. Sumps. Classification of settling tanks.
20. Recommended parameters for the selection and operation of settling tanks.

21. Radial sumps. What necessary conditions must be met when commissioning settling tanks, including radial ones.

22. Methods of intensification of water purification in settling tanks, including radial ones.

23. Approximate wastewater compositions of machine-building and instrument-making enterprises and recommendations for their treatment.

24. Composition of municipal wastewater and recommended schemes for their treatment (ITS - BAT).

25. Properties of wastewater.

26. Wastewater disposal systems.

Wastewater disposal systems in Moscow and St. Petersburg.

1. Mechanical wastewater treatment.
2. Grill.
3. Sand traps.
4. Sumps.
5. Drum sieves.
32. The main methods of chemical wastewater treatment.
33. Wastewater neutralization. Basics.
34. Oxidation of wastewater contaminants using the most common oxidants in practice.
35. Advantages and disadvantages of ozonation of wastewater.
36. Use of chlorine-containing substances as an oxidizing agent.
37. Methods of flotation wastewater treatment.
38. Mechanical flotation. The essence of the method. Advantages and disadvantages.
39. Pneumatic flotation. The essence of the method. Advantages and disadvantages.
40. Electroflotation. The essence of the method. Advantages and disadvantages.

Pressure flotation. The essence of the method. Advantages and disadvantages.

41. Adsorption treatment of wastewater. Basics. Advantages and disadvantages.
42. Types of adsorbents. The most commonly used in the practice of wastewater treatment are adsorbents.
43. The most commonly used carbon adsorbents.
44. Membrane methods of post-treatment of wastewater. Basics.
45. The difference between membranes used for post-treatment of wastewater and membranes used in water treatment.
46. Features of wastewater disinfection.
47. Chlorination of wastewater. Advantages and disadvantages.
48. Ozonation of wastewater. Advantages and disadvantages.
49. Treatment of wastewater with ultraviolet light. Advantages and disadvantages.
50. Basics of biological wastewater treatment.
51. Composition of activated sludge. The role of bacteria in biological wastewater treatment processes.
52. Biological methods of removal of biogenic elements.
53. Processes of nitrification and denitrification.
54. Chemical and biological methods of removing phosphorus from wastewater.
55. Technological schemes for the removal of nutrients of the Universities of Cape Town and Johannesburg.
56. Removal of biogenic elements using the Bardenfo method.
57. Use of membrane bioreactors in technologies of biological wastewater treatment.
58. The concept of the age of active sludge. Aerobic and general age of activated sludge.
59. Microbiological bases of biological removal of biogenic elements.
60. Recommendations for the operation of biological treatment plants.
61. Recommendations for preventing the swelling of activated sludge.

62. The main causes of swelling of activated sludge.

63. The concept of the silt index.

Annex 1

Section 1. Hygienic requirements and standards for the quality of drinking water (sanitary-epidemiological rules and regulations "Drinking water. Hygienic requirements for water quality of centralized drinking water supply systems. Quality control. SanPiN 2.1.4.1074-01", approved by the Chief State Sanitary Doctor of the Russian Federation on 26.09.2001)

3.1. Drinking water should be safe in epidemic and radiation terms, harmless in chemical composition and have favorable organoleptic properties.

3.2. The quality of drinking water must comply with hygienic standards before it enters the distribution network, as well as at the points of water intake of the external and internal water supply network.

3.3. The safety of drinking water in epidemic terms is determined by its compliance with the standards for microbiological and parasitological indicators presented in Table P-1.1.

Table P-1.1

Indicators	Units	Standards
Thermotolerant coliform bacteria	Number of bacteria per 100 ml	Absence
Common coliform bacteria	Number of bacteria per 100 ml	Absence
Total microbial number	Number of colony-forming bacteria in 1 ml	Not more than 50
Coliphages	Number of plaque-forming units (BOE) per 100 ml	Absence
Spores of sulfi-reducing clostridia	Number of spores in 20 ml	Absence
Cysts of giardia	Number of cysts in 50 l	Absence

Notes:

1) In the determination, a three-fold study of 100 ml of the selected water sample is carried out.

(2) Exceeding the standard shall not be allowed in 95 per cent of the samples taken at the water intake points of the external and internal water supply network within 12 months, with the number of samples examined at least 100

per year.

(3) The determination shall be carried out only in water supply systems from surface sources before supplying water to the distribution network.

4) The determination is carried out when assessing the effectiveness of water treatment technology.

3.3.1. When studying microbiological indicators of the quality of drinking water in each sample, thermotolerant coliform bacteria, total coliform bacteria, total microbial number and coliphages are determined.

3.3.2. If thermotolerant coliform bacteria and (or) common coliform bacteria and (or) coliphages are detected in a drinking water sample, they are determined in repeated water samples taken on an emergency basis. In such cases, chlorides, ammonium nitrogen, nitrates and nitrites are simultaneously determined to identify the causes of pollution.

3.3.3. If total coliform bacteria in an amount of more than 2 in 100 ml and (or) thermotolerant coliform bacteria and (or) coliphages are found in repeated water samples to determine pathogenic bacteria of the intestinal group and (or) enteroviruses.

3.3.4. Studies of drinking water for the presence of pathogenic bacteria of the intestinal group and enteroviruses are also carried out according to epidemiological indications by the decision of the state sanitary and epidemiological surveillance center.

3.3.5. Water tests for the presence of pathogenic microorganisms can be carried out only in laboratories that have a sanitary and epidemiological conclusion on the compliance of the conditions for performing work with sanitary rules and a license for activities related to the use of infectious disease pathogens.

3.4. The harmlessness of drinking water by chemical composition is determined by its compliance with the standards for:

3.4.1. generalized indicators and content of harmful chemicals most commonly found in natural waters on the territory of the Russian Federation, as well as substances of anthropogenic origin that have become globally distributed (Table 2);

3.4.2. the content of harmful chemicals entering and forming in the water during its treatment in the water supply system (Table P-1.2);"

3.4.3. Content of harmful chemicals entering water supply sources as a result of human economic activity (Appendix 2).

Table P-1-2

Indicators	Units	Standards (maximum permissible concentrations (MPC), not more than	Harmfulness index	Hazard class
1	2	3	4	5
Generalized indicators				
Hydrogen index	pH units	within 6-9		
Total mineralization (dry residue)	mg/l	1000 (1500)		
Overall stiffness	mg-eq./l	7,0 (10)		
Oxidizability permanganate	mg/l	5,0		
Petroleum products, total	mg/l	0,1		
Surfactants(surfactants), anion-active	mg/l	0,5		
Phenolic index	mg/l	0,25		

Inorganic substances				
Aluminium (Al)	mg/l	0,5	s.-t.	2
Barium (IA)	-"-	0,1	-"-	2
Beryllium (Ve)	-"-	0,0002	-"-	1
Boron (B, total)	-"-	0,5	-"-	2
Iron (Fe, total)	-"-	0,3 (1,0)	org.	3
Cadmium (Cd, total)	-"-	0,001	s.-t.	2
Manganese (Mn, total)	-"-	0,1(0,5)	org.	3
Copper (Cu, total)	-"-	1,0	-"-	3
Molybdenum (Mo, total)	-"-	0,25	s.-t.	2
Arsenic (As, total)	-"-	0,05	s.-t.	2
Nickel (Ni, total)	mg/l	0,1	s.-t.	3
Nitrates (by)	-"-	45	s.-t.	3
Mercury (Hg, total)	-"-	0,0005	s.-t.	1
Lead (Pb, total)	-"-	0,03	-"-	2
Selenium (Se, total)	-"-	0,01	-"-	2
Strontium (Sr)	-"-	7,0	-"-	2
Sulfates (SO)	-"-	500	org.	4
Fluorides (F)				
for climatic regions				
- I и II	-"-	1,5	s.-t.	2
- III	-"-	1,2		2
Chlorides (Cl)	-"-	350	org.	4
Chromium (Sr)	-"-	0,05	s.-t.	3
Cyanides (CN'')	-"-	0,035	-"-	2

Zinc (Zn)	-"-	5,0	org.	3
Organic matter				
-GHCG (lindane)	-"-	0,002	s.-t.	1
DDT (Sum of Isomers)	-"-	0,002	-"-	2
2,4-D	-"-	0,03	-"-	2

Notes:

1) The limiting feature of the harmfulness of the substance, for which the standard is established: "s.-t." - sanitary-toxicological, "org." - organoleptic.

