BASICS OF BIOLOGICAL WASTEWATER TREATMENT

(Biological wastewater treatment with the basics of microbiology and biotechnology)

Ksenofontov B.S.

Moscow 2022

Annotation

The textbook outlines the theoretical and practical foundations of biological wastewater treatment both in natural and in artificial conditions. For a more in-depth understanding of the basics of biological wastewater treatment, the sections relating to the basics of microbiology are set out in sufficient detail. Much attention is paid to the choice of the best technologies for biological wastewater treatment with effective methods for removing nutrients. In the expanded version, methods of biological wastewater treatment using membrane bioreactors are considered. The experience of biological treatment of municipal and industrial wastewater is described in sufficient detail.

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

The book is intended for undergraduate, graduate, graduate students, teachers and specialists interested in wastewater treatment methods, and is recommended for an enlarged group of specialties and directions 20.00.00 "Technospheric safety and environmental engineering".

Contents

Introduction

The biological method of wastewater treatment has become widespread in practice. This is due, first of all, to its natural origin. The use of this method in the practice of wastewater treatment for more than a hundred years has shown that with its correct application it is possible to obtain a sufficiently high treatment effect in almost many indicators of the quality of water treatment. In addition, the economic comparison of biological and chemical methods is undoubtedly in favor of the former.

At the initial stage of development of the biological method, soil purification was widely used. It is well known that the soil is a very complex complex of organic and mineral substances, containing a large number of different microrganisms. At the same time, it should be emphasized that the soil does not have optimal conditions for the vital activity of pathogenic microflora, including sometimes present in the human body. In this regard, the soil version of wastewater treatment, along with the mineralization of organic pollution, also includes a method of disinfecting wastewater.

In the future, the development of the method of biological wastewater treatment was associated with its implementation in artificial conditions. At the same time, in the initial stages of development, the contact of wastewater with microrganisms was carried out mainly under aerobic conditions, and then the technology began to be increasingly used, including the use of both aerobic and anaerobic conditions. The latter option is mainly associated with the extraction of nitrogen and phosphorus from wastewater.

The name of the aeration tank, dating back to the beginning of the 20th century, when biological treatment facilities were aerated with the creation of aerobic conditions, is not always applicable to modern treatment facilities from biogenic elements. Currently, more and more often they are switching to a broader

concept - bioreactors, which are containers or devices for carrying out bio-oxidation processes by creating and maintaining, if possible, the optimal conditions necessary for the vital activity of cultivated microorganisms. For example, for all nitrogen and phosphorus removal reactors, the designation NPR (Nitrogen and Phosphorus Removal) is proposed.

The introduction of various new technologies also causes a radical change in the qualitative and quantitative composition of activated sludge. The effectiveness of biological treatment under these conditions depends on the number and activity of various new groups of microorganisms. The need to maintain a sufficient number and activity of bacteria in the composition of activated sludge is due to the need to solve the tasks set.

In this regard, it is obvious that specialists in the operation of treatment facilities need to have a clear understanding of the conditions under which activated sludge microorganisms are cultivated. At the same time, it is necessary to be able to identify and create operating conditions that are most optimal for the cultivation of activated sludge microorganisms. Taking into account the fact that the course "Fundamentals of Microbiology and Biotechnology" is not currently taught in technical universities, the problem arises of familiarizing students with the basics of microbiology at least in a short version, which is proposed in this manual. It should also be noted that a technologist who creates new effective modes of biological treatment must know and solve not only water problems, but also be able to find approaches to the implementation of related tasks, for example, in the treatment of exhaust gas-air emissions formed in the processes of biotreatment of wastewater, etc. We also note that now there is an increasingly clear trend towards the use of selective microorganisms in biotreatment processes, obtained in fermenters with the maintenance of strictly controlled conditions, which have long been used in industrial biotechnological practice. All this indicates the need to

outline the basics of industrial biotechnology with a description of the technologies and designs of fermentation equipment used in the implementation of controlled biotechnological processes. Along with the noted features, the textbook offered to the reader summarizes modern ideas about the structure of bioflocules of activated sludge, the composition and properties of microbial populations inhabiting active sludge, describes the role of various physiological groups of bacteria in biochemical processes occurring at the stage of complete biological purification with activated sludge: oxidation of organic pollutants, nitri- and denitrification, rough removal of phosphorus.

In view of the foregoing, the proposed textbook differs from well-known publications in that it provides more information on related disciplines, in particular microbiology and biotechnology. Without knowledge of the basics of microbiology and biotechnology, it is much more difficult for students to understand the processes of biological wastewater treatment.

Recently, the Russian Federation has been considering the possibility of using the best available technologies (BAT). The listener must understand in what cases to use this or that technology.

When mastering the discipline according to this manual, it is planned to form the competencies provided for by the main professional educational program on the basis of the Federal State Educational Standards or the SUOS in the direction of training 20.04.01 Technospheric Safety (Profile 20.04.01_01 "Integrated Use of Water Resources") (Master's level):

To know:

- characteristics of pollutants in different states in natural waters;
- the main methods of natural water purification and water treatment equipment;
- special methods of purification of natural waters and their disinfection;
- the interaction of contaminants in natural water and their impact on the quality of purified water;

- method of choosing the technology of natural water purification, taking into account the interaction of pollution;
- characteristics of pollutants in various states in wastewater;
- requirements for the treatment of wastewater discharged into sewage or into natural water bodies;
- the main methods of wastewater treatment and water treatment equipment;
- the interaction of contaminants in wastewater and their impact on the quality of the purified water;
- method of choosing a wastewater treatment technology, taking into account the interaction of contaminants;
- methods of optimizationof technological processes of wastewater treatment;
- safe operating modes of water treatment plants.

Can:

- carry out calculations of the main methods and devices of wastewater treatment;
- choose criteria and methods for determining the best availabletechnology (BAT) for wastewater treatment;
- ensure safe operating modes of water treatment plants.

Possess:

- methods for determining and developing wastewater treatment technology with different qualitative and quantitative composition of contaminants;
- developmentof a technological scheme for the treatment of wastewater, taking into account the contaminants contained in it;
- creation of safe modes of operation of water treatment plants.

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

At the same time, it should be emphasized that according to SP 32.13330.2012 (Code of Rules. Sewerage. External Networks and Structures), the calculation of facilities for the treatment of industrial wastewater and the treatment of their

sediments should be carried out on the basis of data from research and engineering organizations,

experience of operating existing similar facilities, taking into account this set of rules and design norms for enterprises of the relevant industries.

1. Fundamentals of Microbiology

1.1. General information

1.1.1. Structure of prokaryote and eukaryotic cells

The division of the living world into kingdoms of animals, plants and protists became possible only in the second half of the X1X century. In 1866, the German biologist E. Haeckel proposed to isolate microorganisms in the third kingdom of living nature and called it the "kingdom of protists."

The basis of the structure of the cells of protists, as well as the cells of higher animals and plants, are the cytoplasm and nucleus. With the development of instrumental research methods, it turned out that, despite the commonality of structural, biochemical and physiological organization inherent in living organisms, the kingdom of protists is divided into two groups. The first consists of higher protists-eukaryotes, whose cells are similar in structure to the cells of animals and plants. Distinctive features of the eukaryotic cell are the structural organization of the nucleus and the way it divides. Eukaryotic cells have a separate nucleus separated from the cytoplasm by a membrane (Fig. 1.1).

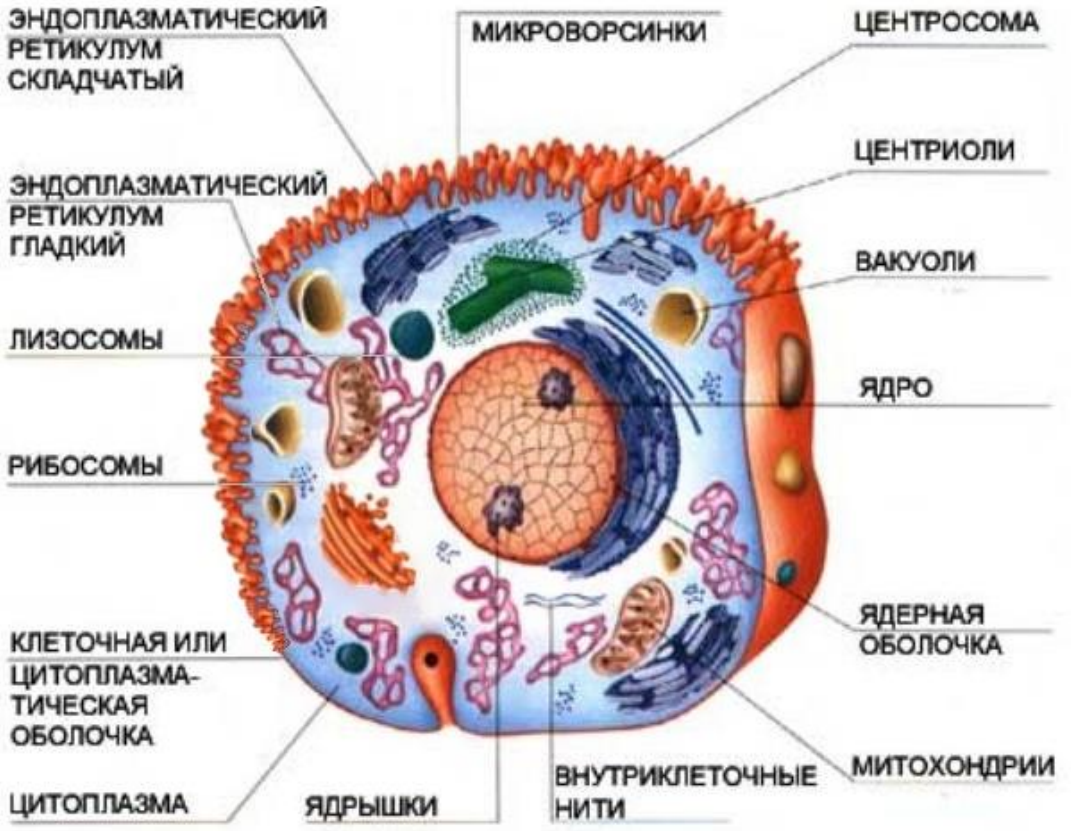


Fig. 1.1. Diagram of the structure of the eukaryotic cell

Let us consider in more detail the structure of a eukaryotic cell on the example of a yeast cell. The eukaryotic cell has a cytoplasm that includes a rather complex structure and which is enclosed in a multilayered cell wall. In eukaryotic cells, the cell wall is represented by a strong elastic shell that allows separating the contents of the cell from the external environment and regulating its permeability. The pores of the cell wall have dimensions up to about 3.5 nm, which make it possible for biopolymers with a large molecular weight to penetrate into the cell, as well as to carry out their withdrawal into the environment. The cell wall is a significant proportion in the mass of the cell (approximately 10 to 30% by dry weight) and has a thickness of about 150 to 280 nm. The cell wall consists of 60 - 70% of hemicelluloses, which are approximately equal parts represented by

mannane and glucan. In addition, the composition of the cell wall includes protein, chitin, lipids and various mineral compounds.

The cell wall consists most often of three layers, although there may be more than ten of them. The outer layer is a lipoprotein membrane with a thickness of about 15-30 nm. The next fibrillar layer consists of a mannanoprotein complex and is up to about 100 nm thick. The third layer may be fibrillar or homogeneous and consist primarily of glucan.

The cell wall, as well as between the wall and the cytoplasmic membrane, contains various enzymes, transport proteins and other substances.

Directly behind the cell wall is the cytoplasmic membrane (CPM), which has a thickness of about 8 ... 10 nm. CPM regulates the metabolic process in the cell. The surface of the MTC may be smooth or have protrusions (intussusception). It is known that cytoplasmic membrane intussusceptions, for example for yeast cells, can reach a length of 300 nm, and a width and depth of up to 30 and 5 nm, respectively. The number of intussusceptions and their size depend on the physiological state of the cells. Deep intussusceptions of CPM are close to mesosomes, and their number increases with a decrease in the content of essential substances in the nutrient medium.

The internal semi-liquid contents of the cell, limited by the CPM, is called the cytoplasm, in which all cellular organoids are located: endoplasmic reticulum, nucleus, ribosomes, Golgi apparatus, lysosomes, vacuoles, mitochondria. The cytoplasm of the cell is in constant motion. This promotes the movement of solutes within the cell, such as enzymes, amino acids, carbohydrates, vitamins, minerals, etc.

Endoplasmic reticulum (ER) - does not have a strictly defined place in the cell. ER is a membrane system that has the form of tubules, vesicles and cisterns and is

in contact with the CPM and the nucleus. It consists of lipoproteins. In this case, lipids make up about half by weight. ER can be smooth and folded (rough). Yeast cells have a predominantly smooth ER responsible for carbohydrate and lipid metabolism. The surface of the folded ER is insignificant, and here the ribosomes are concentrated, in which protein synthesis occurs.

The Golgi apparatus (complex) (AG) is the membrane structure of the cell. It is named after the Italian scientist C. Golgi (1987). AG consists of vesicles and a number of disc-shaped plates. The membranes in the Golgi apparatus are packed very tightly with a distance from each other from about 20 to 230 nm.

The functions of the Golgi apparatus are the synthesis of material for the formation of cell walls, the place of formation of lysosomes, the accumulation of metabolic products before their withdrawal from the cell and, most importantly, for the excretion of substances synthesized in the ER.

Ribosomes are composed of nucleoproteins and are distributed throughout the cytoplasm. The number of ribosomes in a cell responsible for protein synthesis depends on the age of the cell and its habitat. In this case, ribosomes can degrade or group into polyribosomes. Only when the conditions of compliance with a certain size of the ribosome and its condition are met, normal protein synthesis is ensured.

Lysosomes are cellular structures and formations that perform various functions, in particular, storing granules containing enzymes, digestive vacuoles, secondary lysosomes, etc. At the same time, lysosomes also include segregation granules that are formed in cells when they are adversely affected by any factor. A feature of lysosomes is the presence of proteolytic and lysing enzyme systems in them.

Vacuoles are derivatives of the endoplasmic reticulum or Golgi apparatus, performing various functions: localization of reserve substances in the cell, accumulation of metabolic products. Vacuoles are separated from the cytoplasm by a lipoprotein membrane, on the surface of which there are enzymes. With the age of the cell, the number of vacuoles increases

Mitochondria are closed cellular structures with numerous partitions. They arise as a result of intussusception of the cytoplasmic membrane. In this case, the sizes of mitochondria are different, and the shape can be ellipsoidal, round or elongated. These structures are responsible for the energy metabolism of the cell. In the mitochondria, a complete set of a system that synthesizes protein was found. Apparently, this system synthesizes the structural proteins of the inner membrane of the mitochondria and the enzymes found in this membrane.

The nucleus plays a major role in the transmission of hereditary information, regulates metabolism, protein synthesis, the process of reproduction, etc. The nucleus is separated by a special nuclear shell. The cell nucleus is usually one per cell (there are examples of multinucleated cells), consists of a nuclear shell that separates it from the cytoplasm, chromatin, nucleus, karyoplasm (or nuclear juice). These four main components are found in virtually all non-dividing cells of eukaryotic unicellular and multicellular organisms.

The main component of the nucleus of eukaryotes is chromatin, which in the period before division is all concentrated in chromosomes - a kind of information stores containing deoxyribonucleic acid (DNA) and proteins of a special type.

During cell division, the entire gene apparatus doubles and at the same time each cell receives the entire set of chromosomes that provide the entire amount of necessary information.

The nucleus is necessary for the life of the cell, since it regulates all its activity in the process of the full cycle of vital activity of the cell.

Of the microorganisms, eukaryotes include protozoa, fungi, algae (except for blue-green).

The second group is formed by lower protists called prokaryotes (prenuclear). In prokaryotic cells, the formed nucleus is absent, but there are nucleoid-like formations. Nucleoids have a simpler structure and are not separated from the cytoplasm by a shell. Hereditary information is carried by one chromosome, which is a long DNA molecule. Prokaryotes lack directed movement of the cytoplasm, intracellular digestion, the phenomena of phagocytosis and pinocytosis. Prokaryote cells are significantly smaller than eukaryotic cells. And in general, it should be noted that prokaryote cells represent a simpler form of life than eukaryotes.

Taking into account the particularly important role that prokaryotes play in the processes of purifying water, soil, waste and air, we will consider in more detail their properties.