(2) The value indicated in parentheses may be established by a decision of the Chief State Sanitary Doctor for the relevant territory for a particular water supply system on the basis of an assessment of the sanitary and epidemiological situation in the locality and the water treatment technology used.

3) The standards have been adopted in accordance with WHO recommendations.

Table P-1.3

Indicators	Units	Standards (maximum permissible concentrations (MPC), not more than	Harmfulness index	Hazard class
Chlorine				
- residual free	mg/l	in the range of 0,3-0,5	org.	3
- residual linked	-"-	in the range of 0,8-1,2	-"-	3

Chloroform (when chlorinating water)	-"-	0,2	s.-t.	2
Residual ozone	-"-	0,3	org.	
Formaldehyde (when ozonizing water)	-"-	0,05	s.-t.	2
Polyacrylamide	-"-	2,0	-"-	2
Activated silicic acid (according to Si)	-"-	10	-"-	2
Polyphosphates (by)	-	3,5	org.	3
Residual amounts of aluminium- and iron-containing coagulants	-"-	see indicators "Aluminium", "Iron" of table 2		

Notes:

(1) When disinfecting water with free chlorine, the time of contact with water should be at least 30 minutes, with chlorine bound - at least 60 minutes. The residual chlorine content is monitored before water is supplied to the distribution network. With the simultaneous presence of free and bound chlorine in the water, their total concentration should not exceed 1.2 mg / l. In some cases, in coordination with the center of state sanitary and epidemiological surveillance, an increased concentration of chlorine in drinking water may be allowed.

2) The standard was adopted in accordance with WHO recommendations.

(3) The residual ozone content shall be monitored after the mixing chamber with a contact time of at least 12 minutes.

3.4.4. When several chemicals belonging to hazard classes 1 and 2 and standardized for the sanitary and toxicological sign of harmfulness are detected in drinking water, the sum of the ratios of the detected concentrations of each of them in water to the value of its MPC should not be more than 1. The calculation is carried out according to the formula: where , , - concentrations of individual chemicals of hazard class 1 and 2: fact. (actual) and add. (permissible).

$$\frac{C^{1}_{\text{факт}}}{C^{1}_{\text{доп}}} + \frac{C^{2}_{\text{факт}}}{C^{2}_{\text{доп}}} + \ldots\ldots + \frac{C^{n}_{\text{факт}}}{C^{n}_{\text{доп}}} \leq 1,$$

3.5. Favorable organoleptic properties of water are determined by its compliance with the standards specified in Table P-1.4, as well as the standards for the content of substances that affect the organoleptic properties of water, given in Tables 2 and 3 and in Appendix 2.

Table P-1.4 Post requirements

Indicators	Units	Standards, not more than
Smell	Points	2
Smack	-"-	2
Chromaticity	Degrees	20 (35)
Turbidity	EMF (formazine turbidity units) or mg/L (kaolin)	2,6 (3,5)1,5 (2)

Note: The value indicated in parentheses can be established by the decision of the Chief State Sanitary Doctor for the relevant territory for a particular water supply system on the basis of an assessment of the sanitary and epidemiological situation in the settlement and the water treatment technology used.

3.5.1. The presence in drinking water of aquatic organisms and surface film distinguishable to the naked eye shall not be allowed.

3.6. Radiation safety of drinking water is determined by its compliance with radiation safety standards according to the indicators presented in Table P-1. 5.

Table P-1.5

Indicators	Units	Radiation safety indicators
Summary		
Specific total -activity	Bq/kg	0,2
Specific total -activity	Bq/kg	1,0
Radionuclides		
Радон (Rn)	Bq/kg	60
Radionuclides	Units	1,0

Notes: If the indicators are exceeded, the content of radionuclides in the water is analyzed. The list of detectable radionuclides in water is established in accordance with sanitary legislation. The determination of radon for underground water supply sources is mandatory. With the joint presence of several radionuclides in the water, the condition (A / UV) 1, where A is the specific activity of the i-th radionuclide in the water, must be met; Hydrocarbon - the appropriate level of intervention in accordance with

Annex 2a to SanPiN 2.6.1.2523-09* "Radiation safety standards (NRB-99/2009)". In case of non-fulfillment of the condition, water assessment is carried out in accordance with sanitary legislation"._ (Paragraph 3.6 as amended on 1 May 2010 Amendment No. 2 of February 25, 2010. - See above. previous editing http://docs.cntd.ru/document/902212546I.E.)

3.6.1. Clause is deleted from May 1, 2010 by Amendment No. 2 dated February 25, 2010.

Section 2. Example of requirements for the quality of water used in washing operations in electroplating shops (Enlarged norms of water consumption and sanitation for various industries. 2nd ed., pererab. M.: Stroyizdat, 1982. P. 413-414)

Here is an example of the requirements for water used in electroplating and pcb shops. Water in these industries is mainly used in the operations of washing parts and only in a small amount in other technological processes. Requirements for the water used are given in Table P-1.6.

Table P-1.6

Requirements for the quality of water used in washing operations in electroplating shops

Indicators	Unit measure ments	Water used in production facilities					
		precision instruments			Engineering		
		1*	2*	3*	1*	2*	3*
Suspended solids	mg/l	1	2	5	5	10	50
Overall stiffness	mg-eq./l	0,36	1,07	1,79	1,79	5,36	10,72
Dry residue	mg/l	5	10	50	50	300	3000
Concentration:							
Fобщ	mg/l	0,1	0,2	0,5	0,5	1	5
Mg2+	mg/l	0,1	0,2	0,5	0,5	1	2

SO42–	Ditto	10	20	40	40	200	500
Cl–	-”-	10	20	40	40	200	500
NH4	-”-	3	7	15	15	40	300
CO2	-”-	1	5	10	10	20	200

1* - water for the preparation and adjustment of electrolytes; 2* - water for pre-washing before coating baths and for final washing; 3* - water for the preparation of pickling solutions and irresponsible washings.

Section 3

Table P-1.7 General requirements for industrial wastewater discharged into urban sewage SystemAppendum No. 5

to the Cold Water Supply Regulations

and wastewater disposal

LIST

MAXIMUM PERMISSIBLE VALUES OF NORMATIVE INDICATORS

GENERAL PROPERTIES OF WASTEWATER AND CONCENTRATIONS OF CONTAMINANTS

SUBSTANCES IN WASTEWATER INSTALLED FOR

PREVENTION OF NEGATIVE IMPACT ON WORK

CENTRALIZED WASTEWATER DISPOSAL SYSTEMS

Name of substances (indicator)	Unit	Maximum permissible value of the indicator and	Group	Coefficient of exposure of a pollutant or indicator of the properties of	The ratio of ACi "1" to PCi "2" or the value of the

			(or) concentration (according to the gross content in the natural sample of wastewater)		wastewater on centralized wastewater disposal systems	indicator at which the excess is gross
I. Maximum permissible values of normative indicators of general properties of wastewater and concentrations of pollutants in wastewater, established in order to prevent negative impact on the operation of centralized all-alloy and household wastewater disposal systems, as well as centralized combined wastewater disposal systems (in relation to discharge into all-alloy and domestic wastewater disposal systems)						
1.	Informed Substances	mg/dm3	300	1	0,7 "7"	3
2.	BOD5	mg/dm3	300 (500 "3")	1	0,7 "7"	3
3.	COD	mg/dm3	500 (700 "3")	1	0,7 "7"	3
4.	Total nitrogen	mg/dm3	50	1	0,7 "7"	3
5.	Total phosphorus	mg/dm3	12	1	0,7 "7"	3
6.	Petroleum products	mg/dm3	10	2	1	3
7.	Chlorine and chloramines	mg/dm3	5	2	2	2
8.	Correlation COD:BOD5	-	2,5 "4"	2	0,5	1,3
9.	Phenols (total)	mg/dm3	5	2	5	3
10.	Sulfides (S-H2S+S2-)	mg/dm3	1,5 "5"	3	2	2
11.	Sulphates	mg/dm3	1000 "5"	3	2	2
12.	Chlorides	mg/dm3	1000 "5"	3	2	2
13.	Aluminium	mg/dm3	5	4	2	3
14.	Iron	mg/dm3	5	4	2	3
15.	Manganese	mg/dm3	1	4	2	3
16.	Copper	mg/dm3	1	4	2	3

17.	Zinc	mg/dm3	1	4	2	3
18.	Chromium general	mg/dm3	0,5	4	2	3
19.	Hexavalent chromium	mg/dm3	0,05 (0,1 "6")	4	2	3
20.	Nickel	mg/dm3	0,25 (0,5 "6")	4	2	3
21.	Cadmium	mg/dm3	0,015 (0,1 "6")	4	2	3
22.	Lead	mg/dm3	0,25	4	2	3
23.	Arsenic	mg/dm3	0,05 (0,1 "6")	4	2	3
24.	Mercury	mg/dm3	0,005	4	2	3
25.	Hydrogen index (pH)	Units	6 - 9 "5"		1 (at 5.5 " pH" 6 and 9" PH " 10), 2 (at 10 pH from "11), 3 (at 5" pH 5.5 and 11 pH 12), 5 (pH at 4.5 5)	values of the indicator less than 5 and more than 11
26.	Temperature	°C	+40 "5"	-	0,5 (+40 " FC " +50), 1 (+50 FC "+60), 2 (+60 FC "+70), 3 (+70 FC " +80)	+60 or more
27.	Fats	mg/dm3	50 "5"	-	1	3
28.	Volatile organic compounds (VOCs) (including toluene, benzene, acetone, methanol, butanol, propanol, their isomers and alkyl derivatives by the sum of VOCs)	mg/dm3	20 "5"	-	1	2
29.	SPAV non-ionogenic	mg/dm3	10	5	0,6	3
30.	SPAV anionnye	mg/dm3	10	5	0,6	3

31.	Polychlorinated biphenyls (PCB amount)	mg/dm3	0,001	-	1	5

II. Maximum permissible values of normative indicators of the general properties of wastewater and concentrations of pollutants in wastewater, established in order to prevent a negative impact on the operation of centralized storm water disposal systems, as well as centralized combined wastewater disposal systems (in relation to discharge into storm drainage systems)

32.	Suspended substances	mg/l	300	1	0,7 "7"	3
33.	BPK5	mg/l	30	1	0,7 "7"	3
34.	Ammonium nitrogen	mg/l	2	1	0,7 "7"	3
35.	Petroleum products	mg/l	8	2	1	3
36.	Sulfides	mg/l	1,5 "5"	3	2	2
37.	Sulfates	mg/l	500 "5"	3	2	2
38.	Chlorides	mg/l	1000 "5"	3	2	2
39.	Hydrogen index (pH)	Units	6 - 9 "5"	-	1 (at 5.5" pH " 6 and 9 " pH " 10), 2 (at 10 pH " 11), 3 (at 5 " pH 5.5 and 11 pH 12), 5 (at 4.5 pH 5)	values of the indicator less than 5 and more than 11
40.	Temperature	°C	+40 "5"	-	0,5 (+40 " FC " +50), 1 (+50 FC "+60), 2 (+60 FC "+70), 3 (+70 FC " +80)	+60 or more

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"1" ACi is the actual concentration of the i-th pollutant or the actual indicator of the properties of the subscriber's wastewater declared by the subscriber in the declaration or recorded in the subscriber's wastewater control sample taken by the wastewater disposal organization at a specific sewage outlet (mg/cubic dm). If the subscriber has several outlets to the wastewater disposal system and if there are no wastewater meters on them (except for cases of determining the volume of wastewater from the data of the balance of water consumption and sanitation), the average value of the concentration of the pollutant (an indicator of the properties of wastewater) for the outlets on which the maximum permissible values were exceeded is taken as the ACi value.

"2" PCi is the maximum permissible concentration of the i-th pollutant or the wastewater characteristics specified in this Annex (mg/cc dm).

"3" Requirements for discharge into a centralized all-alloy drainage system.

"4" The COD:BOD5 ratio applies if the COD level exceeds 500 mg/dm3. For discharges into the all-alloy centralized wastewater disposal system, the COD:BOD5 ratio is applied if the COD level of 700 mg/dm3 is exceeded.

"5" Requirements established in order to prevent adverse effects on sewage networks.

"6" When the organization carrying out water disposal uses thermal methods of neutralization of sewage sludge.

"7" Applies until December 31, 2017, from January 1, 2018 to December 31, 2018, the impact coefficient of 0.9 is applied, from January 1, 2019 - 1.2.

Table P-2.7 Post requirements

Annex No. 5k to the Rules of Cold Water Supply and Wastewater Disposal (as amended by the Government Decree of the Republic of Moldova no. 1134 on November 3, 2016)

List of maximum permissible values of normative indicators of general properties of wastewater and concentrations of pollutants in wastewater, established in order to prevent negative impact on the operation of centralized wastewater disposal systems

Name of substances (indicator)	Unit	Maximum permissible value of the indicator and (or) concentration (according to the	Group	Coefficient of exposure of a pollutant or indicator of the properties of wastewater on	The ratio of ACi(1) to PCi(2) or the value of the indicator at

		gross content in the natural sample of wastewater)		centralized wastewater disposal systems	which the excess is gross
I. Maximum permissible values of normative indicators of general properties of wastewater and concentrations of pollutants in wastewater, established in order to prevent negative impact on the operation of centralized all-alloy and household wastewater disposal systems, as well as centralized combined wastewater disposal systems (in relation to discharge into all-alloy and domestic wastewater disposal systems)					
1. Suspended solids	mg/dm3	300	1	0,7(7)	3
2. BOD5	mg/dm3	300 (500(3))	1	0,7(7)	3
3. COD	mg/dm3	500 (700(3))	1	0,7(7)	3
4. Total nitrogen	mg/dm3	50	1	0,7(7)	3
5. Total phosphorus	mg/dm3	12	1	0,7(7)	3
6. Petroleum products	mg/dm3	10	2	1	3
7. Chlorine and chloramines	mg/dm3	5	2	2	2
8. COD ratio: BOD5	-	2,5(4)	2	0,5	1,3
9. Phenols (total)	mg/dm3	5	2	5	3
10. Sulfides (S-H2S+S2-)	mg/dm3	1,5(5)	3	2	2
11. Sulphates	mg/dm3	1000(5)	3	2	2
12. Chlorides	mg/dm3	1000(5)	3	2	2
13. Aluminium	mg/dm3	5	4	2	3
14. Iron	mg/dm3	5	4	2	3
15. Manganese	mg/dm3	1	4	2	3
16. Copper	mg/dm3	1	4	2	3