The individual basic elements of the prokaryotic cell are shown in Fig. 1. 2

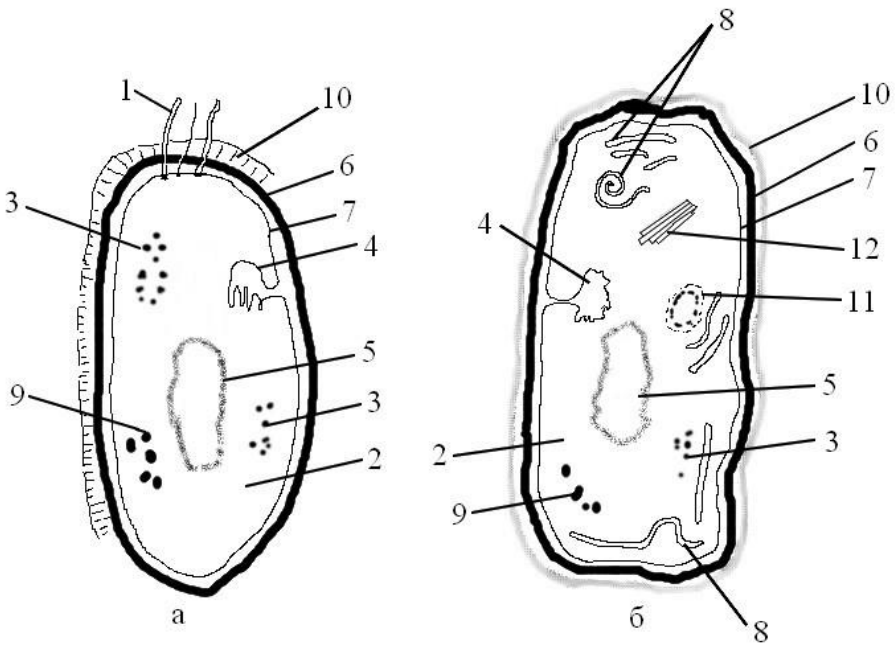


Fig. 1. 2. Diagram of the structure of the prokaryotic cell:

The prokaryote cell is covered with a strong cell wall on the outside. Adjacent to it is the cytoplasmic membrane and then the cytoplasm, in which the nucleoid, organoids and reserve substances of the cell are located.

According to the structure and composition of the cell wall, bacteria are divided into two groups depending on the color according to Gram: gram-negative and gram-positive. Recall that this property of cell walls was discovered and first described by the Dane Gram G.K. in 1884.

The cell wall is permeable to the transport of nutrients and the excretion of metabolic products. In the cell walls there are pores up to 6 nm in size. In this case, there are also openings for the exit of flagella, structural cords and fimbriae. The wall protects the cell from various external influences and, depending on the conditions, contributes to the formation of a capsule.

The cytoplasmic membrane (CPM) is in direct contact with the wall. Although it should be noted that some bacteria have some space between them, in which,

apparently, there are enzymes and substances transported between the cell and the environment. The CPM of bacteria is a lipoprotein membrane about 7.5 nm thick, being the main osmotic barrier of the cell. The membrane has many intussusceptions, with vesicles and tubules inside them, represented in the form of tubular and lamellar thylakoids of mesosomes of various shapes. It should be noted that the most important biochemical reactions involving various enzymes occur in the CPM, the synthesis of the material of the cell wall and capsule is carried out.

The cytoplasm is the internal contents of the cell, including all the most important organoids found in a liquid structureless substance consisting of a soluble and insoluble component. In the soluble component, including about 70-80% of all water in the cell, there are sugars, pigments, amino acids, etc. In the cytoplasm of the cell there are ribosomes, various membrane systems and at the same time reserve substances may be present, for example, glycogen, starch, polyphosphates, etc. In the central part of the cytoplasm there is a nuclear substance.

In a bacterial cell, the nuclear substance is a nucleoid. Unlike eukaryotic cells, the DNA of prokaryotic cells is not separated from the cytoplasm by a nuclear membrane. In this case, DNA is a separate fragment, never mixed with the cytoplasm. This is evidence of a simpler form of nuclear matter organization in prokaryotes compared to eukaryotes.

Quite often, bacteria have a capsule or other additional external structures, for example, flagella, structural strands, fimbriae.

In this case, the capsule is not an obligatory element of the bacterial cell and can, depending on the conditions, represent a thick or thin layer of a substance consisting most often of polysaccharides and glycoproteins and less often of polypeptides and fiber. The capsule performs a protective function against possible damage, drying, penetration of phages, etc. It should be noted that the secretion

of mucus in some species of bacteria can be very intense, which can lead to the aggregation of individual cells into zooglea, which are mucous clusters with bacterial cells included in them.

For movement, bacteria use flagella with a length of about 10- 30 μm or more and a thickness of about 0.01-0.03 μm. The composition of flagella is represented by molecules of flagellin, which belongs to contractile proteins. The location and number of flagella is a characteristic species feature. Bacteria with a single flagellum are called monotrichs. Bacteria with a bundle of flagella located in one or two places of the cell are called lofotriches, if the entire surface of the cells is covered with flagella, then peritriches.

It is interesting to note that although cyanobacteria do not have flagella, many cyanobacteria are able to move. The movement of cyanobacteria is carried out due to the secretion of mucus. There are other features of cyanobacteria, for example, the presence in their cells of special membrane structures - thylakoids, which are the site of localization of photosensitive pigments. The set of such pigments leads to a kind of blue-green, olive-green, yellow-green and purple color of cyanobacteria. At the same time, the color of cyanobacteria cells is determined by the quantitative ratio of the pigments contained.

1.1.2. Metabolism in microorganisms

The totality of all the processes occurring in the cells of microorganisms that ensure the reproduction of biomass is called metabolism or metabolism. According to another interpretation, we can say that metabolism is the whole set of biochemical reactions that occur under the action of the enzyme systems of the cell, which are regulated by external and internal factors, and provide exchange of matter and energy between the habitat and the cell itself.

It is known thatto flight metabolism consists of two streams of reactions that have different directions: energy and constructive metabolism. Energy metabolism is a flow of reactions, accompanied by the concentration of energy and its conversion into an electrochemical or chemical form. Constructive metabolism is the flow of reactions resulting from the implementation of which, due to the substances coming from outside, the substance of the cells is built. Metabolic pathways of constructive and energetic orientation consist of a huge variety of enzymatic reactions. Typically, molecules that represent the original substrate are initially affected. This part of the metabolic pathway is often referred to as peripheral metabolism, and the enzymes that catalyze these substrate transformation steps are called peripheral. These transformations involve a number of enzymatic reactions and lead to the formation of intermediate products, or metabolites, and the chain of transformations itself is combined under the name of intermediate metabolism. The final products of the constructive pathways formed in the last stages are used to build the substance of the cells of microorganisms.

It should be especially noted that theonstructive and energy processes take place, for example, in the cell simultaneously. In most prokaryotes, they are quite closely related to each other. However, in individualprokaryotic microorganisms, a sequence of reactions can be distinguished that serve only to obtain energy or only for biosynthesis. It is known that theconnection between the constructive and energy processes of prokaryotes is carried out through several channels. At the same time, aboutthe dream of them - energy. Of particular note is that limiting reactions supply the energy needed for biosynthesis and other functions. Biosynthetic reactions, in addition to energy, often need to be supplied from the outsideto restore the energy in the form of hydrogen, the source of which are the reactions of energy metabolism. Finally, the close connection between the energy and design processes of the processis that at certain stages the metabolites of both

pathways may be the same, which creates opportunities for the use of common intermediates in each of these metabolic pathways.

The metabolism of microrganisms, both energetic and constructive, is characterized by extreme diversity, which is the most important result of the ability of these life forms to use as energy sources and initial substrates for the construction of body substances the widest range of organic and inorganic compounds. This ability is due to differences in the set of cellular peripheral enzymes that affect the original substrates and modify their molecules in a direction that allows them to be further metabolized through the channels of intermediate metabolism.

Of great importance in considering the above issues is knowledge of the kinetic features of enzymatic reactions.

Most often, the kinetics of enzymatic reactions are considered using the Michaelis-Menten equation.

This is the basic equation of enzymatic kinetics, describing the dependence of the reaction rate catalyzed by the enzyme on the concentration of the substrate and the enzyme. In a simplified form, the reaction of conversion of substrate S to product P with the participation of enzyme E can be recorded as follows:

$$E + S \iff ES \longrightarrow E + P$$

The Michaelis-Menten equation, which determines the dependence of the rate of enzymatic reaction on the concentration of the substrate, is: v

$$v = \frac{V_m S}{S + K_M} \qquad (1.1)$$

Where is

V_m– maximum reaction speed;

K_M is the Michaelis constant equal to the concentration of the substrate, at which the reaction rate is half of the maximum;

1. is the concentration of the substrate.

The basic provisions of enzymatic kinetics are also used to describe more complex processes, for example, biological wastewater treatment, in which many substrates and enzymes are involved.

1.1.3. Nutrients of microbial cells

The necessary need of microorganisms for nutrients is determined by the physiological characteristics of the groups of microorganisms under consideration. A sufficient condition for the penetration of nutrients into the cells of microorganisms is the finding of nutrients preferably in the form of a true or colloidal solution. There is an opinion that the qualitative and quantitative composition of nutrients can be approximately determined based on knowledge of the chemical composition of the cells of microorganisms. It should be noted that this does not take into account the metabolites removed by cells into the environment. If we focus on the average data on the composition of various groups of microorganisms, we get approximately the following content of individual elements in the cells of microorganisms in terms of dry matter (%): carbon - 48 ... 51; nitrogen - 5 ... 13;oxygen - 30 ... 41; hydrogen - 6 ... 7; phosphorus (P_2O_5) - 3..5; potassium (K_2O) - 2..3. The content of other elements, for example, sulfur, sodium, magnesium, calcium, iron, silicon is less than 1%, and the so-called trace elements, which include boron, molybdenum, manganese, zinc, copper, bromine, iodine, cobalt, etc., are even less. In some cases, trace elements present in tap water

replenish the necessary content of them in the nutrient media used to grow microorganisms.

For the effective management of the process of obtaining biomass of microorganisms, it is necessary to have all the necessary elements in the nutrient medium. The absence of at least one of the elements leads to a noticeable decrease in the growth rate of microorganisms. As can be seen from the above data, carbon, which is part of almost all organic substances of the cell, is of paramount importance for the cells of microorganisms. It is well known that such substances containing carbon form the basis of compounds important for the vital activity of the cell, including amino acids, proteins, nucleic acids, fats, carbohydrates, etc.

No less important for the cells of microorganisms is nitrogen, which is part of amino acids, nucleic acids, proteins. It should be noted the importance for the life of the cells of microorganisms and elements such as phosphorus, sulfur, oxygen, iron, potassium, etc. Along with the need for the presence in the nutrient media of all substances vital for the cells of microorganisms, it should be noted a remarkable property of microorganisms as adaptability. In the case of a change in the nutrient medium, microorganisms easily adapt to new conditions.

Thus, the nutrient medium for the cultivation of microorganisms should be a true or colloidal aqueous solution, and in some cases an aqueous suspension, which should include all the elements necessary for the vital activity of the cells of microorganisms. In this case, the nutrient medium should have an optimal pH value for these microorganisms. In some cases, vitamins and other necessary growth stimulants are added to the nutrient media for the normal growth of microorganisms.

1.2. Mathematical models of microbial growth

Many models have been proposed that take into account the influence of various factors on population growth, including cell populations. The simplest model is the Verhulst model, which assumes the existence of some limit *K*, called the capacity of the medium, to which the population of *N* at $t \to \infty$ *tends*:

$$dN/dt=\varepsilon(K-N)\,N, \qquad (1.2)$$

where $\varepsilon K=\mu$ *is* the specific rate of population growth. The model shows that mortality in a population is proportional to its abundance. However, this model does not take into account limiting factors that can limit growth.

The simplest equations describing the growth of a cell on a nutrient medium include models that take into account the effect of the dependence of growth on the concentration of only one substrate, which is called limiting. Other substrates rely on being in excess and not affecting the growth rate.

The limiting factor (limiting) is any environmental factor, the quantitative and qualitative indicators of which limit the vital activity of the organism. The law of limiting factors was first studied and formulated by Justus von Liebig in 1840 In the course of observations, he noted that restrictions on the introduction of any of the substances lead to the same result of slowing down the growth of plants. Thus, Liebig concluded that if even the only factor affecting the growth and development of plants is outside its optimum, then this factor will lead to a stressful state of the body, and later to death.

Further observations have shown that the law of limiting factors, or Liebig's law of minimums, refers to all abiotic and biotic factors affecting the body.

The development of the system is limited if there is a lack of at least one factor necessary for it. The limiting factor is understood as a factor primarily responsible for limiting the growth of microorganisms.

The simplest model of cell growth follows from the determination of the specific growth rate (μ) and has the form:

$$dC / dt = \mu C \qquad (1.3)$$

where μ is the specific growth rate of the biomass of microorganisms,

C is the concentration of biomass of microorganisms.

The Blackman model is of some interest, which at low concentrations of substrate S gives the same equation, but when the value of S reaches a certain critical level of S * (that is, such a level of concentration of the substrate when its action as a limiting factor is removed), the growth rate stops increasing:

Graphically, Blackman's model is shown in Fig. 1.3.

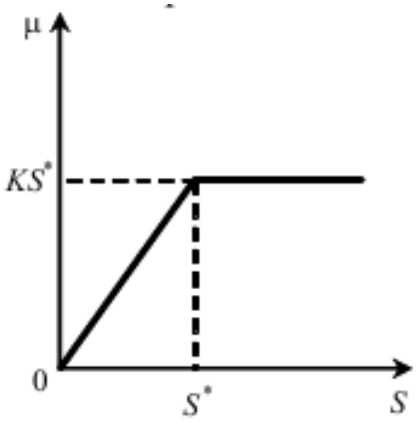


Fig. 1.3. The dependence of the specific growth rate on the substrate according to Blackman

The Mono model is quite widespread, which describes the dependence of the specific growth rate of microorganisms on the concentration of the substrate:

$$\mu = \frac{\mu_m S}{K_S + S}, \qquad (1.4)$$

Where is K_s — constant;

μ_m *is* the maximum specific growth rate of microorganisms;

S – substrate concentration.

The constant K_s is numerically equal to the concentration of the substrate at which the specific velocity is equal to half of its maximum specific growth rate of microorganisms.

This expression bears a resemblance to the Michaelis–Menten formula for the rate of enzymatic reaction.

Graphically, the Mono model is presented in Fig. 1.4.

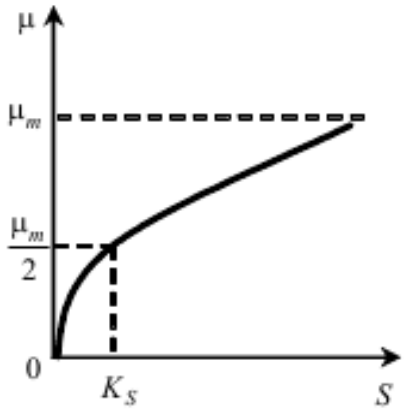


Fig. 1.4. Dependence of the specific growth rate on the concentration of the substrate according to the Mono model.

N. D. Jerusalem took into account the influence of metabolic products on the growth rate of microorganisms and obtained a more complex expression than the Mono equation. In this case, the expression for the specific growth rate of microorganisms is:

$$\mu = \mu_m \frac{S}{K_s + S} \cdot \frac{K_P}{K_P + P}, \qquad (1.5)$$

where P is the concentration of metabolic products,

K_P – constant.

In the case of small values of the concentration of metabolic products (at P = 0), the Mono-Jerusalem equation passes into the Mono equation.

We also note that the growth of theculture of microorganisms depends on other factors, in particular temperature, pH, pressure, the presence of stimulants and inhibitors, etc.

It should be emphasized that one of the main features of the use of microbial growth models in biological wastewater treatment processes is that active sludge is a mixed culture, and the above ratios are valid for monocultures.

Biological wastewater treatment processes are the result of the metabolic activity of microorganisms, which are based on reactions catalyzed by enzymes both inside and outside the cell.

At the same time, the species composition of activated sludge is specific and individual for each type of wastewater and, mainly, is determined by the qualitative and quantitative composition of contaminants, as well as the degree of treatment.

1.3. Participation of microorganisms in the cycle of substances

The most important feature of microorganisms is their participation in the cycle of substances. It is known that green plants synthesize organic substances using the energy of the sun and carbon dioxide, so they are called producers. Animals are consumers (consumers). The bodies of animals and plants eventually undergo decomposition, during which the transformation of organic substances into mineral substances occurs. This process, called mineralization, is carried out by microorganisms - destructors. All these bioelements are thus involved in cyclic processes. Of greatest interest, of course, is the cycle of elements such as carbon, nitrogen, phosphorus and sulfur.

Carbon is included in all nutrient mixtures of microorganisms, plants and animals. For microorganisms, this element forms a substrate, which in the process of consumption undergoes a number of changes and is excreted into the environment in the form of carbon-containing metabolic products, including carbon dioxide.

Biogenic elements (nitrogen and phosphorus) are removed from the water by means of specialmodes of cultivation of activated sludge microorganisms. And in this regard, at the cultivation stage, special attention is paid to the alternation of anaerobic and aerobic conditions. These conditions are separately considered when describing the processes of biological wastewater treatment.

Sulfur is the most important element of living matter. Bacteria that oxidize sulfur compounds are quite diverse. For example, certain types of bacteria, consuming hydrogen sulfide, contribute to the disappearance of an unpleasant odor. Other useful properties of certain species of bacteria that contribute to the utilization of sulfur-containing substances are also known.

1.4. Prokaryotes and conditions of their cultivation

1.4.1. Composition of prokaryote cells

Prokaryote cells contain up to 90% water, the share of dry substances accounts for the remaining 10%, the bulk of which (more than 95%) are proteins, polysaccharides, lipids and nucleic acids (Table 1). Several percent of the dry matter of cells falls on low molecular weight organic substances and salts (approximately 3%, see Table 1.1).