17. Zinc	mg/dm3	1	4	2	3
18. Chromium general	mg/dm3	0,5	4	2	3
19. Chromium hexavalentыу	mg/dm3	0,05 (0,1(6))	4	2	3
20. Nickel	mg/dm3	0,25 (0,5(6))	4	2	3
21. Cadmium	mg/dm3	0,015 (0,1(6))	4	2	3
22. Lead	mg/dm3	0,25	4	2	3
23. Arsenic	mg/dm3	0,05 (0,1(6))	4	2	3
24. Mercury	mg/dm3	0,005	4	2	3
25. Hydrogen index (pH)	Units	6 - 9(5)	-	1 (at 5,5<pH<6 и 9<pH<10), 2 (at), $10 \leq pH < 11$ 3 (at $5 < pH \leq 5,5$ and $11 \leq pH \leq 12$), 5 (at $4,5 \leq pH \leq 5$)	values of the indicator less than 5 and more than 11
26. Temperature	°C	+40(5)	-	0,5 (+40<AC<+50), 1 ($+50 \leq ФК < +60$), 2 ($+60 \leq ФК < +70$), 3 ($+70 \leq ФК < +80$)	+60 or more
27. Fats	mg/dm3	50(5)	-	1	3

28. Volatile Organic Compounds (VOC) (including toluene, benzene, acetone, methanol, butanol, propanol, their isomers and alkyl derivatives by the amount of VOC)	mg/dm3	20(5)	-	1	2
29. SPAV non-ionogenic	mg/dm3	10	5	0,6	3
30. SPAV anionnye	mg/dm3	10	5	0,6	3
31. Polychlorinated biphenyls (PCB amount)	mg/dm3	0,001	-	1	5

II. Maximum permissible values of normative indicators of the general properties of wastewater and concentrations of pollutants in wastewater, established in order to prevent a negative impact on the operation of centralized storm water disposal systems, as well as centralized combined wastewater disposal systems (in relation to discharge into storm drainage systems)

32. Suspended solids	mg/l	300	1	0,7(7)	3
33. BOD5	mg/l	30	1	0,7(7)	3
34. Ammonium nitrogen	mg/l	2	1	0,7(7)	3
35. Petroleum products	mg/l	8	2	1	3
36. Sulfides	mg/l	1,5(5)	3	2	2
37. Sulphates	mg/l	500(5)	3	2	2
38. Chlorides	mg/l	1000(5)	3	2	2
39. Hydrogen index (pH)	Units	6 - 9(5)	-	1 (при 5,5<pH<6 и 9<pH<10), 2 (at $10 \le pH < 11$), 3 (at $5 < pH \le 5,5$ and $11 \le pH \le 12$	values of the indicator less than 5 and more than 11

				), 5 (at $4,5 \le pH \le 5$)	
40. Temperature	°C	+40(5)	-	0,5 (+40<ФК<+50), 1 ($+50 \le ФК < +60$), 2 ($+60 \le ФК < +70$), 3 ($+70 \le ФК < +80$)	+60 or more

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(1) ACi - the actual concentration of the i-th pollutant or the actual indicator of the properties of the subscriber's wastewater declared by the subscriber in the declaration or recorded in the subscriber's wastewater control sample taken by the water disposal organization at a specific sewage outlet (mg/cubic dm). If the subscriber has several outlets to the wastewater disposal system and if there are no wastewater meters on them (except for cases of determining the volume of wastewater from the data of the balance of water consumption and sanitation), the average value of the concentration of the pollutant (an indicator of the properties of wastewater) for the outlets on which the maximum permissible values were exceeded is taken as the ACi value.

(2) PCi is the maximum permissible concentration of the i-th pollutant or the wastewater characteristics specified in this Annex (mg/cc dm).

(3) Requirements established for discharge into a centralized all-alloy wastewater disposal system.

(4) The COD:BOD5 ratio shall be applied if the COD level of 500 is exceeded. For discharges into the all-alloy centralized wastewater disposal system, the COD:BOD5 ratio is applied if the COD level of 700 is exceeded.$мг/дм^3$ $мг/дм^3$

(5) Requirements established in order to prevent negative impact on sewage networks.

(6) When a wastewater disposal organization applies thermal methods for the neutralization of sewage sludge.

(7) Apply until 31 December 2017, from 1 January 2018 to 31 December 2018 the impact coefficient of 0.9 shall apply, from 1 January 2019 - 1.2.

Amendments that are made to the acts of the Government of the Russian Federation (utv. Decree of the Government of the Russian Federation No. 644 of July 29, 2013)

With changes and additions from:

Dec. 30, 2013, Nov. 14, 2014

1. Paragraphs 1 - 8, 10 - 18, 32 - 60, 63, 66, 68 and 72 - 94 of the Rules for the Use of Public Water Supply and Sewerage Systems in the Russian Federation, approved by the Decree of the Government of the Russian Federation dated February 12, 1999 No. 167 (Collected Legislation of the Russian Federation, 1999, No. 8, Article 1028; 2003, No. 33, Article 3269; 2006, No. 8, Art. 920; No. 23, art. 2501; 2012, No. 27, Art. 3745), to declare invalid.

2. In the Decree of the Government of the Russian Federation dated February 13, 2006 No. 83 (Collected Legislation of the Russian Federation, 2006, No. 8, Art. 920; 2010, No. 21, Art. 2607; No. 50, art. 6698; 2012, No. 17, art. 1981):

a) in the Rules for determining and providing technical conditions for connecting a capital construction object to engineering and technical support networks approved by the said resolution:

the fifth paragraph of paragraph 4 should be supplemented by the words "heat, water supply and sanitation schemes";

In paragraph 7:

the first paragraph, after the words "of local importance," should be supplemented by the words "heat, water supply and sanitation schemes";

the second paragraph should be supplemented by the words "as well as in cases of connection to centralized water supply and (or) wastewater disposal systems";

the eighth paragraph of paragraph 8 should be supplemented by the words "as well as the types of connected engineering networks";

In paragraph 11:

The fifth paragraph, after the words "to engineering and technical support networks", should be supplemented by the words "(with the exception of engineering and technical support networks used in the process of cold water supply and sanitation)";

Add the following paragraph:

"The fee for connection to engineering and technical support networks used in the process of cold water supply and sanitation is determined in accordance with the Federal Law "On Water Supply and Sanitation".";

In paragraph 12:

the second paragraph, after the words "relevant resources", should be supplemented by the words "and the reception of wastewater";

The fourth paragraph should be supplemented by the words ", and with regard to heat, water supply and sanitation networks, also taking into account the schemes of heat, water supply and sanitation";

In paragraph 13:

the first paragraph, after the words "to engineering and technical support networks", should be supplemented by the words "(with the exception of engineering and technical support networks used in the process of cold water supply and sanitation)";

Add the following paragraph:

"If there is a technical possibility of connection (technological connection) to engineering and technical support networks used in the process of cold water supply and sanitation, and if there is free capacity necessary for the implementation of cold water supply and (or) wastewater disposal, the organization operating these networks is not entitled to refuse to issue technical specifications.";

In paragraph 17:

the second paragraph, after the words "to engineering and technical support networks", should be supplemented by the words "(with the exception of engineering and technical support networks used in the cold water supply and sanitation process)";

Add the following paragraph:

"The fee for connection (technological connection) to engineering and technical support networks used in the process of cold water supply and sanitation is determined in accordance with the Federal Law "On Water Supply and Sanitation".";

b) ceased to be in force on March 1, 2014.

Section 4

Protection of water bodies from pollution is carried out in accordance with the "Sanitary Rules and Norms for the Protection of Surface Water from Pollution". The rules include general requirements for water users in terms of wastewater discharge into water bodies. The rules establish two categories of water bodies:

I - water bodies for drinking and cultural purposes;

II - water bodies for fishery purposes.

The composition and properties of water in type II water bodies must comply with the standards at the place of wastewater release with a dissipation release (if there are currents), and in the absence of a scattering outlet - no further than 500 m from the place of release.

The rules establish standardized values for the following water parameters of water bodies: the content of floating impurities and suspended particles, odor, taste, color and temperature of water, pH value, composition and concentration of mineral impurities and oxygen dissolved in water, biological water demand for oxygen, composition and maximum permissible concentration (MPC) of toxic and harmful substances and pathogenic bacteria.

The maximum permissible concentration is the concentration of a harmful (poisonous) substance in the water of the reservoir, which, with daily exposure for a long time to the human body, does not cause any pathological changes and diseases, including in subsequent generations detected by modern methods of research and diagnosis, and also does not violate the biological optimum in the reservoir.

Harmful and poisonous substances are diverse in their composition, and therefore they are standardized according to the principle of a limiting indicator of harmfulness (LIH), which is understood as the most likely adverse effects of this substance.

For water bodies of the first type, three types of HDL are used: sanitary-toxicological, general sanitary and organoleptic, for water bodies of the second type - in addition, two more types: toxicological and fishery.

The MPC has been established for more than 400 harmful basic substances in drinking and cultural water bodies, as well as more than 100 harmful basic substances in fishery reservoirs. Table P-1.8 shows the MPC of some substances entering the water of water bodies.

Table P-1.8. Standard MPC of treated wastewater entering the reservoir for fishery purposes.

No p/p	Name of the indicator	Standard MPC of treated wastewater entering the reservoir for fishery purposes
1.	Hydrogen index	pH 6,0-9,0
2.	Nitrates	9 mg/dm3
3.	Iron	0,1 mg/dm3
4.	Sulphates	100 mg/dm3
5.	Chlorides	300 mg/dm3
6.	SLEPT	0,5 mg/dm3
7.	Petroleum products	0,05 mg/dm3
8.	Ammonium (on nitrogen)	0,4 mg/dm3
9.	Ammonium ion	0,5 mg/dm3
10.	Nitrites	0,2 mg/dm3
11.	BOD is full.	3 mgO2/dm3

12.	Phosphate ion	0,2 mg/dm3
13.	Phosphates by(P)	1-2 mg/dm3
14.	Alkalinity	pH 7-9
15.	Suspended solids	10 mg/dm3
16.	Aluminium	0,04 mg/dm3
17.	Barium	0,74 mg/dm3
18.	Copper	0,001 mg/dm3
19.	Mercury	Absence
20.	Lead	0,1 mg/dm3
21.	Phenol	0,001 mg/dm3
22.	Fluoride	0,75 mg/dm3
23.	Chromium	0,07 mg/dm3
24.	Zinc	0,01 mg/dm3
25.	COD	30 mgO2/dm3

The MPC standards were approved by the Order of the Committee of the Russian Federation on Fisheries No. 20 "On Approval of Water Quality Standards for Water Bodies of Fishery Significance, including Standards for Maximum Permissible Concentrations of Harmful Substances in the Waters of Water Bodies of Fishery Significance".

The criterion of the quality (suitability) of water for fishery water use is determined by the presence in the water of conditions that ensure the stocks of commercial fish and other aquatic organisms and a certain level of their catches. The maximum permissible concentration is considered to be a substance that does not adversely affect the sanitary regime of the reservoir and aquatic organisms of the weakest biological link in relation to this substance.

Water quality standards for water bodies used for fisheries purposes are established for two types of water use: the first type includes water bodies used for the reproduction and conservation of valuable varieties of fish; to the second - water bodies used for all other fishery purposes. The type of fishery use of the reservoir is determined by the Fish Protection bodies, taking into account the prospective development of fisheries and fishing.

Comparing the maximum permissible concentrations developed by us for fishery reservoirs with the approved ICG for public water bodies, we see that they do not always coincide. This is understandable, since there can be no uniform regulatory requirements for water bodies of different water use. The interests of health and fisheries in the problem of protecting water bodies from pollution are quite close, but do not always coincide, since harmful substances contained in wastewater affect humans and fish in various ways, as well as the feed facilities of the latter (Table 1.9)

Table 1.9. General requirements for the composition and properties of water

Indicators of the composition and properties of water bodies	Category of water use	
	highest and first	Second
Suspended solids	When discharge of return (waste) water by a specific water user, work on a water body and in the coastal zone, the content of suspended substances in the control leaf (point) should not increase in comparison with natural conditions by more than:	
	0,25 mg/dm3	0,75 mg/dm3
	In water bodies of fishery importance, when the content of natural suspended substances in the boundary is more than 30 mg / dm3, an increase in their content in the water within 5% is allowed.	
	Return (waste) water containing suspended solids with a deposition rate of more than 0.4 mm/s is prohibited from being discharged into watercourses and more than 0.2 mm/s. – water bodies	
Floating impurities (substances)	On the surface of the water should not be detected films of petroleum products, oils, fats and accumulations of other impurities	

<table>
<tr><td rowspan="2">Temperature</td><td colspan="2">The water temperature should not rise by more than 5 °C compared to the natural temperature of the water body, with a total temperature increase of not more than 20 °C in summer and 5 °C in winter for water bodies inhabited by cold-loving fish (salmon and whitefish) and not more than 28 °C in summer and 8 °C in winter in other cases.</td></tr>
<tr><td colspan="2">In places of burbot spawning grounds, it is forbidden to increase the water temperature in winter by more than 2 ° C</td></tr>
<tr><td>Hydrogen index (pH)</td><td colspan="2">Must not go beyond 6.5 - 8.5</td></tr>
<tr><td>Mineralization of water</td><td colspan="2">Standardized according to the categories of fishery water bodies or its sections</td></tr>
<tr><td rowspan="3">Dissolved oxygen</td><td colspan="2">In the winter (subglacial) period should be at least</td></tr>
<tr><td>6,0 mg/dm3</td><td>4,0 mg/dm3</td></tr>
<tr><td colspan="2">In the summer (open) period in all water bodies should be at least 6 mg / dm3</td></tr>
<tr><td rowspan="2">Indicators of the composition and properties of water bodies</td><td colspan="2">Category of water use</td></tr>
<tr><td>highest and first</td><td>Second</td></tr>
<tr><td rowspan="3">Biochemical oxygen consumption BOD</td><td colspan="2">At a temperature of 20 °C shall not exceed</td></tr>
<tr><td>3,0 mg/dm3</td><td>3,0 mg/dm3</td></tr>
<tr><td colspan="2">If in winter the content of dissolved oxygen in water bodies of the highest and first category decreases to 6.0 mg / dm3, and in water bodies of the second category to 4 mg / dm3, then it is possible to allow the discharge into them of only those wastewater that do not change the BOD of water</td></tr>
<tr><td>Chemicals</td><td colspan="2">Must not be contained in the water of water bodies of fishery importance in concentrations exceeding the STANDARDS of the MPC of substances</td></tr>
</table>

Water toxicity	Wastewater at the release into the water body should not have an acute toxic effect on test objects.
	The water of the water body in the control alignment should not have a chronic toxic effect on the test object

Section 5. Updating of SNiP in the field of water supply and sanitation (Quoted from the materials of the magazine "Plumbing", 2013, No. 2, pp.56-57)

Since January 1, 2013, a number of updated SNiP have come into force, including the main norms governing design solutions in the field of water supply and sanitation: SNiP 2.04.01–85* "Internal water supply and sewerage of buildings", SNiP 2.04.02–84* "Water supply. External networks and structures" and SNiP 2.04.03–85 "Sewerage. External networks and structures".