Table 1.1. Composition of prokaryotic cells

Substance	Quantity, % of cell solids
Proteins	52
Polysaccharides	17
Lipids	9
RNA	16
DNA	3

1.4.2. Nutrient needs of prokaryotes

Prokaryotes are usually fairly small microorganisms, about tenths to a few micrometers.

Depending on the food sources, prokaryotes are divided into two groups. One of them includes the so-called autotrophs, which are able to create all cell elements from carbon dioxide. Another group consists of heterotrophs, which use various organic compounds for constructive metabolism.

A special degree of heterotrophy have prokaryotes belonging to intracellular parasites, the vital activity of which can be fully carried out only inside the cells of other microorganisms.

Individual parasitic prokaryotes can also be grown on artificial media. Such environments tend to have a complex composition.

It should be especially noted that a large group of prokaryotes are saprophytes, which use various organic substances as a source of nutrition. At the same time, the requirements for the substrate of this group are very different. In

this regard, they are grown on media rich in proteins, vitamins, amino acids, etc., for example, on meat hydrolysates, yeast autolysates, plant extracts, etc.

It is interesting to note that there are prokaryotes that use a very limited number of organic substances for their nutrition, which they cannot synthesize themselves. Even heterotrophs that use a single source of carbon, such as alcohol or sugar, etc.

Another opposite example involves bacteria of the genus Pseudomonas. Some species of this genus are capable of oxidizing 100 to 200 or more sources of carbon.

Of particular note is the group of prokaryotes, which, for example, live in water bodies. This group is represented by oligotrophic bacteria that grow at low concentrations up to 1-15 mg of carbon per liter.

It is well known that along with carbon, oxygen and hydrogen, nitrogenous substances are also the most important element. It is known that a significant proportion of prokaryotes absorb nitrogen in reduced form. Although it is well known that prokaryotes also use oxidized forms of nitrogen, such as nitrates. In this case, nitrates are included in organic compounds with preliminary reduction.

Prokaryotes also consume phosphorus most often in the form of phosphates.

Most prokaryotes consume sulfur in the form of sulfates, which are reduced to sulfides. It should be noted that some groups of prokaryotes are not capable of reducing sulfates and need reduced sulfur compounds.

1.4.3. Carbon sources

It is well known that the source of carbon for microorganisms are both carbohydrates of simple and complex structure. Starting from about the middle of

the last century, the possibilities of industrial use as a source of carbon hydrocarbons of oil, natural gas, alcohols, including methanol, as well as hydrolysates of plant raw materials, etc. It should be noted that in the USSR in the 80-90s of the last century, the microbiological industry produced about one million tons per year of fodder yeast biomass on these substrates, which are sources of protein, vitamins and other valuable additives for cattle and pigs, as well as poultry.

When using hydrolysates of plant raw materials as substrates, its special preparation is required. In a simplified version, it includes the grinding of raw materials, subsequent processing at temperatures of 150 ... 250 0C and at increased pressure in an acidic environment with the use, as a rule, of sulfuric acid. At the same time, the equipment design of this method of preparation requires the use of corrosion-resistant materials and, in addition, to fulfill the necessary environmental standards, the use of multi-stage technologies for the purification of exhaust gas-air flows and those formed in a large amount of wastewater.

1.4.4. Nitrogen sources

It is well known that the cells of microorganisms contain about 10... 12% nitrogen. It is also known that under natural conditions, nitrogen occurs in oxidized and reduced forms and in the form of molecular nitrogen. Note that most microorganisms consume nitrogen in reduced form, for example, in the form of ammonium salts, urea. It should be noted that oxidized forms of nitrogen, such as nitrates, can also be consumed by microorganisms.

It should be especially noted that the ability of individual representatives of prokaryotes to use molecular nitrogen from the atmosphere is known. At the same

time, prokaryotes belonging to different groups, including aerobes and anaerobes, have this property.

1.4.5. Sources of phosphorus and sulfur

The participation of phosphorus in biological wastewater treatment processes is of great importance. The main form of phosphorus in nature are phosphates, which satisfy the needs of prokaryotes in it.

In the processes of biological wastewater treatment, the task of removing excess phosphorus, which in excess quantities enters the sewerage system with spent detergents, is most often solved. It should be noted that recently in the Russian Federation various decisions have been taken to reduce the discharge of used detergents into the sewerage, as well as to reduce the phosphorus content in detergents.

It is known that phosphorus is an essential element of nucleic acids, phospholipids, coenzymes, and sulfur is part of amino acids, vitamins and cofactors. It should be noted that most prokaryotes consume sulfur in the form of sulfate, which is reduced to the level of sulfide. Note that some groups of prokaryotes consume only reduced sulfur compounds.

Of particular interest are the sources of sulfur for the cultivation of thione bacteria. Our long-term research on the cultivation of thione bacteria confirms that these bacteria obtain energy for constructive metabolism by oxidizing sulfides, elemental sulfur, thiosulfates and sulfites to sulfates.

1.4.6. Metal ions in the nutrient medium

It is well known that the composition of the nutrient medium for prokaryotes should contain ions of various metals, including potassium, magnesium, calcium, iron, etc. Some metals, in particular calcium, magnesium, potassium, iron, should be contained in sufficiently high concentrations, and others - in small quantities, for example, manganese, molybdenum, zinc, sodium, copper, vanadium, nickel, cobalt.

It should be noted that metals enter the nutrient medium, as a rule, in the form of sulfates or chlorides.

1.4.7. The need for growth factors

An important role in the vital activity of prokaryotic cells is played by vitamins, amino acids, as well as various nitrogenous substances.

Often such organic substances, necessary for microorganisms in small quantities, are called growth factors. In this case, organisms that need one or more growth factors in addition to the source of carbon are called auxotrophs, in contrast to prototrophs, which synthesize all other necessary organic substances.

1.4.8. Energy resources

It is known that the available external energy resources for microorganisms are, for example, electromagnetic energy and chemical, in particular reduced chemical compounds. It should be noted that the ability to use light energy has a fairly large group of photosynthetic microorganisms, including prokaryotes. For

other microorganisms, the processes of oxidation of chemicals appear as sources of energy.

Energy resources may be biopolymers present in the environment, in particular proteins, polysaccharides, nucleic acids, and lipids.

1.4.9. Energy costs of the cell

It is well known that the energy of prokaryotes is consumed in different directions (Fig. 1.5).

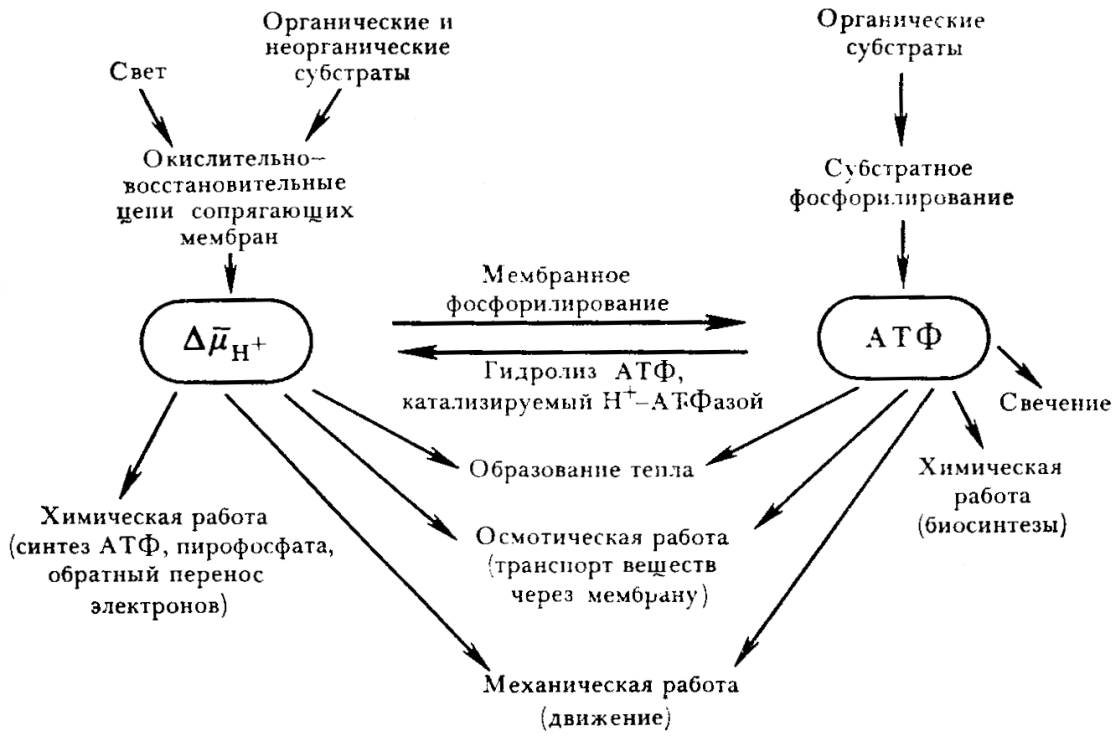


Fig. 1.5. Energy conversion in the prokaryote cell (according to Skulachev V.P.).

First of all, energy is spent on the biosynthesis of substances of the cell material. In addition, part of the energy is spent on various processes that are not related to cell growth. Such processes are called life support processes. This part of

the energy is called the life support energy. The amount of this energy depends significantly on the growth conditions. Approximately the energy of life support is 10 - 20% of all energy. Although there are also such conditions when microorganisms spend up to 90% of energy on this.

1.5. Prokaryotes and environmental factors

Compared to eukaryotes, prokaryotes as a group as a whole tend to live in a much wider range of changes in environmental conditions. This is manifested in almost all aspects of the vital activity of prokaryote cells.

1.5.1. Relation to oxygen

A significant number of microorganisms satisfy their oxygen needs in both a bound and free state. It should be noted that in relation to prokaryotes to oxygen, they can be divided into several physiological groups (Fig. 1.6). Prokaryotes that need oxygen are called obligate. It should be noted that ablagat aerobic prokaryotes, which can grow only at low concentrations, are called microaerophiles.

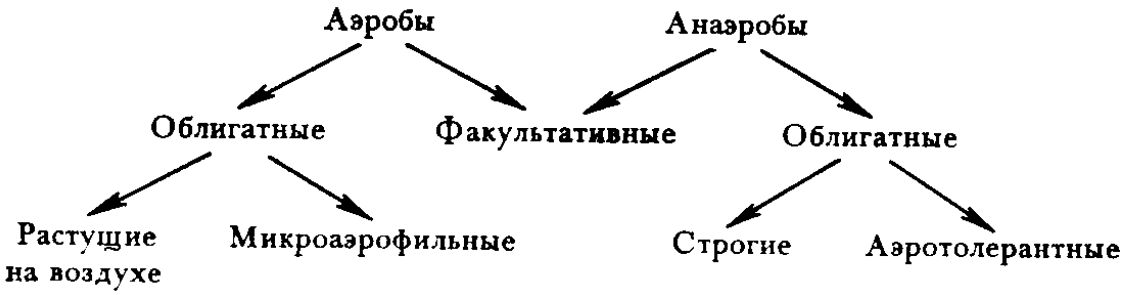


Fig. 1.6. Scheme of division of prokaryotes into groups depending on the relationship to molecular oxygen.

Among obligate aerobes, there are large differences in resistance to high levels of oxygen in the environment. It is known that in the absolute environment of oxygen, the growth of almost all obligate aerobes is suppressed.

Prokaryotes are well known, for the metabolism of which oxygen is not needed. Such microorganisms are called obligate anaerobes. It should be noted that there are many obligate anaerobic prokaryotes that evolved from aerobes as a result of secondary adaptation to anaerobic conditions.

Many of the obligate anaerobes do not tolerate the presence of even small amounts of molecular oxygen in the environment and die quickly. Such microorganisms are called strict anaerobes.

1.5.2 Effect of temperature

Temperature is the most important factor affecting the growth of microorganisms. At optimal temperatures, the maximum growth of microorganisms, including prokaryotes, is observed. In this regard, in strictly controlled biotechnological processes, the temperature regime is adhered to. In biotechnological processes, where the temperature regime for some reason cannot be maintained at a certain level, the temperature is set taking into account the influence of the environment. As an example of such a temperature regime, biological wastewater treatment processes should be pointed out. In the case of large wastewater consumption, for example, at the treatment facilities of Moscow (Kuryanovskaya and Lyuberetskaya stations), the ambient temperature does not affect the temperature of wastewater as much as in the case of wastewater treatment at relatively small treatment facilities. In the latter case, treatment facilities must be located in special production facilities with heating.

1.5.3. Relation to the acidity of the medium.

It is well known that the acidity of the environment is an important factor determining the possibility of the existence of prokaryotes. This is clearly manifested in the processes of biological wastewater treatment. The concentration of hydrogen ions in the surrounding environmentacts on the body directly or indirectly: through the influence on the ionic state and the availability of many inorganic ions and metabolites, the stability of macromolecules, the equilibrium of electrical charges on the surface of the cell.

Depending on the acidity of the medium, prokaryotes can beseparated into several groups (Fig. 1.8). The optimal pH for the growth of the vast majority of prokaryotes, called neutrophils, is an area close to neutral, and growth is possible, as a rule, in the range of *4* to 9, considered normal. Typical neutrophils are different strains *of Escherichia coli, Bacillus megaterium, Streptococcus faecalis.* The maximum detected pH limits for the growth of representatives of the prokaryote world are approximately from 1 to 11. Although many are able to grow or survive at pH values that lie outside the normal range, the optimum of their growth is usually within this range. Such prokaryotes are considered acid- or alkaline-resistant (tolerant). Acid-resistant include many bacteria that produce organic acids, for example, acetic acid, lactic acid, etc. Alkalieterrantes are many of the enterobacteria, resistant to pH values close to 9-10.

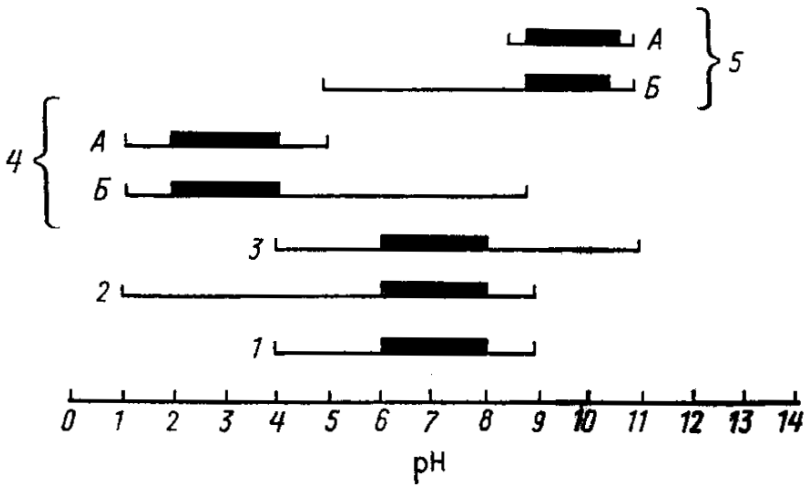


Fig. 1. 8. Boundaries and optimal growth zones of prokaryotes depending on pH and their classification based on this.

Neutrophils (1); groups of acid-resistant (2) and alkaline-resistant (Z) prokaryotes; acidophiles (4) and alkalophiles (5). Obligate (A) and facultative (B) forms. The bold line indicates the optimal pH of growth.

In some species, adaptation to the acidity of the medium has led to the fact that the optimum pH for growth has moved to the acidic (pH *4* and below) or alkaline (pH from *9* and above) zone. Such prokaryotes are called acidophilic or alkalophilic (acid- or alkaline-loving), respectively. Among both groups, there are obligate forms that have lost the ability to grow in the neutral region, and facultative ones that retain this ability. A typical representative of obligate acidophiles are distinguished. A typical representative of obligate acidophiles are distinguished. bacteria of the genus *Thiobacillus.* Of the alkalophiles, some representatives of the genus Bacillus can be attributed to the obligate.

Naturally, the ability to grow at low or high pH values provide the body with certain advantages, since in these conditions competition from other organisms is sharply limited. To date, it is not known what is the mechanism that ensures the stability of cells and the possibility of their active reproduction at high and low values of the acidity of the medium. Naturally, the most advanced such mechanisms should be in obligate acido- and alcalophila. For the former, it has been shown that they do not just tolerate high concentrations of H^+, but need them for growth and stability.

Prokaryotes growing at extreme pH values have developed different mechanisms for maintaining intracellular pH in the neutral region.

In a number of acidophiles, the transmembrane pH gradient is maintained by active metabolic processes based on membrane-related mechanisms of volatile

ejection of hydrogen ions. Similar mechanisms for the removal $^{of\ OH}$ ions are assumed in obligately alkalophilic organisms.

Thus, the main barriers to high concentrations of H^+ and OH^- the external environment in obligate acido- and alkalophiles are the cell wall and CPM. The search for features of the structure and functioning of these cellular structures has not yet led to the decoding of specific mechanisms of their resistance to high concentrations of H^+ and OH^-. It is also unknown why obligate acidophiles and alcalophiles lost the ability to grow in a neutral environment, i.e. why high concentrations of these ions became absolutely necessary for them.