The main laws, in the light of which the SNiP is updated, are:

Federal Law No. 384-FZ "Technical Regulations on the Safety of Buildings and Structures" dated 30.12.2009;

Federal Law No. 261-FZ "On Energy Saving and On Improving Energy Efficiency and on Amendments to Certain Legislative Acts of the Russian Federation" dated 23.11.2009;

Order of the Ministry of Regional Development of the Russian Federation No. 262 "On the requirements of energy efficiency of buildings, structures, structures" dated 28.05.2010.

In the updated SNiP, items have been added that meet the requirements of the above laws. For example, in SP 30.13330.2012 of the updated edition of SNiP 2.04.01–85* such sections as "Energy and Resource Saving" and "Ensuring Reliability and Safety during Operation. Durability and maintainability".

Table P-1.10

Namesp	Name of the actualized SNiP	Name of the old SNiP
Updated SNiP (mandatory use)		
SP 30.13330.2012. Approved by the Order of the Ministry of Regional Development of Russia dated 29.12.2011. Put into effect 01.01.2013	Updated version of SNiP 2.04.01–85*. Internal water supply and sewerage of buildings	SNiP 2.04.01–85*. Internal water supply and sewerage of buildings
SP 31.13330.2012. Approved by the Order of the Ministry of Regional Development of Russia dated 29.12.2011. Put into effect 01.01.2013	Updated version of SNiP 2.04.02–84*. Water supply. Outdoor networks and structures	SNiP 2.04.02–84*. Water supply. Outdoor networks and structures
SP 32.13330.2012. Approved by the Order of the Ministry of Regional Development of Russia dated 29.12.2011. Put into effect 01.01.2013	Updated version of SNiP 2.04.03–85. Sewerage. Outdoor networks and structures	SNiP 2.04.03–85. Sewerage. Outdoor networks and structures
SP 61.13330.2012. Approved by the Order of the Ministry of Regional Development of Russia dated	Updated edition of SNiP 41–03–2003. Thermal insulation of equipment and pipelines	SNiP 41–03–2003. Thermal insulation of equipment and pipelines

27.12.2011. It was put into effect on 01.01.2013.		
Updated JVs (voluntary application)		
SP 66.13330.2011. Approved by the Order of the Ministry of Regional Development of Russia dated 28.12.2010. Put into effect 20.05.2011	SP 66.13330.2011. Design and construction of pressure networks of water supply and sanitation using high-strength pipes made of cast iron with spherical graphite	SP 40–106–2002. Design and installation of underground water supply pipelines using pipes made of high-strength cast iron with spherical graphite. SP 40–109–2006. Design and installation of water supply and sewerage networks using high-strength pipes made of cast iron with spherical graphite
SP 73.13330.2012. Approved by the Order of the Ministry of Regional Development of Russia dated 29.12.2011. Put into effect 01.01.2013	Updated version of SNiP 3.05.01–85. Internal sanitary systems of buildings	SNiP 3.05.01–85. Internal sanitary systems of buildings

At the same time, the calculation and methodological sections in the SNiP continue to be reduced, which caused a number of complaints among professionals. Perhaps the exclusion of sections is due to the fact that at the moment there is a situation in which designers use various software products in their calculations, in which various types of calculation methods are often used. Also, new technical products and, accordingly, new calculation methods designed specifically for these products are constantly appearing on the market. This situation has developed not only in our market, but also abroad.

Section 6. Best Available Technologies (BAT) Brief

water supply and disposal

FEDERAL AGENCY FOR TECHNICAL REGULATION AND METROLOGY

INFORMACIONNO-TEHNIHESKIYSPRAVOHNIK

PONAILUHWIMDOSTUNYMTEHNOLOGIM

ITS 10 – 2015

WASTEWATER TREATMENT USING CENTRALIZED WASTEWATER DISPOSAL SYSTEMS OF SETTLEMENTS, URBAN DISTRICTS

Moscow

BAT Bureau 2015

Summary of the BAT Handbook

Introduction. The introduction provides a summary of the BAT handbook and an overview of the legal instruments used in its development. Preface. The preface indicates the purpose of the development of the BAT directory, its status, legal context, a description of the specific problems solved by the BAT directory, a description of the procedure for creation in accordance with the established procedure, as well as the procedure for its application. Application domain. The section provides a detailed description of the scope of BAT, which is covered by the BAT directory in accordance with the current legislation. The boundary of attribution to the scope of application of treatment facilities that receive both wastewater of settlements (through a centralized wastewater disposal system) and wastewater of facilities where production of products or provision of services is carried out (directly) has been determined.

Section 1. Subsection 1.1 describes various aspects of the formation and disposal of wastewater of centralized wastewater disposal systems of settlements (hereinafter referred to simply as wastewater in a generalized sense). It is shown that two fundamentally different wastewater streams are treated at sub-industry facilities: a mixture of household and industrial wastewater (municipal wastewater, GSV), as well as surface wastewater (PSV). Information is provided on the sources of formation and wastewater disposal systems, factors affecting the amount of wastewater, trends in the long-term dynamics of inflow to treatment facilities, on indicators and values of wastewater pollution and its dependence on sources of discharge, on the factor of uneven inflow and the specifics of monitoring flow and pollution indicators.

Subsection 1.2 summarizes the tasks and methods of wastewater treatment, technological and environmental aspects of the development of the wastewater treatment sub-industry in the USSR and Russia, shows the specifics of the sub-industry from the point of view of BAT methodology. VIII

Subsection 1.3 shows the leading role of the sub-industry in protecting water bodies from the negative impact of settlements on water bodies. Subsection 1.4 provides general information on the sub-branch, including: the location and scope of the sub-branch, the organizational and economic foundations of the sub-branch, the economic situation of enterprises, data on the number of enterprises and facilities subject to mandatory transition to BAT and the use of complex permits, as well as those entitled to voluntarily join the rationing by technological indicators. The data on the objects of the sub-industry, obtained by means of a questionnaire: on productivity, service life, productivity, load on wastewater, pollution of incoming wastewater, are given.

Subsection 1.5 introduces gradations of sub-industry objects by performance. Subsection 1.6 provides data on energy and resource consumption of subdivisions, including questionnaire data. Subsection 1.7 describes the features of the conditions for the modernization of sub-facilities, subsection 1.8 describes the systemic problems of the water supply and sewerage industry as a whole and the sub-sector of wastewater treatment in particular. The main task of this bat directory has been determined: to ensure the presentation of achievable standards for treatment facilities and the achievement of the greatest environmental and economic efficiency of the technologies used.

Section 2. Subsection 2.1 contains a separate description of twenty-one subprocesses, and the main equipment used for the treatment of urban wastewater, the results of the analysis of data from two hundred questionnaires on the use of the main subprocesses of urban wastewater treatment are given. Auxiliary environmental equipment is described. Information on the current levels of consumption of resources and production of secondary products is given. Subsection 2.2 provides a similar description of the twelve sub-processes and related equipment for surface wastewater. Available information on the objects of this part of the sub-sector, current levels of resource consumption and production of secondary products at surface wastewater treatment facilities is given.