Among the obligate acidophiles, two physiological groups are clearly distinguished. The first includes organisms growing in an acidic environment at moderate temperatures (mesophilic acidophiles). This group includes members of the genus *Thiobacillus.* The second group is formed by thermophilic acidophiles, primarily *Bacillus acidocaldarius, Sulfolobus acidocaldarius* and *Thermoplasta acidophila.* Studies of the structure and chemical composition of the cell wall and membranes of thiobacilli showed that they have a thin structure typical of Gram-negative prokaryotes. Thiobacilli did not have any specific structures or chemical components responsible for acidophilia.

Obligate alkalophiles have not yet found any features in the structure and chemical composition of their cell walls and CPM, explaining not only resistance to high concentrations of OH ions, but also the absolute need for them.

The influence of pH on the process of cultivation of microorganisms, including the process of biological wastewater treatment, has a very significant impact. In this regard, it is necessary to strictly monitor this indicator.

Test questions for section 1

1. What is the position of microorganisms in the system of the living world?

2. What are the principles of systematics of microorganisms?
3. What is the structure of eukaryote cells?
4. What is the elemental composition of a bacterial cell?
5. What is the dependence of the growth rate of microorganisms on the concentration of the substrate?
6. What are the main ways to inhibit microorganisms?
7. What is the role of cell enzymes and their role in the processes of its vital activity?
8. What are the main differences between prokaryotes and eukaryotes?
9. What is the influence of physical environmental factors on the vital activity of microorganisms?
10. What is the influence of chemical factors of the external environment on the vital activity of microorganisms?
11. What are the structural features of cyanobacteria cells?
12. What are the main groups of eukaryotes?
13. What are the main differences between activated sludge and monocultures?
14. What is the approximate qualitative composition of activated sludge?

Section 2. Application of industrial biotechnologicalprocesses in the technology of biological water purification

2.1. Cultivation system and nutrient medium

Cultivation of microorganisms in industrial conditions is carried out in bioreactors, in which the necessary conditions are created for the vital activity of microorganisms and their metabolism, and in most cases monocultures of selected strains of the producer are used for this purpose. Perth distinguishes between open and closed cultivation systems. Closed, he calls such a fermentation system, in which at least one of the components of the medium is constantly present and is not removed from it; open — a system in which all components of the environment can enter and exit from it. Such a separation of fermentation systems is convenient from the point of view of mathematical analysis and process modeling, as well as for theoretical calculations of cell growth and the study of individual stages of metabolism, but it does not fully characterize the system as a whole and its functioning. For each artificially created system of cultivation of microorganisms, the following interrelated factors are of great importance: microorganisms and nutrient substrates, the method and mode of cultivation, as well as fermentation equipment.

2.2. Cultivation methods.

There are different methods of cultivation. The cultivation method is developed taking into account the factors by which the external conditions of cultivation are regulated in order to meet the needs of the producer, mobilize the biochemical potential of microbial cells and direct their metabolism along a certain pathway.

Currently, the following cultivation methods are widely used: 1) the deep method - aerobic, deep, periodic (or semi-continuous), mesophilic cultivation using monoculture. For example, biosynthesis of lysine, glutamic acid, antibiotics, some enzymes, cultivation of fodder and baker's yeast, etc .;

2) surface method - aerobic, surface, periodic (or semi-continuous), mesophilic cultivation using monoculture. For example, the production of certain enzymes.

3) anaerobic method - anaerobic, deep, semi-continuous, thermophilic cultivation using monoculture or microbial associations. For example, the biosynthesis of vitamin B12 by methane fermentation;

4) solid-phase method - aerobic, solid-phase, periodic (or semi-continuous), mesophilic cultivation using monoculture or microbial associations. For example, the biosynthesis of avamorine and other enzymes.

5) continuous method - aerobic, deep (less often - surface or solid-phase), continuous, mesophilic (or thermophilic) cultivation using monoculture (less often microbial associations). For example, acetic acid, ethyl and methyl alcohols, etc.

There are other methods that can be applied to different culture methods, for example, immobilization of producer cells, in different combinations in order to better meet the needs of the producer.

2.3. Aerobic processes.

Consider the aerobic processes of cultivation of microorganisms. In aerobic processes during the exchange between the cultivation system and the external environment, the assimilation of atmospheric oxygen by the producer (less often pure oxygen) and the removal of excess carbon dioxide from the system are of great importance. Substances assimilated by microorganisms are used for:

1) synthesis of biomass, 2) production of metabolites, 3) maintaining a certain level of metabolism.

This pattern is also characteristic of the absorption of oxygen. In industrial culture, the bulk of oxygen is used by bacteria to synthesize biomass and maintain metabolic rates. Of all the substances entering the cell from the nutrient substrate, oxygen due to the high rate of consumption in most cases is considered the main

limiting factor. The rate of dissolution of oxygen in pure water is quite low. Dissolved and suspended substances in the nutrient substrate can not only reduce, but also increase the rate of dissolution of oxygen (Table. 2.1 – 2.3).

Table 2.1. Dependence of the rate of oxygen dissolution in distilled water on temperature and pressure (mg About$_2$/l/min)

t, °C	Overpressure, atm		
0	0	0,5	1.0
5	21	23	24
10	17	18	19
20	13	15	16
30	12	13	14
40	10	11	12

Table 2.2. Dependence of the rate of oxygen dissolution in distilled water on the presence of dissolved substances (at 18 ° C without excessive pressure)

Substance	Concentration	mg About$_2$/l/min
Water	—	13,5
Glucose	2,0	10,0
Glucose	20,0	6,3
$(NH_4)_{-2}The_4$	0,35	10,3
$(NH_4)_{-2}The_4$	0,50	8,3
NaCl	0,20	11,0
NaCl	2,0	10,2

Table 2.3. Solubility of oxygen in water depending on the concentration of dissolved emulsified and dispersed particles of the nutrient substrate

Sucrose, %	mg About$_2$/l	Sunflower oil, %	mg About$_2$/l	Biomass, g/l	mg About$_2$/l
0	8,2	0	8,9	0	8,0
2,5	7,8	0,5	11,6	3,0	4,1
5,0	7,2	0,10	18,9	6,0	2,4
7,5	6,6	0,15	19,0	9,6	1,5
10,0	5,9	0,20	22,3	16,0	1,2
15,0	4,8	—	—	32,0	0,8
20,0	4,2	—	—	,—	

The need of aerobic microorganisms for oxygen dissolved in the medium depends both on the source of carbon and on the physiological properties of microorganisms and the conditions of cultivation (Table. 2.4, 2.5).

Table 2. 4. The amount of oxygen needed by the yeast to synthesize 1 g of ASB, depending on the carbon source.

Carbon Source	Oxygen, d	Carbon Source	Oxygen, d
Glucose	0,74	Amber k-ta	1,60
Glycerin	1,84	Dairy company	1,00
Ethanol	1.83	Fats	2,02
Acetic K-ta	1,64	Paraffins	2,60

Table 2.5. The need of the *producer of Penicillium chysogenum* in oxygen and sugar, depending on the source of carbon

Carbon Source	Sugar, mg/l/min	mg About$_2$/l/min	Carbon Source	Sugar, mg/l/min	mg About$_2$/l/min
Galactosis Lactose Saharoza	3,3 5,3 7,7	0,83 1,33 1,83	Fructose GlucoseGlucose + fructose	9,2 11,9 13,3	2,53 3,50 4,00

In the vital activity of aerobic microorganisms, oxygen plays the role of: 1) an electron activator; 2) regulator of enzyme activity; 3) inhibitor of growth activity and biosynthesis; 4) regulator of the activity of the respiratory chain when it is conjugated with oxidative phosphorylation; 5) the constituent part of the substrate (H_2O, CO_2, unsaturated fatty acids, sterols and other oxidized organic compounds).

When studying the aeration regimen, it is customary to talk about the critical concentration of oxygen, at which there is a limit of cell respiration. For most aerobic microorganisms in sugar-containing substrates, the critical oxygen concentration is 0.05-0.1 mg / l, which corresponds to 3-8% of the total oxygen saturation of the medium. The limit of cell growth and supersynthesis of some metabolites is observed at higher oxygen concentrations. On media with glucose, the growth rate of yeast is limited at pO_2 at 20 - 30% of the total saturation of the medium with oxygen, and the limit of respiration at 59%. On n-alkanes, the growth *of Candids lipolytica* is limited at 70-80% oxygen saturation, and respiration at 10-20%. Insufficient aeration is the cause of the slow growth of pigmented yeast *Rhodotorula gracilis* and reduced carotene formation. Under conditions of insufficient aeration, a change in cell metabolism occurs. For example, the producer of lysine *Brevibacterium flavum* with a lack of oxygen instead of lysine intensively produces lactic acid.

For the normal growth of *yeast Saccharomyces serevisiae* on a medium with glucose, the optimal oxygen concentration is 3-4 mg / l, for yeast growing on n-alkanes - 5-7 mg / l. Aeration modes in industrial conditions have been studied by many authors and in most cases a significant effect of dissolved oxygen concentration on the processes of cultivation of microrganisms has been established. It is known that intensive aeration completely suppresses alcohol fermentation and promotes the growth of yeast biomass. It was found that the maximum concentration of oxygen in the medium is 6.0-6.5 mg O_2 / l. If it is exceeded, a decrease in biomass growth is observed. During the biosynthesis of lysine by the auxotrophic mutant *Brevibacterium flavum* on a molassic medium, the optimal oxygen concentration is 3-5 mg / l (Z5-45% of the full saturation of the medium with oxygen), and during the active biosynthesis of lysine 1.5-2.0 mg / l (about 15% of the full saturation). Synthesis of the antibiotic gramicidin 8 producer *Bacillus brevis* begins after a decrease in the growth rate caused by a decrease in the concentration of dissolved oxygen. The growth limit of the producer of gramicidin *S* from dissolved oxygen seems to be a prerequisite for the synthesis of an antibiotic.

Microorganisms react differently to changes in the aeration regime. Optimal growth of *Candida humicola* yeast on a paraffin-containing medium was observed at an oxygen dissolution rate of 7.0-8.5 mg / l / min. A further increase in aeration intensity leads to a sharp decrease in biomass productivity. *Candida parapsilosis* yeast on a medium with paraffins grew better at an oxygen dissolution rate of 23 mg / l / min. Further increased aeration led to a decrease in biomass growth. Lysine producer *Brevibacterium flavum* on a molassic medium at an oxygen dissolution rate above 15 mg / l / min, morphological changes occur, leads to the formation of thick microcapsules and thickening of cell walls and at the same time the distribution of ribosomes becomes uneven, etc. In addition, the extracellular synthesis of lysine is markedly reduced.

However, in *the yeast Candida sp*. and the carotene-forming yeast *Sporobolomyces sp.,* increased aeration did not cause a slowdown in biomass growth.

In the cultivation of aerobic microorganisms, the following aeration modes should be distinguished: minimum (limiting cell respiration), optimal (differentiated for biomass growth in the biosynthesis of the target product), maximum (above which oxygen inhibition is observed).

The necessary conditions for saturation of the medium with oxygen are created with the help of aeration and mixing devices. In numerous laboratory experiments and industrial installations, it was shown that in some cases, when using effective aeration devices, the need for mechanical mixing of the medium disappears. However, it should be noted that the technical and economic results of the production of fodder yeast on petroleum paraffins indicate the feasibility of using mechanical aeration systems.

Data on the effect of aeration and mixing of the medium on the rate of dissolution of oxygen in water, as well as on the biosynthesis of lysine and pectolytic enzymes are presented in Table. 2.6 - 2.8.

Table 2.6. The rate of dissolution of oxygen in water (mg / l / min) depending on the aeration and mixing of the medium (laboratory fermenter with a working capacity of 8 liters).

Air quantity, rpm/rev/min	Cole's Agitator speed				
	0	500	800	1000	1200
0,35 0,65 1,00 1,30 1,60	1,3 3,5 6,0 7,5 11,0	4,0 7,3 10,0	7,5 12,1 15,0	14,5 19,1 23,0	15,1 22,1 24,0

		13,9 15,5	18,0 20,0	26,0 27,0	28,0 29,0

Table 2. 7. Biosynthesis of lysine in a culture of *Brevibacterium flavum* depending on the oxygen mass transfer regime (laboratory fermenter with a working capacity of 60 liters).

Amount of air, rev/rev/min	Number of agitator revolutions, rpm	Growth time, h	Biomassa, g/l	Lysine-HCl, d/l
0,7	160	96	9,2	10
1,0	160	84	10,5	16
1,3	160	72	10,9	21
0,7	200	84	9,5	16
1,0	200	84	12,2	25
1,3	200	72	14,9	28
0,7	230	72	12,2	23
1,0	230	68	14,6	31
1,3	230	68	15,1	36

Table 2.8. Biosynthesis of pectolytic enzymes by the mutant *Penicillium digitatum* depending on the oxygen mass transfer regimen.

Amount of air, rev/rev/min	Number of agitator revolutions, rpm	Growth time, h	Enzymatic activity, units. ml	
			PCA	PTE
1,0	200	96	0,820	1,1

1,0	300	72	0,820	1,2
1,0	500	60	0,820	1,5

Designations: PCA pectological activity, PTE pectin transeliminase activity.

In industrial conditions, the aerative agent is usually pre-purified and disinfected atmospheric air. However, there are examples with a different approach. For example, the company "Linde" (Germany) began in Romania the production of microbial protein using the technology of the Japanese company (Garrido-Shika method), according to which the aeration of the medium containing methanol, ethanol and molasses is carried out with 95% oxygen. With continuous cultivation, 10 times more biomass (45 kg/^{m3}/h) was obtained than conventional aeration methods.

2.5. Receipt of ingredients in the nutrient medium.

In the process of cultivation, the main components are often added to the nutrient medium once or repeatedly. This allows you to effectively use the fermentation equipment, creates conditions for a more even distribution of the ingredients of the medium, eliminates the occurrence of concentrations inhibiting them. However, the addition of the main nutritional components disrupts the course of the natural development of the population of microorganisms, the sequence of cell development or delays this process. Targeted fertilization helps to lengthen the stage of intensive biosynthesis, which increases the efficiency of the directed metabolism of microorganisms. Therefore, in industrial practice, the so-called "pre-pour" (one-time or periodic additions of fresh medium) and "tidal-pre-pouring" methods are widely used in industrial practice. fermentation (periodic additions of fresh medium with simultaneous withdrawal from the culture system of an equivalent amount of fermented solution).

With deep fermentation of lysine for the 16-28th hour, 10-20% of the fresh medium is added. This contributes to a more rational use of fermentation equipment and efficient management of the fermentation process. For example, the feed biomass of the micromycete *Penicillium digitatum* can be grown by the tidal-pre-pour method. With periodic cultivation of micromycetes on a natural medium (potatoes and mineral salts), 9 g / l of biomass accumulates for 36 hours. By rebuilding the cultivation system to an tidal-pre-pouring regime with a dilution factor of the medium B = 0.02-0.1 $^{h-1}$, it is possible to stabilize biomass growth at the level of 7.2-7.9 g / l, which corresponds to a specific biomass growth rate of 0.6 g / l / h (with a dilution coefficient D = 0.1 $^{h-1}$). In this case, the performance of the system increases by 1.6-2.0 times.

The most effective is the continuous cultivation method. An example of such a process is continuously operating plants for growing micromycetes on a belt drying plant of the SPK type or on an automatic vibrating installation of a vertical type, in which a growing culture is successively poured from one shelf to another.

More complex is the continuous cultivation in the chemostat, in which fresh nutrient medium is fed into the culture system at a constant rate, and the volume of the fermentation substrate is maintained by continuously removing part of the fermentation substrate from the system. The complexity of the method of chemostatic cultivation lies in the fact that the self-regulating functions of the integration of the microbial population system are partially blocked by the continuously changing environment, so the equilibrium of the system is adjusted artificially and the cultivation process is controlled. In cases where it is possible to manage the process quite effectively, the method of continuous cultivation will give high results. For example, with continuous cultivation of the fungus *Endomycopsis fibuligera* on a medium containing ethanol at a concentration of 1.0%, the maximum biomass productivity (7.0 g / l / h) is achieved at a dilution coefficient of the medium D = 0.6 h-1.

Czech scientists together with employees of the Austrian company "Vogelbusch" have developed a technology for continuous cultivation of yeast *Candida utilis* and *Candida tropicalis* on a sulfite bard with ethanol additive (in 1 m^3 medium must contain 32 kg RV and 26 kg ethanol) at dilution rate D=0.33 h^{-1}. Biomass yield is 10 kg of ASB per 1 m^3 Leith & Layle (UK) has developed a technology for continuous biosynthesis of ethanol with the recycling of yeast biomass. Ethanol yield is 82 kg per 1 m^3 Medium at 1 h (compared to 4 kg/m^3/h under conditions of periodic cultivation). With continuous cultivation of the fungus *Kluiveromyces Fragile* (D=0.6 h^{-1}) obtained 80 times more ethanol than with periodic. The rate of inflow of fresh media has a significant impact on the intensity of biomass growth and the activity of enzyme systems of producers; the morphology and chemical composition of cells also change. In aerobic deep cultivation of the fungus *Polyporus squamosus* on a molasses medium in periodic or tidal-pre-filling modes or under conditions of continuous fermentation, the amount of total protein in biomass was 18-20, *40—45,* 56-65%, respectively. Significant differences were also found in the total content of nucleic acids - 4-5, 5-6, 6-8% and lipids - 4-5, 3-4, 0.5-1%. The true protein content in the mycelium of this fungus did not change in all three cultivation options and amounted to 30-33% of the ASB.

2.6. Co-cultivation.

Despite the fact that the use of microorganisms for the preparation of bread, sour-milk products, wine and other products has a long history, the creation of artificial cultivation systems, the regulation of the composition of microbial associations and directed biosynthesis have become possible relatively recently.

Mixed crops used in industrial biotechnology can be conditionally divided into three groups.

The first group includes cultures consisting of two or more species of microorganisms capable of a process of biosynthesis that individual members of

the association cannot carry out or in this case the process of biosynthesis occurs at a low rate.

In such associations, there is a close relationship between its members. An example of such a mixed culture is the association of thermophilic bacteria growing on methanol. In this association, 4-5 species of morphologically different bacteria are stably retained, and the non-methylotrophic flora prevails over the methylotrophic. Non-methylotrophic bacteria develop due to methylotrophs. It is not possible to single out pure crops from the association.

The second group is formed by relatively independent species of microorganisms, the physiological activity of which is independent and the process of biosynthesis of which is carried out by monoculture or alternative members of the association. An example of this type is the association of *the fungus Aureobasidium pullans* - the producer of the valuable commercial product of the polysaccharide pullulan - and the fungus *Ceratocystis ulmi.* The producer of pullulan in industrial conditions is advantageous to grow on media prepared on the basis of by-products of the dairy industry - whey and buttermilk. The biosynthesis of pullulan in monoculture on lactose media proceeds slowly, but it can be significantly intensified when co-cultured with the fungus *Ceratocystis,* which forms the β-galactose.

The third group of mixed crops includes those whose composition varies. The relative stability of the association depends only on the constancy of the composition of the nutrient medium and the conditions of cultivation. Of great importance are the adaptive properties of the participants in the mixed culture. Sometimes it is possible to distinguish the main types of association that determine the direction of the process, as well as random concomitant species. An example of such an association is the microflora of biological treatment facilities used for municipal wastewater treatment.

For the first time, mixed cultures were studied by Pinua (1921), who established that in the presence of certain bacteria, the growth of myxobacteria is stimulated. Imshenetsky and Solntseva (1936) noted an acceleration in the growth of cellulosic myxobacteria in the presence of other microorganisms. There are many examples of the stimulating effect of joint cultivation of lactic acid bacteria with other bacteria, enhancing growth and increasing their biochemical activity during joint cultivation. Some microorganisms, when cultured with azotobacter, form heteroauxins. Enhanced biosynthesis of vitamin B_{12} propionic acid bacteria in the presence of lactic acid bacteria has been described. When stored in the laboratory, some actilomycetes lose their ability to synthesize antibiotics, but it can be restored by their co-cultivation with micromycetes from the genus *Penicillium*.

In the co-cultivation of actinomycetes *(Actinomyces violocinereus, Act. Rimosus* et al.) biosynthesis of proteolytic enzymes, including exoproteases of thrombolytic action, increases up to six times compared to the biosynthesis of these enzymes by monocultures. Although unilateral or mutual inhibition of microorganisms is often observed in joint cultivation, the study of their assimilation of environmental components and the identification of growth patterns of different types of microorganisms is of great importance, especially when the goal of the process is the synthesis of microbial biomass or the destruction of natural compounds. American researchers have developed a technology for the joint cultivation of microorganisms of the genera *Celullomonas* and *Alcaligenes,* which made it possible to increase the yield of their biomass and improve the amino acid composition of the synthesized protein.

In Sweden, a process involving a two-component mixed culture has been developed to treat the effluents of potato processing and microbial protein production plants: *Endomycopsis fibuligera,* which hydrolyzes potato starch and low molecular weight sugars, but has a low growth rate, and *Candida utilis,* which assimilates the metabolic products *of Endomycopsis fibuligera* with a high growth

rate. *andida utilis* dominates the association and makes up about 96% of the population. The composition of the final feed product (%): carbohydrates - 40-50, protein - 36, lipids - 4-5, vitamins of group B. Product yield - 0.6 kg per 1 kg of assimilated starch, productivity - 1-2 kg of dry weight per 1 m^3 of medium in 1 h. To ensure a balanced growth of this association in the seed material, the dominance of representatives of *Endomycopsis fibuligera* is necessary.

Mixed cultures are used to produce feed protein, amino acids, vitamins, antibiotics, enzymes, organic acids. When microorganisms of different species are co-cultivated, completely new properties are often discovered that are uncharacteristic of these species when they are grown in the form of monocultures. N. S. Egorov and N. S. Landau proposed a method for increasing the yield of proteolytic enzymes by creating microbial associations from actinomycetes, fungi and corynebacteria. In this case, the producer of proteases, regardless of whether it is an actinomycete, a fungus or a corynebacterium, is cultivated with a closely related microorganism. The greatest yield of proteases is observed in the presence in the mixture of 75-80% of the producer fungus and 20-25% of the inactive indicator fungus, as well as 90% of the producer's actinomycetes and 10% of inactive actinomycetes.

It is known that during the joint cultivation of propionic acid and lactic acid bacteria *Streptococcus lactis diastaticus, Propionibacterium shermanii, Lactobacterium plantarum*, grown on vegetable juice, the biosynthesis process intensifies. Many other examples are known. For example, the possibilities of co-culturing the cellulase producer of *the fungus Trihcoderma lignorum* with a number of microorganisms *Brevibacterium sp*., *Candida lipolytica, Penicillium lanso viridae, Streptomyces sp*., grown on a cellulose-containing substrate, have been investigated. and the producer of glucoamylase *Endomycopsis fibuligera* on cellulose-containing substrates under deep conditions, as well as under conditions of solid-phase fermentation, the intensification of the biosynthesis of hydrolytic

enzymes has been established. Joint cultivation of these cultures by the solid-phase method makes it possible to obtain cellulase in addition to glucoamylase, which is not detected during deep cultivation. Obtained by joint cultivation *trihcoderma lignorum* and *Endomycopsis fibuligera* protein feed concentrate from straw contains up to 16% protein and about 23% fiber.

The interaction between *Azotobacter* and nodule bacteria has been established during their joint cultivation: azotobacter supplies nodule bacteria with nitrogen and vitamins, ensuring their development on nutrient substrates unsuitable for the growth of monocultures of nodule bacteria.

It is known that different types of yeast selectively use the nutritional components of the medium. Skillful selection of cultures can create a stable association that can more fully use the multicomponent carbon source environment, enhance the rate of cell growth and increase the productivity of the system during continuous cultivation.

The Institute of Biochemistry and Physiology of Microorganisms of the Russian Academy of Sciences proposed a technology of microbial protein synthesis using a microbial association consisting of *yeast Candida quilliermondi, C. tropicalis, C. lipolytica, Torulipsis candida,* and the bacteria *Pseudomonas aeruginosa.* A successful selection of the association of microrganisms made it possible to increase the productivity of the cultivation system by 2.5 times.

The technology of production of ethanol from cellulose using the association of microorganisms is known. Within 120 hours, the mixed culture decomposes by 90% a substrate containing 2% microcrystalline cellulose. From 1 mol of glucose equivalent contained in cellulose, 0.73 mol of ethanol, 0.42 mol of acetic acid, 0.24 mol of hydrogen and 0.6 mol of carbon dioxide are formed.

With the help of microbial associations (yeast and lactic acid bacteria), it is possible to obtain protein-vitamin preparations from whey containing lactose, and

it turned out to be possible to use such yeast cultures that under normal conditions do not assimilate lactose.

There are many examples of the use of mixed crops to clean the soil, in particular when it is contaminated with oil and oil products.

The use of natural microbial associations in industrial biotechnology does not cause particular difficulties. However, the use of artificially created microbial associations is often difficult for the following reasons: 1) due to competition for the limiting component of the medium; 2) due to inhibition of the growth of one type of association by metabolites of another species; 3) due to the imbalance in the growth of all members of the association, which causes biological and biochemical instability of the association.

2.7. The main factors affecting the speed of the biochemical process.

The main factors that have a significant impact on the speed of the biochemical process include: the presence of inhibitors in the reaction medium, pH, pressure and temperature.

Influence of inhibitors. Enzyme activity in the process of biochemical transformation of a substance is often inhibited by the action of substances called inhibitors. According to the effect on the process, inhibitors are divided into competitive, non-competitive and combined action.

When competitively inhibited, part of the enzyme interacts with the inhibitor to form a so-called enzyme-inhibited complex. This leads to a partial loss of activity by the enzyme during the formation of the product.

The rate of product formation will depend on both the concentration of the substrate and the concentration of the inhibitor, since there is competition between the substrate and the inhibitor on the surface of the enzyme for its use.

With non-competitive inhibition, the formation of an additional triple enzyme-substrate-inhibitor complex is characteristic. In this type of inhibition, neither the substrate nor the inhibitor competes for the use of the enzyme. The affinity of the enzyme for these substances does not change depending on whether the enzyme exists in its pure form, in the form of an enzyme-inhibited or an enzyme-substrate complex.

In biochemical processes, the rate of the reaction catalyzed by the enzyme changes with a change in the concentration of hydrogen ions in the reaction medium. At the same time, the activity of the enzyme, and consequently the reaction rate, reaches a maximum at a certain pH value, after which they decrease. In the region of maximum activity, the reaction rate changeswith the variation in the pH of the environment. 2.1).

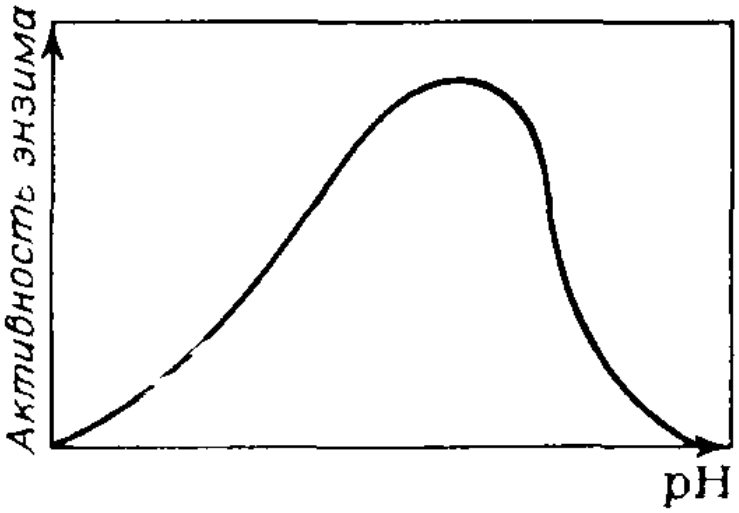


Fig. 2.1. The influence of the pH of the medium on the rate of biochemical reaction (on the activity of the enzyme)

Influence of temperature and pressure. The effect of temperature on the activity of the enzyme and the rate of biochemical reaction, as well as the influence of the pressure of the medium, is complex and is expressed by a curve passing through the maximum. The decreasing part of the curve corresponds to an increase in the

reaction rate with temperature, and the increasing part of the curveis the denaturation of the enzyme (Fig. 2.2).

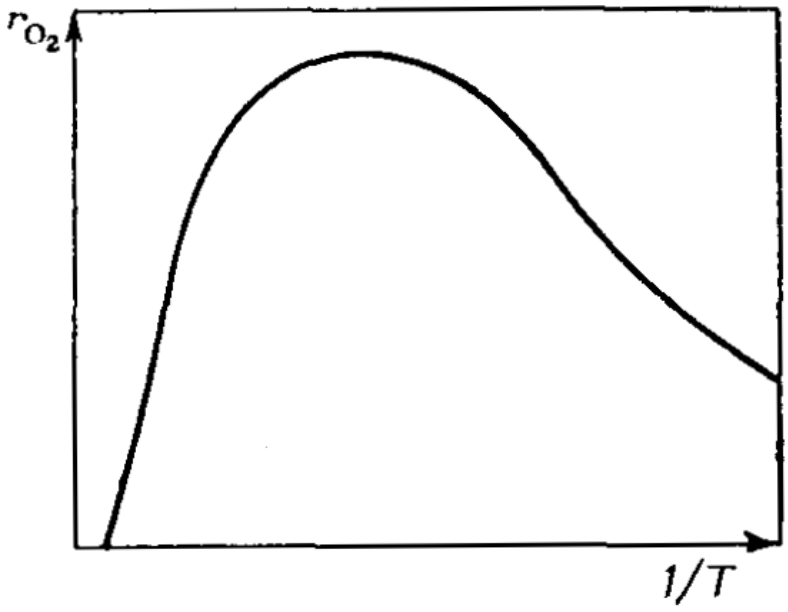


Fig. 2.2. Influence of temperature (T) on the rate of biochemical reaction (r_{O2})

2.8. Fermentation apparatus and technological modes.

Fermentation equipment and auxiliary devices are a system that should provide optimal living conditions for cultured microorganisms. With the help of this system, exchange with the environment is carried out, external influences are corrected and metabolism is purposefully carried out. To carry out these operations, measuring devices are needed that serve to collect information on the chemical, biochemical and physicochemical parameters of the cultivation system, as well as regulatory mechanisms.

For each specific process of microbial synthesis, special equipment is required, the adjustable parameters of which differ depending on the processes: sterilization of the medium, air and additional ingredients, aeration, mass transfer O_2 and CO_2, pH of the medium, heating and heat removal, defoaming, addition and

evacuation of individual components of the medium from the system, etc. The key point in controlling the biosynthesis process is to ensure optimal modes depending on the from the composition of the environment and the living conditions of microorganisms. Devices for aeration and mixing of the medium, foam-regulating mechanisms and the bioreactor as a whole must correspond to the morphophysiological properties of the cultivated producer. In large-scale production, it is necessary to create bioreactor complexes or fermentation lines that include a full set of special technological operations. In the practice of culturing microorganisms, several types of fermenters are known, either for deep or for surface cultivation, which the manufacturer, at the direction of the customer, adapts to the required technological regimes. Sometimes the customer, to the best of his ability, completes and re-equips typical equipment, bringing it closer to the production conditions. For industrial biosynthesis at the first stage - fermentation, specific equipment is used - fermenters, and others use equipment designed for other technological processes. Thus, ribbon dryers of vegetables are adapted to implement a continuous method of solid-phase fermentation. Due to a number of technical reasons, the efficiency of industrial biosynthesis is now in many cases lower than that in the laboratory. Of these reasons, it should be noted: 1) insufficient tightness of pressure fittings, as a result of which it will not be possible to protect the cultivation system from the introduction of foreign microflora in industrial conditions; 2) lack or absence of installations for ultrafiltration and cold sterilization of environmental ingredients that are productive for large-scale production; H) insufficient reliability of equipment for automatic measurement and regulation of sterile processes, lack of sterilizable electrodes; 4) poor use of computers for collecting and processing information about the conditions of the internal cultivation system necessary to adjust the programmed technological regimes.

2.9. Examples of hardware design of biochemical reactors.

The description of the equipment design of various processes of biochemical production will be considered on specific examples of obtaining a variety of products: yeast, protein preparations, amino acids, antibiotics, enzymes, food acids, as well as microbiological wastewater treatment, etc.

Examples of instrumentation are given by groups of devices in accordance with the principle of energy input and the main design features, i.e. according to one of the accepted, most general classifications of biochemical reactors (Fig. 2.3).