Section 3. Subsection 3.1 describes the methodological features of the sub-branch, substantiates the list of pollutants for which technological regulation should be carried out (the so-called technological indicators of biological wastewater treatment). Information on the current situation with the control of atmospheric emissions is given. The impossibility of using the methodology of marker substances in relation to the treatment of urban wastewater has been substantiated. A marker of contamination of treated surface wastewater and a marker of the content of foul-smelling substances in emissions have been determined. Subsection 3.2 analyzes in detail 18 indicators according to the questionnaires on the quality of municipal wastewater treatment (indicators of discharges into water bodies). It is concluded that there are very significant differences in the quality of cleaning and the existence of several groups of objects requiring the use of different approaches. Also, according to available information, discharges from surface wastewater treatment facilities were analyzed. A system of integral assessment of the quality of treated wastewater has been introduced, based on summation of the ratios of the quality of treated wastewater to the target technological indicators achieved using various technologies (IPKO indicator). The results of the calculation of the IPKO indicator for the main technologies of wastewater treatment, as well as for all surveyed objects, are presented. Based on the results of the analysis, the maximum values of the IPKO indicators separately for GSV and PSV are substantiated, which are the basis for requiring objects to prioritize the transition to BAT. Subsection 3.3 provides information on emissions of foul-smelling substances from GSV treatment plants, gives a classification of subprocesses using open surfaces by the intensity of release of foul-smelling substances, ranks the technological factors affecting the intensity of release of foul-smelling substances. The inexpediency of emission regulation and, on the contrary, the expediency of regulating the effectiveness of the effect on emissions have been substantiated. Subsection 3.4 shows the multiplicity of factors affecting the generation of waste at wastewater treatment plants, provides data on the range of possible waste generation. The inexpediency of rationing the amount of waste generated and the expediency of rationing the efficiency of treatment of sediments placed as waste have been substantiated.

Section 4. Subsection 4.1 shows the features of the methodology for determining BAT in relation to a sub-industry. The main environmental tasks that should be solved with the help of BAT are listed. The necessity for this sub-development in order to prevent irrational spending of investment resources for the use of BAT, which ensure maximum environmental and economic efficiency, as well as the use of a combined approach, taking into account the capabilities of the water body when choosing a technology as BAT, has been substantiated. Using the IPKO methodology, the possibility of using a combined approach based on the use of four levels (according to the achieved environmental result) of proven technologies (groups of technologies) available to the industry has been substantiated. Proposals for ranking water bodies for the purpose of selecting BAT are also formulated within four groups (categories A - D). Subsection 4.2 analyzes technologies as possible BAT for GSV, including technologies for wastewater treatment, post-treatment, decontamination, stabilization and reduction of sludge mass. The description of reference objects selected according to the questionnaire data, according to literary and expert data is given. Subsection 4.3 provides similar information on SRS. In subsection 4.4, the actual definition of BAT is carried out on the basis of the criteria established by the legislation, the standards and recommendations in force in this area. Defined BAT for subprocess groups for GSV and PSV. A comprehensive assessment of the benefits that can be achieved with the introduction of BAT was carried out; Data on the quality of cleaning achieved, waste generation, resource consumption and energy efficiency improvement are given.

Section 5. A description of universal BAT applicable to most areas of BAT application, including BAT of an organizational and managerial nature, is given; energy saving and resource saving; industrial environmental control; prevention and reduction of odor formation, BAT prevention and reduction of noise emissions. A brief description of the wastewater treatment previously substantiated in section 4 of BAT using centralized wastewater disposal systems of settlements and urban districts is given. A total of 75 individual BAT, grouped into 16 groups, have been described. Some of them are universal, for others data are provided to limit the applicability of BAT, including depending on the scale of the object, the conditions for discharge into water bodies, existing or new treatment facilities.

Section 6. Subsection 6.1 provides information on the cost of measures for the transition to BAT, summarized from the data of the part of the questionnaires that contained sufficient information on these sections. In total, information on 36 implemented or planned projects is provided, divided into six groups. XI In subsection 6.2, an analysis of the economic feasibility of the introduction of BAT for water supply and sewerage organizations is carried out, performed for several options: with new construction and reconstruction, in conditions of high (industry average) and low tariffs. It is concluded that the construction of new treatment facilities or facilities for thermal processing of sediment is inaccessible to the suppressing number of organizations of the water supply and sewerage sector. In subsection 6.3, an analysis of the ecological and economic efficiency of the use of BAT is carried out. First, a comparison of the ways of expressing the economic indicators of technologies is given. It is concluded that the optimal tool for the economic assessment of BAT is the ecological and economic efficiency of the life cycle costs of the technology (including the equipment and facilities with which it is implemented). A comparison of five variants of GSV OS technologies is carried out. It is shown that with new construction, the unit costs of removing the same amount of pollution at the stage of post-treatment to the MPC for water bodies for fishery purposes are 8 times higher than at the stage of biological treatment. In reconstruction, this difference is 12 times. It is concluded that the rationing system should ensure the unconditional priority of measures for the introduction of technologies for the removal of nitrogen and phosphorus in air tanks (and similar methods) in comparison with post-treatment. The use of post-treatment should be considered as BAT only in strictly limited situations of strict protection of water bodies. In all other situations, the use of sub-treatment processes in the project is equivalent to causing damage to water bodies as a result of a lack of funds inefficiently spent on a given facility to obtain a basic effect on another facility.

Section 7. At the beginning of the section, a classification of developing (promising) methods consisting of five groups, differing in the degree of development and testing, is formulated. These include technologies that are at the stage of research, development, pilot implementation, production testing, as well as foreign technologies for which there is no information on application in the territory of the Russian Federation. The main problems, primarily environmental, are given, which cannot be solved by technologies related to BAT. A description of technologies aimed at solving these problems is given.

Final provisions and recommendations. The section provides information on the members of the technical working group who took part in the development of the PR-XII BAT participant, their mutual agreement on certain provisions of the BAT handbook. Recommendations are given on the directions of further research and information collection in the field of BAT for wastewater treatment in the production of products (goods), the performance of work and the provision of services at large enterprises. Application. Additional information is provided in the annexes to the BAT handbook.

Bibliography. The list of sources used in the development of the BAT reference book "Wastewater treatment using centralized wastewater disposal systems of settlements, urban districts". The bibliography contains a list of sources used in the development of the bat information and technical reference book "Wastewater treatment using centralized wastewater disposal systems of settlements, urban districts".

Annex 2

Table P-2.1 - Table of estimated values of rain intensities of hourly duration [11]

NoNo districts	Hourly rain intensity (mm/min) VP in %:							
	10	5	4	3	2	1	0,3	0,1
1	0,22	0,27	0,29	0,32	0,34	0,40	0,49	0,57
2	0,29	0,36	0,39	0,42	0,45	0,50	0,61	0,75
3	0,29	0,41	0,47	0,52	0,58	0,70	0,95	1,15
4	0,45	0,59	0,64	0,69	0,74	0,90	1,14	1,82
5	0,46	0,62	0,69	0,75	0,82	0,97	1,26	1,48
6	0,49	0,65	0,73	0,81	0,89	1,01	1,46	1,73
7	0,54	0,74	0,82	0,89	0,97	1,15	1,50	1,77

NoNo districts	Hourly rain intensity (mm/min) VP in %:							
	10	5	4	3	2	1	0,3	0,1
8	0,79	0,98	1,07	1,15	1,24	1,41	1,78	2,07
9	0,81	1,02	1,11	1,20	1,28	1,48	1,83	2,14
10	0,82	1,11	1,23	1,35	1,46	1,74	2,25	2,65

Table P-2.2 - Table of coefficients of reduction of hourly precipitation intensity (Ct) [11]

Catchment area F, km2	Coefficients of reduction of calculated precipitation Kt for the following areas:						
	№ 1	№ 2	№ 3, 4	№№ 5, 7	№ 6	№ 8	№ 9, 10
0,0001	4,10	4,20	4,20	4,30	4,75	4,05	3,85
0,0005	3,50	3,50	3,50	3,70	3,90	3,50	3,30
0,001	3,00	2,80	2,90	3,05	3,20	3,00	2,75
0,005	2,50	2,30	2,40	2,55	2,65	2,50	2,30
0,01	2,15	1,95	2,07	2,12	2,20	2,0	1,90
0,05	1,85	1,70	1,80	1,82	1,90	1,75	1,65
0,1	1,60	1,50	1,60	1,62	1,65	1,55	1,45
0,5	1,35	1,30	1,40	1,37	1,35	1,35	1,30
0,8	1,20	1,20	1,30	1,25	1,25	1,20	1,20
1,0	1,18	1,15	1,20	1,20	1,20	1,18	1,15
5,0	1,05	1,03	1,10	1,09	1,05	1,05	1,03
7,0	1,0	1,0	1,05	1,04	1,0	1,0	1,0
10,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
50	0,94	0,95	1,0	0,99	0,98	0,96	0,97
100	0,90	0,90	0,93	0,91	0,92	0,91	0,92