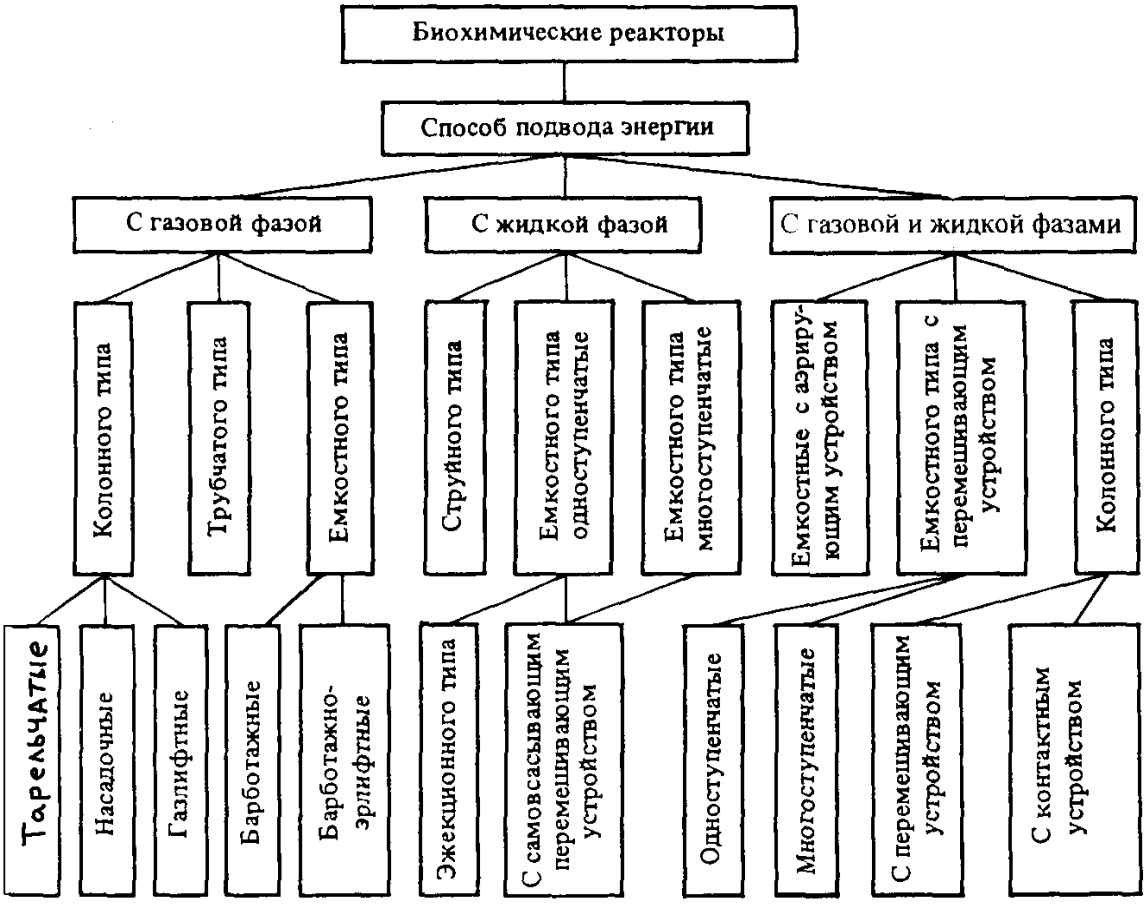


Fig.. 2.3. General classification scheme of biochemical reactors.

In microbiological production, the most widespread reactors are with mechanicalmixing devices. Figure 2.4 depicts a typical protozoan fermenter reactor with a mechanical agitator.

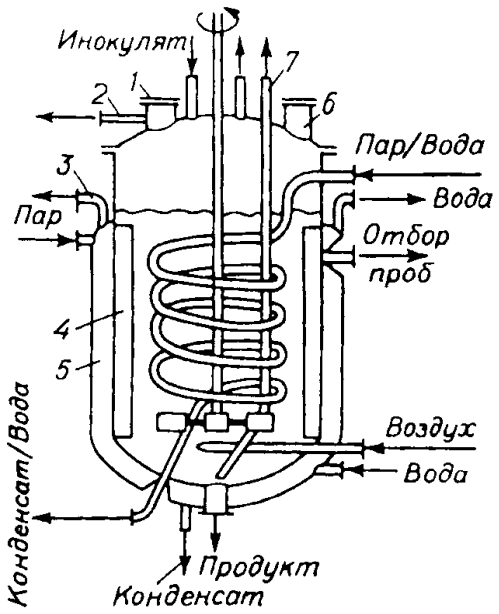
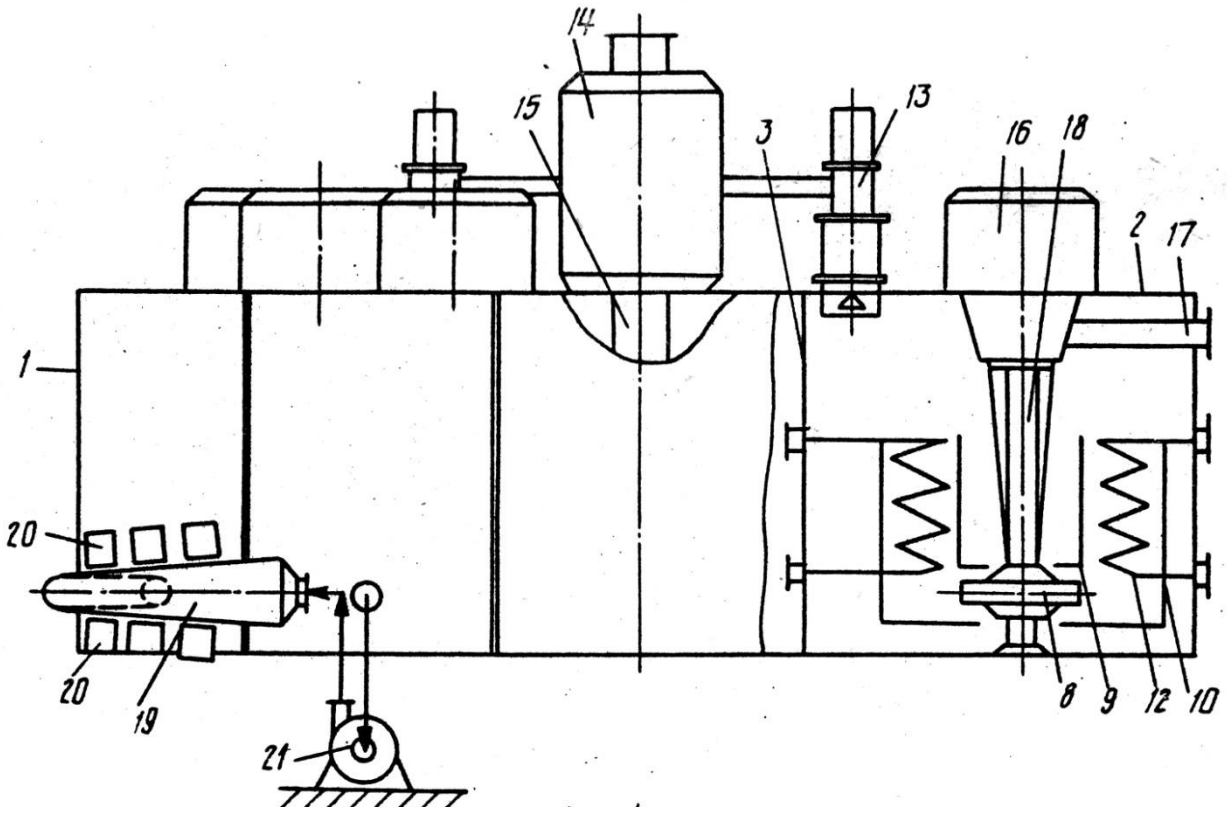


Fig. 2.4. Fermenter reactor:

1 — observation window; 2 — air vent; W — fitting for removing the air plug; 4 — partition; 5 - shirt; 6 — glasses for illumination. 7 – Transmission line

In Figure 2.5 shows one of the designs of a this type of apparatus for obtaining biomass of fodder yeast.



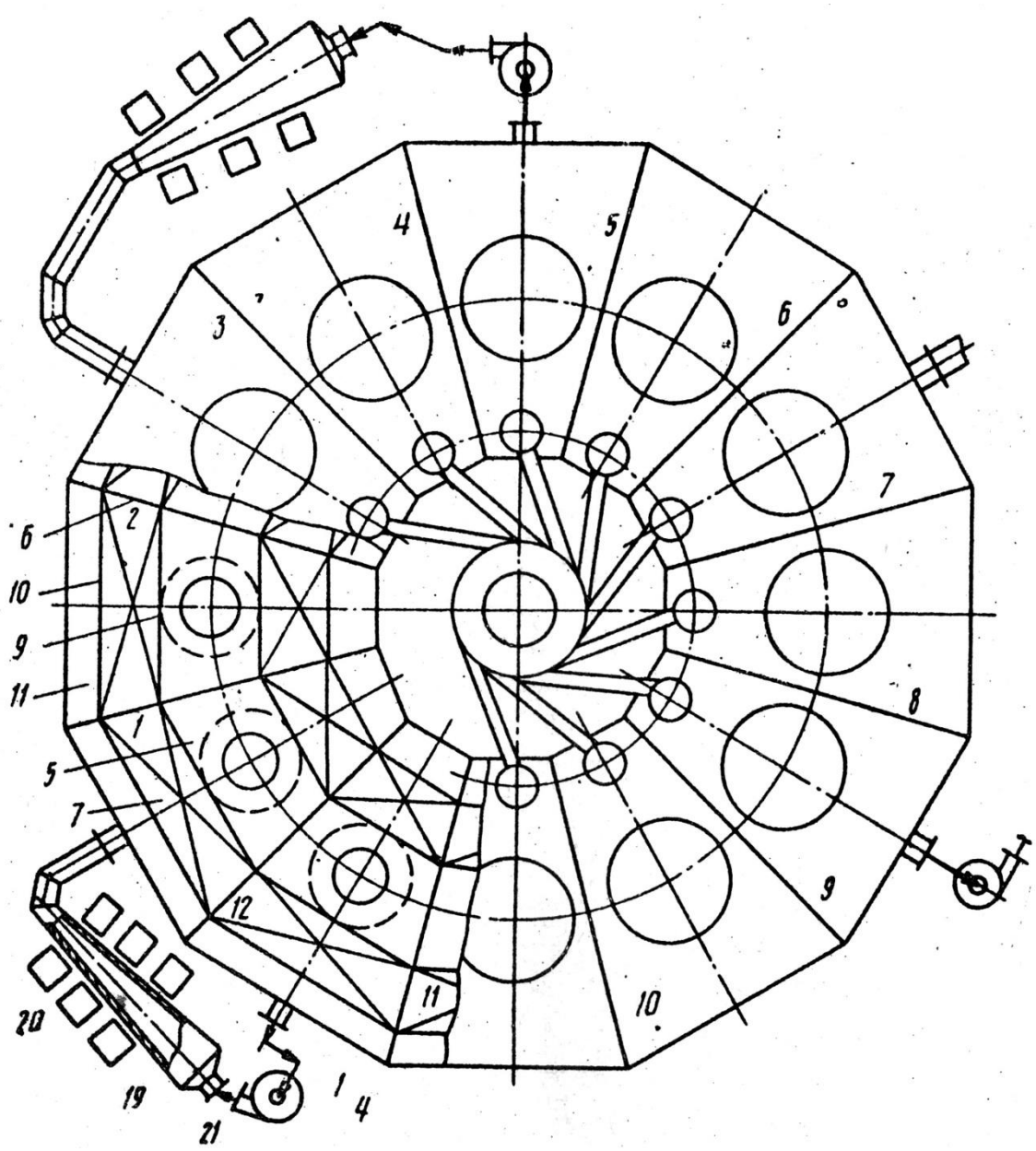


Fig. 2.5. Apparatus for growing microorganisms (author's development)

1 — capacity; 2 – lid; 3 – cylinder; 4 – radial partitions; 5 – geometric sections; 6 – radial partitions; 7 – sections; 8 – aeration and mixing device; 9 – diffuser; 10 – glass; 11 – circulation channel;

12 – heat exchangers; 13 – defoamers for exhaust gas removal;

14 – separator; 15 – pipeline for gas diversion for further purification;

16 – electric motors; 17 – pipeline for supplying air from the atmosphere;

18 - a channel for supplying air from the atmosphere; 19 - a cone-shaped chamber;

20 – magnets; 21 – pumps.

The reactor is a capacitive type apparatus equipped with a diffuser *1* and a disc type stirrer 2 located under it with curved hollow blades. When the stirrer rotates inside the blades, a vacuum is created and air from the upper part of the apparatus is self-sucked. Air is supplied to the apparatus forcibly. During aeration, along with mixing of the liquid, it is sucked out of the diffuser. Together with the resulting foam, the liquid overflows over the top edge of the diffuser.

Apparatus for extractionof microorganisms (Fig. 2.5) is a receptacle 1 with a cover 2 in which the cylinder 3 is centrally mounted to form an annular space between it and the wall of the receptacle. The annular space is divided by radial partitions 4 reaching up to cover 2 into a series of geometric sections 5, and radial partitions 6 not reaching the lid 2 into a series of interconnected sections 7 for growing microorganisms. Each section is provided with an aeration and transfer device 8 above which a diffuser 9 is mounted, and a beaker 10 arranged concentrically to a diffuser 9 with a gap relative to the walls and bottom of the section to form a circulation channel 11. Between the diffuser 9 and the beaker 10 are heat exchangers 12. To remove the exhaust gas, defoamers 13 are provided, the outlet pipes of which are connected from the separator 14, from which the gas is diverted for further purification, for example, through pipeline 15. The device 8 is rotated by the electric motors 16, at the same time, air from the atmosphere enters them through the pipeline 17 and the channel 18.

The apparatus is equipped with devices for magnetic treatment of culture liquid, each of which consists of a cone-shaped chamber 19 facing a smaller base in the direction of movement of the liquid located outside the chamber with alternating polarity of magnets 20 (permanent magnets or electromagnets).

Devices for magnetic treatment of culture fluid are installed in section recirculation circuits and/or in liquid recirculation circuits comprising pumps 21.

The device works as follows. In one of the sealed sections 5, the culture medium is recruited, a minimum amount of substrate is fed into it and dilution is

performed. Next, the resulting seeding material enters section 7 for growing microorganisms, which are also fed with substrate. The resulting suspension is then fed into the subsequent hermetic sections of the cultivation process 5 for pre-healing, sub-utilization of the substrate and the production of the finished product, which is then fed to the biomass separation stage.

When the device 8 rotates from the electric motor 16, air from the atmosphere aerated from the conduit 17 and the air channel 18 enters the device 8, in which the medium is mixed with air and aerated. The gas-liquid mixture flow ejected from the device 8 rises in the space between the diffuser 9 and the glass 10, and the medium is thermostated as a result of washing the heat exchangers 12 with the liquid. Further, the liquid flow is divided into two: one descends along the central space of the diffuser 9 and again enters the space 8 from above, and the other descends through the channel 11 and from below also enters the device 8.

The diversion of microorganisms is recirculated by pumping it by the pump 21 through the sections and/or recirculation circuits installed in the recirculation circuits between the sections of the cone chambers 19.

The strength of the electromagnetic field, the magnitude of which determines the intensity of the process of growing microorganisms, is created by magnets 20. The intensity is 500 – 4000 E.

The proposed installation for magnetic treatment of culture fluid allows to increase the specific productivity of the device by 5 - 10%.

Another example of a reactor with mechanical mixing and bubbler is the apparatus with a central diffuser and mechanicalsewing, shown in Fig. 2.6.

The turbine-type *agitator 5,* located at the bottom of the diffuser, provides high aeration of the air flow in the liquid. Complete mixing of the medium in the apparatus is achieved by additional axial (vertical) circulation using an external circulation circuit created by the pump *4*.

It should be noted that devices such as a diffuser are often used in the design of reactors with agitators, as it allows you to limit the zone of the most intensive mixing and at the same time ensure the organization of directed fluid circulation in the apparatus.

The mixing mechanical device in the reactors may be multi-tiered, as, for example, in the yeast-growingap parata presented in Fig. 2.7.

In the device, the central diffuser (circulation pipe) is made multi-stage and encloses several double-sided wheels located one above the other. In the upper part, the pipe has output holes of small diameter, and in the central part - large. In this design, the movement of aerated air creates multiple contact with the stirred liquid to form a highly dispersed gas-liquid mixture.

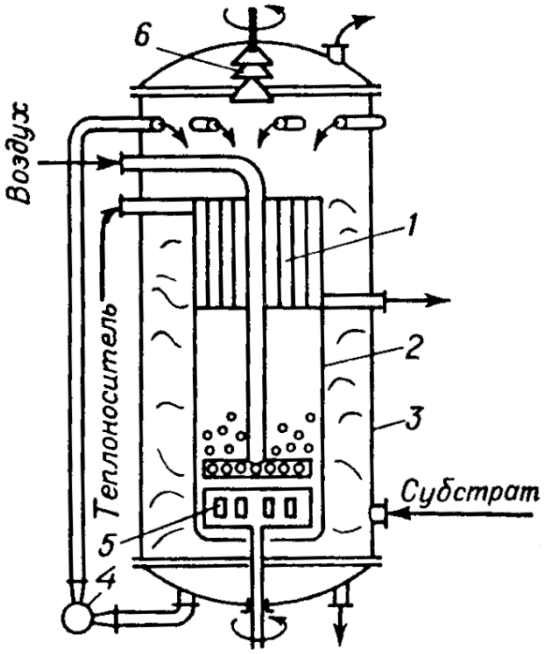


Fig. 2.6. Reactor with central diffuser and mechanical mixing:
1 – heat exchanger; 2 — diffuser; 3 – hull; 4 — pump; 5 — turbine-type agitator; 6 — mechanical defoamer.

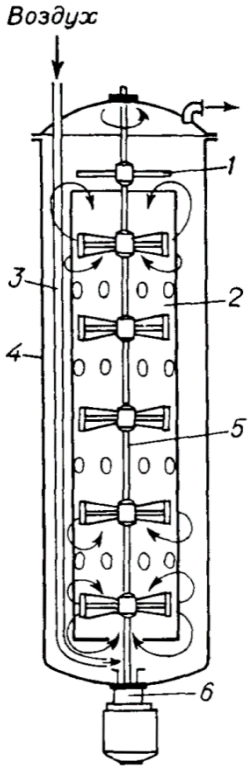


Fig. 2.7. Reactor—yeast-growing apparatus:

1 — mchemical defoamer; 2 — central diffuser; W — pipe for air supply; 4 — hull;

5 - shaft with agitators; b — drive for the mixing device.

Single-shaft and multi-shaft reactors with self-suction agitators are widespread, which do not require additional installation of a machine for compressing and supplying air. Air enters the reactor due to the vacuum created by the mixing device, which is connected to the atmosphere on one side and to the culture liquid on the other.

A single-shaft reactorof hydrotic action (Fig. 2.8) is a container inside which a heat exchanger *1* and a self-suction agitator *2* are located, creating a circulation circuit. This apparatus is used in low-tonnage industries (for example, for growing pure yeast microbiological cultures). In large-scale industries (for example, feed protein), multi-shaft structures of a continuous ramp are used (Fig. 2). 2.9).

The reactor is a horizontal tank, inside of which self-priming agitators are evenly located. To create a directed circulating movement of the liquid, there are corresponding circuits with internal heat exchangers included in them. Heat

exchangers can be of remote type. In this case, the circulation of the culture fluid requires the additional installation of special diffusers and pumps.

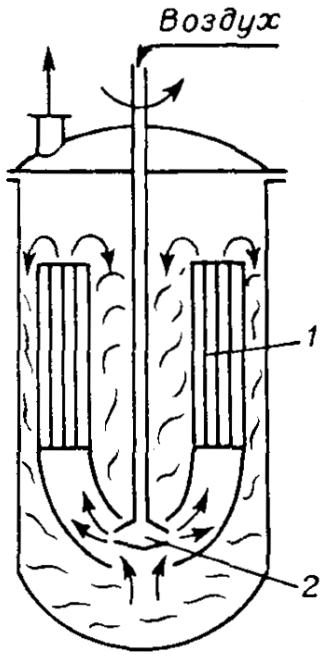


Fig. 2.8. Single-shaft reactor with self-suction agitator:

1 — heat exchanger; 2 — self-suction agitator.

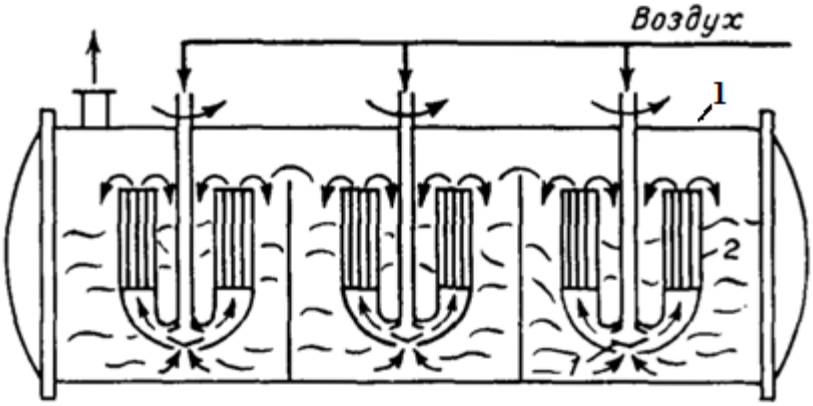


Fig. 2.9. Multi-shaft reactor:

1 — hull; 2 — circulation circuits with heat exchangers.

For the production of amino acids, vitamins and antibiotics, sealed reactors with agitators and external cooling through the jacket are used. In the case of the

formation of resistant foam in the process of culturing microorganisms, a plate separator is installed, which acts as a mechanical defoamer. The separation of the foam occurs when the exhaust gas escapes through the gaps between the fast-rotating plates. For a finer emulsification of the culture liquid with gas, a diffuser with holes and a multi-tiered agitator are installed in the apparatus.

In Fig. 2.10 presentthe design of such a reactor for the cultivation of microorganisms that form mycelium.

For better air dispersion in devices with several tiers of mixing devices, bubblers can sometimes be installed under each tier of the agitator.

In biotechnological processes with multi-stage development of microorganisms, often taking place, for example, in the production of enzymes, amino acids, plant protection products, etc., column-type reactors sectioned in height by contact devices of various designs are widely used. Structurally, such reactors are filled according to the type of rectification and absorption devices widely used in the food, chemical and petrochemical industries.

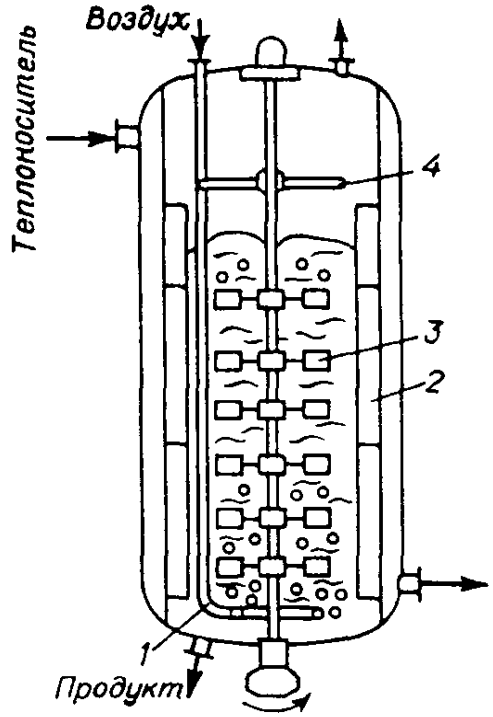


Fig. 2.10. Reactor for the cultivation of microorganisms:

1 — bubbler; 2 — reflective baffles; Z — agitator; 4 – defoamer.

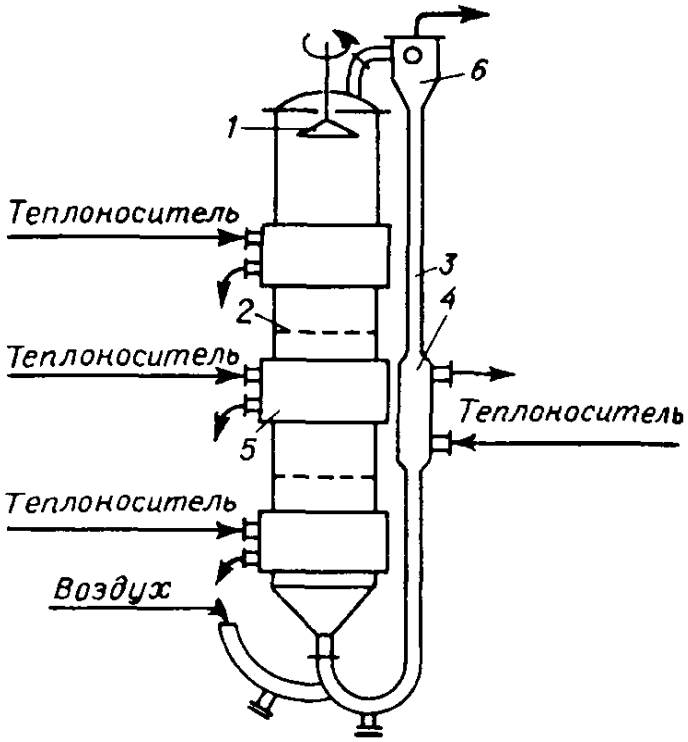


Fig. 2.11. Reactor for the production of amino acids:

1 — mechanical defoamer; 2 — contact device (perforated plate); W — circulation pipe; 4 — heat exchanger; 5 — water jacket; 6 — liquid defoaming devices.

In column devices, various types of plates are used as contact elements, both with an organized and without an organized flow of liquid, for example, sieve, lattice, tubular, etc.). In such devices, the hydrodynamic regime is close to complete displacement throughout the height and complete mixing in each section. For this purpose, in some designs, additional mechanical mixing is used in each section of the apparatus.

Another distinctive feature of column devices is the possibility of a variety of organization of gas and liquid flows not only by volume, but also by direction: direct flow, countercurrent, recirculation, gas feeding along the height of the column, to intensify the process of growth of microorganisms, the devices are usually equipped with heat exchangers or jackets in each section.

For the process of growing microorganisms that do not require intensive mixing and mass transfer with oxygen, for example, the preparation of baker's yeast, the production of certain antibiotics, the production of food acids (salicylic, citric, etc.), and in wastewater treatment systems, column devices of the bubbler type are used. In the lower part of the column there is a gas distribution device, and in the upper part mechanical defothing is carried out. To intensify mixing and approach the full mixing mode, circulation pumps and pipes with tangential flow supply to the upper part of the apparatus are used.

The reactor for the production of amino acids (Fig. 2.11) is a continuously operating column-type apparatus with a direct movement of interacting phases. The apparatus is equipped with internal bubble (contact) devices 2 along the entire height, which provide good turbulization (mixing) of the liquid with gas.

The movement of the substrate, less saturated with gas, occurs along the ring channel between the element and the wall of the apparatus. To increase the multiplicity of circulation, the reactor has a tube *Z* with a remote heat exchanger *4*. Gas is supplied to the reactor through a special air filter. To remove the heat of the biochemical reaction, there is water cooling using external shirts *5.* for foam quenching, the reactor is equipped with mechanical *1* and liquid *6* devices.

The other reactor (Figure 2.12) is a vertical apparatus with internal contact *(3, 4*) and heat *exchanger (5)* devices, as well as a mechanical defoamer *2* and an automatic pulse supply of a chemical defoamer *1.*

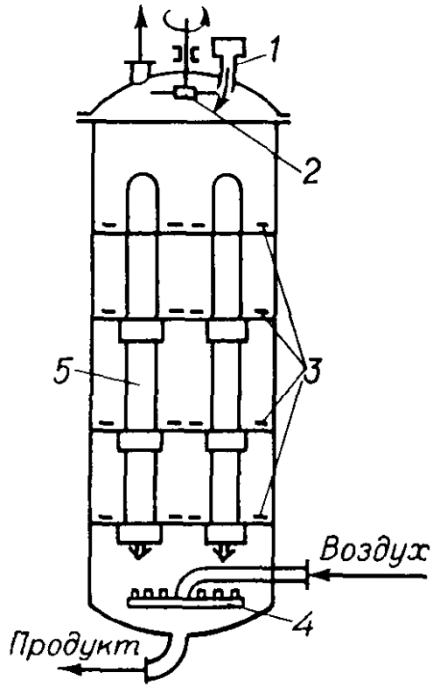


Fig. 2.12. Reactor with contact devices:

1 — automatic pulsed liquid defoaming device; 2 — mechanical defoamer; W = upper contact device; 4 — bottom contact device; 5 – heat exchanger

Additional dispersion of the aerated air flow is achieved by means of six contact devices, having the shape of a truncated cone, with 25 perforated sections and guiding the back flow of the substrate with coils installed in them. This ensures good mass transfer of oxygen to the liquid phase and mixing conditions approaching those that exist in the reactor with a stirrer.

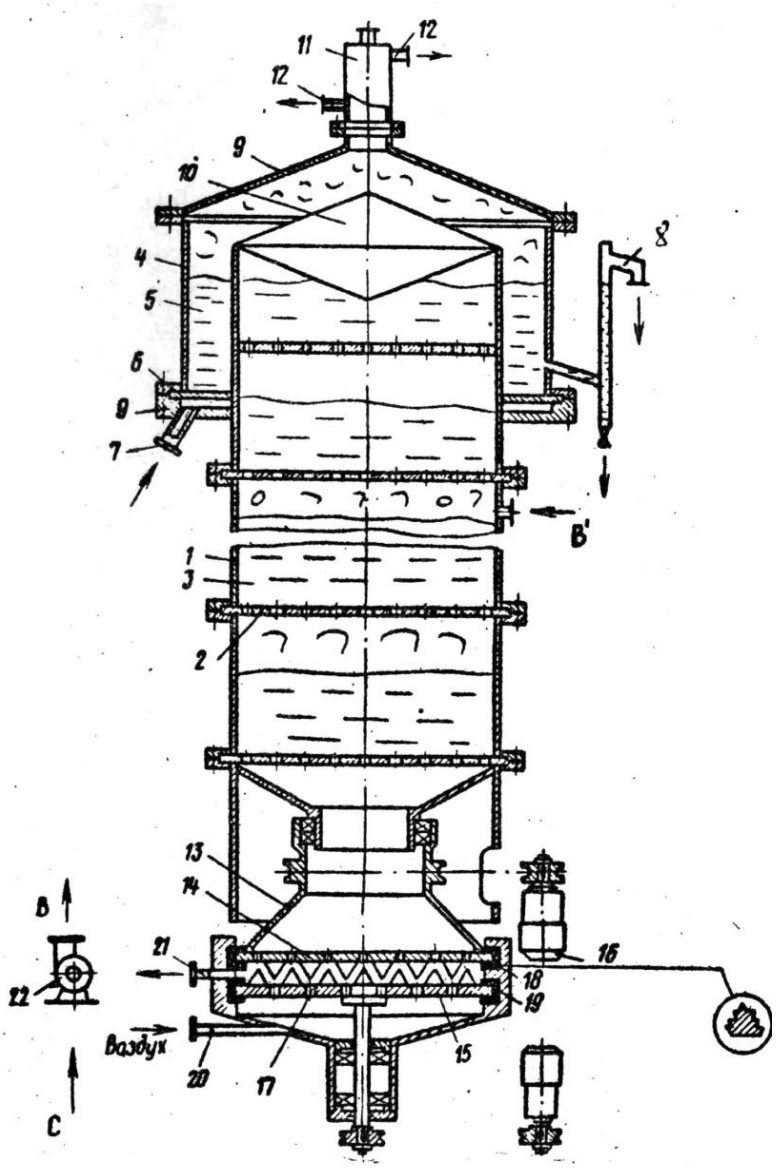


Fig. 2.13. Apparatus for growing microorganisms:

1 – vertical container; 2 - horizontal partitions; 3 – sections; 4 – glass; 5 – annular cavity; 6 – perforated partition; 7 – branch pipe for supplying the aerating agent; 8 – branch pipe for the removal of clarified liquid; 9 – cover; 10 – flow distributor; 11 – mechanical gas separator; 12 – branch pipes for the output of concentrate and exhaust gas; 13 – building; 14, 15 – disk rotors; 16 – drives; 17 – perforation; 18, 19 – conical fingers; 20 – aeration device; 21 – branch pipe; 22 – circulation pump.

Cultivation of microrganisms, including fodder yeast, can be carried out in the fermenter presented in Fig. 23. Apparatus for growing microrganisms (Fig. 2.13), made in the form of a vertical container 1, divided by horizontal partitions 2

into section 3. In the upper part of the container 1, concentrical with it, a glass 4 is installed, forming with the walls of the container 1 annular cavity 5 for the release of concentrated biomass. At the bottom, the glass is equipped with a perforated partition 6, a branch pipe 7 for supplying an aerating agent and a branch pipe 8 for draining clarified liquid. The device is closed with a lid 9. Under the lid above the container 1 in the overflow zone of the gas-liquid medium from the container to the glass 4, a flow distributor 10 is installed, made in the form of a disk formed by two cones facing each other with their bases facing each other. The disc is installed to form a gap between its edges and the walls of the tank 1. On the cover 9 there is a mechanical gas separator 11 with branch pipes 12 for the output of concentrate and exhaust gas. At the bottom under the bottom of receptacle 1 is a liquid suspension dispersant consisting of a housing 13 and disc rotors 14 and 15 arranged one above the other, having drives 16. Disc rotors have a perforation have a perforation 17 and conical fingers 18 and 19 are concentrically fixed on them, having triangular-shaped narifles. An aeration device 20 is located under the lower rotor 15, and the space between the rotary tubes 21 is connected to a circulation pump 22 of the recirculation system that provides a slurry to one of the sections of the tank (flow along the BB arrow').

The device works as follows. In the vertical vessel 1 through the circulation pump 22 (flow C) in one of the sections 3 (along the line BB') feed the nutrient medium, seeding biomass and substrate for further continuous cultivation of microorganisms. Continuous aeration of the medium is carried out by supplying air to the branch pipe of the aeration device 20 located under the lower rotor 15. Further, the aerating air, pumped under excessive pressure, passes through the perforation 17, the interrotor space and, barbating through the nutrient medium, ensures the fluidization of the inert nozzle in the volume of each section of the apparatus, thereby achieving an effective mass transfer of oxygen to microbial cells. The disc rotors 14 and 15 are driven into opposite directional rotation by the

drives 16. The nutrient medium with the substrate and microorganisms, intensively mixed with aerated air and the nozzle in each section of the apparatus, through the perforated partitions 2 enters the lower part of the container 1 and through the perforation 17 in the disc rotor 14 enters the interrotor space, where, under the action of centripetal forces of rotating rotors and due to interaction with the medium of the conical fingers 18 and 19 with narifles, intensive dispersion of the trunosoluble carbon-containing is ensured. substrate in the nutrient medium to a size commensurate with microbial cells. The nutrient medium thus homogenized is supplied via the branch pipe 21 and the circulation pump 22 to one of the sections of the vessel 1. Thus, constantly due to the circulation circuit (flow along the arrow BB'), homogenization in the field of centrifugal forces of the disc digital rotors of the nutrient medium, its interaction with the incoming aerated gas and dispersion of a hard-to-dissolve substrate in it are ensured, which contributes to the intensive utilization of the substrate by microorganisms, the high rate of biomass formation and the productivity of the apparatus as a whole.