300	0,89	0,89	0,90	0,88	0,91	0,90	0,90
500	0,87	0,85	0,87	0,86	0,90	0,85	0,86
1000	0,80	0,79	0,82	0,75	0,76	0,70	0,70
3000	0,78	0,73	0,80	0,70	0,70	0,6	0,6
5000	0,75	0,70	0,77	0,65	0,63	0,52	0,53
10000	0,70	0,64	0,70	0,55	0,50	0,40	0,40
50000	0,60	0,55	0,63	0,42	0,43	0,38	0,38
100000	0,55	0,50	0,57	0,35	0,40	0,35	0,35

Table P-2.3 - Table of effluent coefficients α_0 [11]

NoNo pp	Name of districts	EaP values in %α_0			
		0,3	1	2	3
1	Primorye DCK	1 - 0,9	0,9 - 0,80	0,8 - 0,70	0,70 - 0,60
2	DCK (Khabarovsk Territory), black sea coast of the Caucasus, eastern Transcaucasia, stormy foothills of Central Asia	0,9 - 0,80	0,80 - 0,70	0,70 - 0,66	0,66 - 0,60
3	Stormy areas of the Carpathians, Crimea	0,80 - 0,75	0,75 - 0,70	0,70 - 0,60	0,55 - 0,60
4	Transbaikalia, foothills of the Carpathians, Mountain and foothill regions of the middle Urals. Forest-steppe zone of the European part of Russia.	0,75 - 0,65	0,70 - 0,60	0,60 - 0,55	0,50 - 0,55
5	Steppe zone of the European part of Russia, Southern Urals, Western Siberia	0,65 - 0,55	0,55 - 0,50	0,50 - 0,45	0,45 - 0,40

NoNo pp	Name of districts	EaP values in $\%\alpha_0$			
		0,3	1	2	3
6	Desert and semi-desert regions of Central Asia, Central Asia. Southern tundra regions	0,55 - 0,50	0,50 - 0,40	0,40 - 0,30	0,25 - 0,30

Table P-2.4 - Coefficients of permeability of soils and drainage surfaces γ_{d} in calculated water return [11]

Soil category	Characteristics of the slopes of the pools		γ_d
	Soils and drainage surfaces	Vegetation	
I	Rocky, frozen and poorly permeable soils and drainage surfaces	Turfed or absent vegetation	0,02
		Dense forest with shrubs and grass	0,02 - 004
II	Clays, loams	Pulled	0,04 - 0,09
		Dense forest with shrubs and grass	0,06 - 0,15
	Takyrs	Missing	0,06 - 0,12
III	Sandy loam and sandy soils at natural humidity	Pulled	0,10 - 0,15
		Dense forest with shrubs and grass	0,15 - 0,20
IV	Dry soils (sands and loesses) in arid and desert areas with insufficient moisture	Pinned	0,15 - 0,20
		Loose	0,20 - 0,25
	Loose soils (scree, etc.)	Loose	0,25 - 0,35
In		Partially anchored by vegetation or shrubbery	0,15 - 0,20

Soil category	Characteristics of the slopes of the pools		γ_d
	Soils and drainage surfaces	Vegetation	
	Rocks in mountainous conditions are strongly fractured on the surface	Loose	0,20 - 0,30
WE	Peats	Moisturized	0,10 - 0,17
		Drained	0,15 - 0,25

Table P-2.5 - Coefficients taking into account the condition of soils during the formation of the calculated flood [11]β

NoNo pp	Features of runoff	Coefficients for soil categories according to Table 4β				
		I	II	III	IV	In
1	Runoff on frozen soils or on ice crust	1,0	1,0 - 0,9	0,9 - 0,8	0,8 - 0,7	0,8 - 0,2
2	Coincidence of excessive autumn moisture with runoff in the spring	1,0	0,9	0,8	0,7	0,7 - 0,65
8	Runoff on dry dusty soils (sands, loesses, etc.) with the possibility of the formation of a soil crust that prevents the rapid penetration of water into the ground	-	-	-	0,8 - 0,6	-
4	Preliminary moistening of soils for the beginning of the calculated flood in the monsoon climate	1,0 - 0,9	0,9 - 0,8	0,8 - 0,6	-	-

NoNo pp	Features of runoff	Coefficients for soil categories according to Table 4β				
		I	II	III	IV	In
5	Soil moisture in natural conditions	1,05	1,05 - 1,10	1,10 - 1,15	1,10 - 1,15	-

Table P-2.6 - Correction coefficient P for reducing the permeability of soils of category I - V in formulas (10), (11) [11]

Catchment area, km2	Coefficient for the following areas:P		
	№ 1 - 2 - 3 - 4	№ 5 - 6 - 7	№ 8 - 9 - 10
100 or less	1,0	1,0	1 - 0,9
200	0,91	0,86	0,72
300	0,84	0,70	0,54
400	0,77	0,68	0,32
500	0,70	0,52	0
600	0,68	0,40	-
850	0,46	0	-
1000	0,30	-	-
1250	0	-	-

Table P-2.7 - Recommended reduction factors for maximum costs ϕ in the absence of field survey data [11]

Catchment area km2	F	Catchment area km2	F
0,0001	0,98	6,0	0,40

Catchment area km2	F	Catchment area km2	F
0,001	0,91	8,0	0,36
0,005	0,86	10,0	0,33
0,01	0,81	12,0	0,32
0,05	0,75	15,0	0,31
0,1	0,69	19,0	0,30
0,2	0,68	22,0	0,29
0,3	0,66	26,0	0,28
0,4	0,65	30,0	0,27
0,5	0,63	40,0	0,25
0,6	0,62	50,0	0,24
0,7	0,60	55,0	0,23
0,8	0,58	60,0	0,22
0,9	0,56	80,0	0,20
1,0	0,53	100	0,19
1,5	0,52	200	0,17
2,0	0,50	300	0,16
2,5	0,49	500	0,14
3	0,47	1000	0,12
4	0,44	5000	0,09
5	0,42	10000	0,08
		100000	0,05

Table P-2.8 - Watershed steepness coefficients KJ [11]

Slope of the main log J	KJ for catchments:			
	Single-slope and non-slope			With availability
	asphalt concrete and cement-concrete pavements	crushed stone and gravel coatings	natural rugged slopes	
0,001	0,87	0,75	0,75	0,94
0,005	0,95	0,82	0,78	0,98
0,01	1,03	0,92	0,80	1,01
0,02	1,25	1,10	0,85	1,06
0,03	1,45	1,30	0,90	1,12
0,04	1,65	1,50	0,91	1,14
0,05	1,80	1,65	0,93	1,16
0,06	2,03	1,85	0,95	1,18
0,07	2,20	2,00	0,97	1,21
0,08	2,40	2,20	0,98	1,23
0,09	2,63	2,40	1,0	1,26
0,10	2,80	2,60	1,02	1,28
0,20	-	-	1,21	1,52
0,30	-	-	1,34	1,68
0,40	-	-	1,45	1,82
0,50	-	-	1,56	1,94
0,60	-	-	1,63	2,03
0,70	-	-	1,68	2,10

Table P-2.9 – Coefficient c for taking into account the shape of the catchments in the formula (14) [11]

Catchment area, km2	less than 5	10	20	30	40	50	60	70	80
c	0	0,10	0,2	0,3	0,4	0,5	0,6	0,8	0,9

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