A biochemical countercurrent reactor, made in the form of a sectioned column with flotation thickening of the resulting microbial biomass (Fig. 2.13), allows to reduce the release of the waste gas flow into the environment and, thus, to ensure an increase in the environmental friendliness of the biotechnological process in the apparatus. The device is divided by the height of non-sections by perforated plates, on which a nozzle of various shapes (for example, spherical, paddle, etc.).

When the gas flow moves through the section of the plate, the nozzle goes into a fluidized (floating) state. Such a free-floating nozzle in part of the volume of the section turbulates the flow, increases the contact surface of the interacting phases, increases the stability of the gas-liquid emulsion layer on the plate, eliminates channel formation and stagnant zones on it. This creates good

conditions for the intensification of the mass transfer process between the oxygen of the air and the liquid substrate.

Column-type devices with a floating nozzle are advisable to use in the processes of continuous cultivation of microorganisms, in which effective transfer of oxygen and nutrients is required for the cultivation of cultures of microorganisms.

A high-performance reactor for the production of yeast biomass is a column-type ejection apparatus with a falling jet (Fig. 2.14).

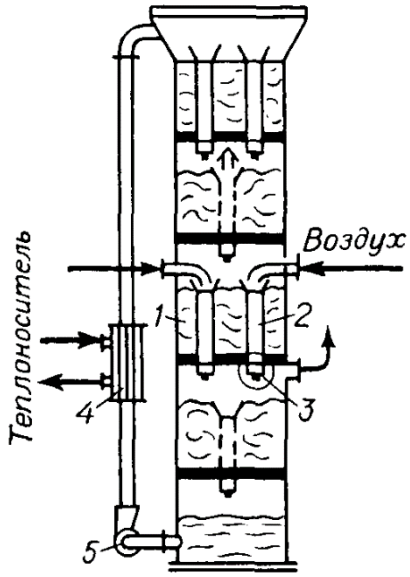


Fig. 2.14. Ejection type reactor with incident jet:

1 - reaction chamber (section); 2 - drain pipe; W = ejection device; 4 - heat exchanger; 5 - circulation pump.

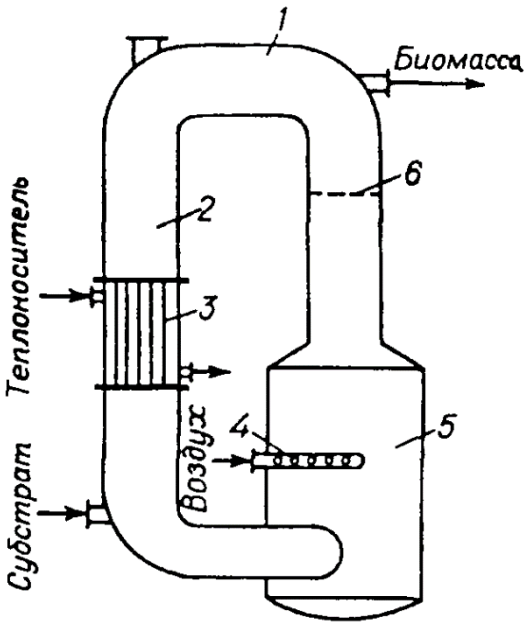


Fig. 2.15. Gas lift reactor for growing yeast biomass. 1 — separation zone; 2 — circulation part (pipe); 3 — heat exchanger; 4 — bubbler; 5 reaction chamber ; 6 — additional air distributor.

The jet ejection reactor consists of several reaction

chambers 1 arranged one above the other and interconnected by drain pipes *2.* Inside the chambers, ejection devices Z are installed, with the help of which the liquid jet captures the air entering the chamber through the gas-underwater pipe, forming a gas-liquid mixture in the form of a free-falling jet. Such a jet, which has a sufficiently high supply of kinetic energy, reaches the bottom of the chamber and, thus, intensively mixes the culture liquid. To remove the heat of biochemical transformation of the substance, there is a remote heat exchanger *4*, and for mixing - an additional external circulation circuit with a pump *5.*

For the cultivation of yeast biomass, a gas-lift reactor of the bubble type is used (Fig. 2.15), consisting of two parts: the main part - reaction and auxiliary - circulating. The reaction part *5* is a column with a different height of cross-section area, having devices *6* for creating local mixing and preventing coalescence of gas bubbles. In the lower part for dispersing gas, a bubbler *4* is installed. The aerated liquid rises to the top of the reaction column and then partially undergoes

degassing in its horizontal section *1,* from which the ejection gas and yeast suspension are discharged. The degassed liquid is lowered into the bottom of the circulation part *2,* which has the shape of a column (or tube), located separately from the reaction part or inside it. It passes through the heat exchanger *3* and then, together with the feed substrate, is sent back to the lower expansion part of the reaction column.

Thus, in the reactor, due to the difference in the densities of aerated and degassed liquids, continuous circulation of the working medium is ensured, and due to hydrostatic pressure, a high concentration of dissolved oxygen in the liquid at the bottom of the column is ensured.

For fermentation processes, in particular in hydrolysis and yeast production, it is possible to use tubular gas-lift reactors (Figure 2.16), the main structural element of which is the reaction chamber *1* based on a shell and tube apparatus. Unlike a standard heat exchanger of this type, a special hydrodynamic mode of movement of the gas-liquid flow through the pipes is created in the reaction chamber. Air for aeration is supplied to the lower chamber suction *2* through the bubbler tubes *3*, the culture liquid is in the tubes of the contact chamber *4*, and a coolant circulates in the intertube space. This internal circulation circuit ensures the creation of the necessary turbulence of the gas-liquid medium and mass transfer conditions in it.

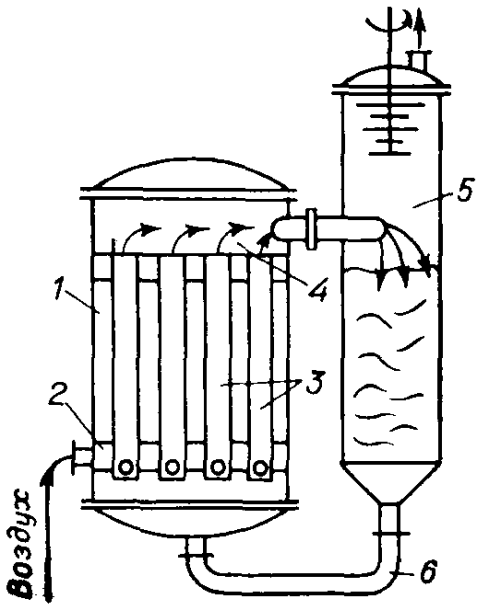


Fig. 2.16. Gas lift reactor of tubular type for fermentation:

1 — reaction chamber; 2 — aeration chamber; 3 — tubes-bubblers; 4 — contact chamber; 5 — separator with mechanical defoamer; 6 — circular pipe.

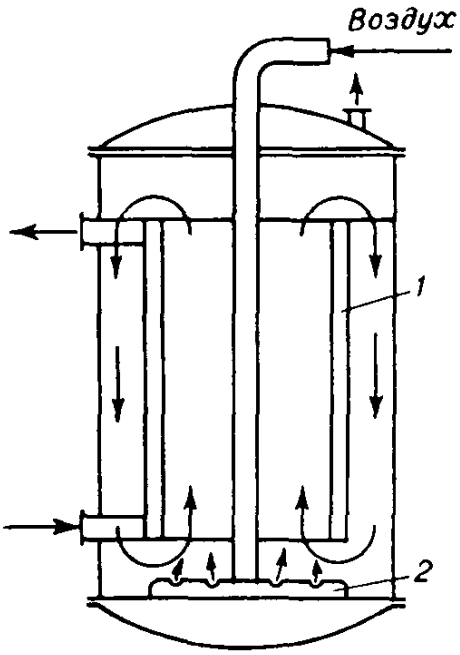


Fig. 2.17. Bubble-airlift reactor:

1 – diffuser; 2 – gas distributor.

The return of the liquid to the suction chamber (recirculation of the culture medium) is organized by an external circulation circuit consisting of contact

chamber tubes, a circulation pipe *6* and a separator with a mechanical defoamer *5.* The gas-liquid mixture formed in the bubbler pipes rises up, is excreted into the separator, and the culture liquid is returned through the pipes of the contact chamber back to the gas suction chamber. The gas-liquid suspension and the substrate fluid have different densities, which creates the circulating movement of the medium in the apparatus.

In the production of microbiological products with a low concentration of starting materials in the processed raw materials, i.e. in cases where a high intensity of mass transfer on oxygen is not required, it is typical to use reactors of the bubble-airlift type (Fig. 2.17), which provide a hydrodynamic regime close to complete mixing. This is achieved due to the large multiplicity of circulation of upward and downward gas-liquid flows having different densities. the devices are used, for example, in yeast production based on hydrolysis and pulp and paper raw materials, in the processes of biochemical oxidation of wastewater.

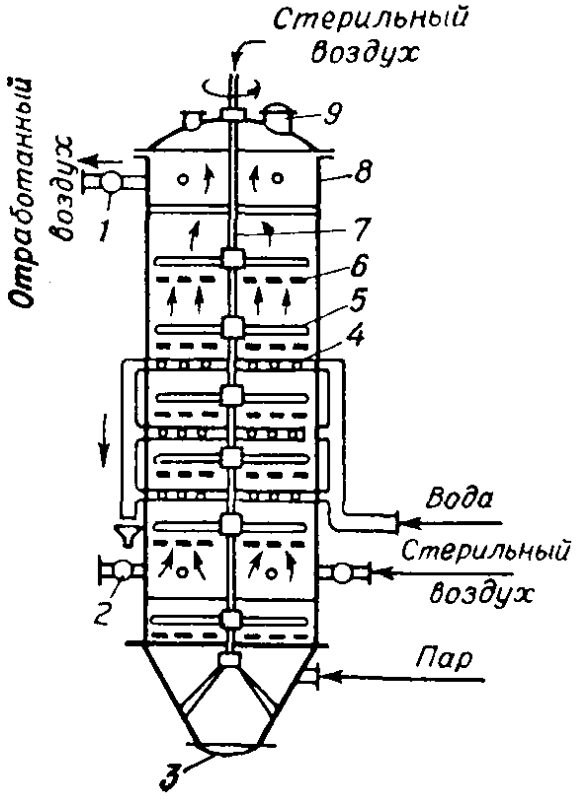


Fig. 2.18. Reactor for surface cultivation of microorganisms on bulk media: 1, 2 — adjustment screens; 3 — conical bottom with hatch; 4 - heat exchanger;

5 — agitator; 6 — distribution grate; 7 — shaft; 8 — building; 9 — viewing window.

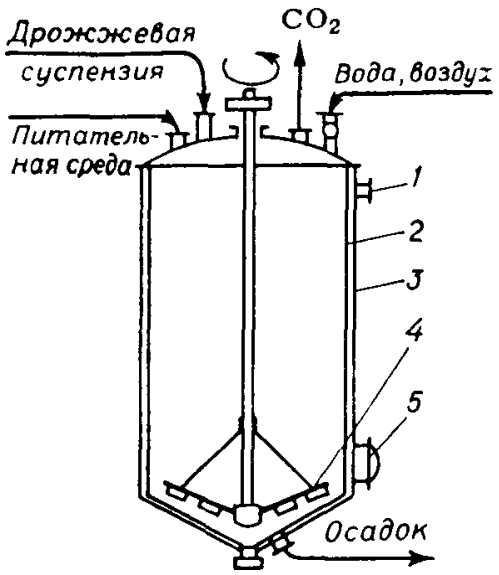


Fig. 2.19. Reactor for alcohol fermentation:
1 — fitting; 2 — acid-resistant coating; 3 — hull; 4 — mixing device; 5 — Hatch

For surface cultivation of microorganisms on bulk media in order to obtain enzyme, and recently protein-vitamin preparations, mechanized and automated reactor plants are used. In the designs of such devices, it is mandatory to have a device for supplying conditioned sterile air. Air serves not only as a source of oxygen, but also provides heat and carbon dioxide removal. In Fig. 2.18, a modern reactor for carrying out these biochemical processes is given. In such a reactor, the cultivation of microorganisms is carried out in a layer of sterile loose nutrient medium 10-20 times larger than previously known devices. This can significantly increase productivity, intensify the production process of the biological preparation.

The reactor is an apparatus in the form of a vertical cylinder equipped with an external heat exchanger (jacket) for cooling a growing crop.

The device is sectioned in height with perforated plates having coils for cooling the medium. Mixing of material on the plates is carried out using blades located on a vertical shaft.

Technological operations in the reactor are mechanized using automatic devices.

The processes of fermentation of organic substances by microorganisms (for example, the production of acetone, vitamin B_{12}) are carried out in special devices, the design of which depends on the characteristics of the biotechnology process.

In Fig. 2.19 shows one of the designs of the fermentation apparatus for alcohol fermentation in hydrolysis production. The capacitive-type reactor is made in the form of a cylindrical vessel with a conical bottom. Inside the apparatus there is a special device for moving the settled solid phase (sludge) to the center and then removing it from the apparatus. The device is equipped with blades with strips of rubberized fabric attached to them and has a rotational speed of about 0.1 c^{-1}. The inner surface of the reactor is protected by an acid-resistant coating.

Test questions for section 2

1. What substrates are most commonly used in practice?
2. What are the main indicators characterizing the biotechnological process?
3. What is the impact of substrate quality on the economy of the biotechnological process?
4. What aeration systems are used in fermenters?
5. What types of devices are used to grow microorganisms?
6. What are the main elements in the composition of nutrient media for the growth of microorganisms?
7. What are the main features of growing microorganisms in laboratory and industrial conditions?

8. What are the comparative characteristics of culturing microorganisms in fermenters of different types, indicating the advantages for the yield of biomass from the substrate?
9. What methods are used to isolate the cells of microorganisms from the spent culture fluid?
10. In what cases is it advisable to use fermenters with a mechanical aeration system?

Section 3. Opportunities for ecological biotechnology

3.1. Basics of the process of bio-oxidation of contaminants

3.1.1. Microorganisms of activated sludge

The essence of the method of biological purification is the contact of wastewater with microorganisms of activated sludge in anaerobic and aerobic conditions. The process of biological wastewater treatment in the aeration tank consists of the following stages: sorption of active sludge contaminants,

intracellular oxidation of sorbed contaminants, separation of activated sludge and purified water. The stages of sorption and oxidation have a biochemical basis and obey the laws of enzymatic reactions. In this regard, special attention should be paid to the study of the composition of activated sludge. When microscopic examination of silt, first of all, attention is paid to the size and density of sludge cotton, the presence of foreign inclusions in it, the number and species composition of microfauna, its mobility. Such observation makes it possible to draw a conclusion about the state of active sludge and the quality of purification.

When observing the state of activated sludge, attention is paid to the ratio of free-swimming bacteria and bacteria in clusters. Zooglean forms predominate in effectively working active sludge. The ability to create zooglean clusters is widespread in microorganisms. Clusters form cells of nitrogenbacter, radiobacter, nodule bacteria. Some species form capsules only when co-cultivated with other species. Many authors note a high activity of bacterial clusters.

It is known that the surface of free-swimming bacteria is twice as large as the bacteria in the clusters, and despite this, with a large number of free-floating bacteria, the cleaning deteriorates. Apparently, the appearance of free-swimming bacteria is not the cause, but the consequence of the deterioration of cleaning.

The most characteristic and common bacterial organism of activated sludge that forms clusters is *Zoogloea ramigera*. The genus *Zoogloea* belongs to the family *Pseudomonadacea*.

The *pseudomonadacea* family as a whole is characterized by the following: rods are straight or curved, mobile, have a polarly arranged flagellum, are gram-negative, receive energy by the method of respiration, do not absorb molecular nitrogen, are able to use compounds containing more than one carbon atom as a carbon source, belong to strict aerobes, have catalase and usually oxidases, grow in a wide range of temperatures from 4 to 43 ° C.

Organisms of the genus *Zoogloea* are always present in the active sludge in the form of clusters. It is this feature that makes it possible to distinguish them from other pseudomonas. Morphologically, *zoogloea* microcolonies consist of separate, clearly distinguishable rods of 0.5-1.0x2-4 μm. The ends are rounded, each cell is surrounded by a capsule, as a result of which the cells do not stick together.

The capsule is a carbohydrate polymer probably containing nitrogen. The capsular substance zooglei is able to adsorb various substances, including radioactive ones, and thereby contributes to purification.

The capsule polymer also sorbs the cells of flaky-forming bacteria, which are involved in the processes of destruction of contaminants. Thus, *Z. ramigera* is the basis on which active sludge is collected.

Of interest is the state form of microcolonium Z. ramigera in active sludge (Fig. 3.1) .

Fig. 3.1. The shape of the Z microcolonium. ramigera in active sludge that purifies wastewater: a - from the production of fiberboard; b - from the production of citric acid.

In Fig. 3.1, presents a very characteristic microcolonium *Z. ramigera* in active sludge, which purifies wastewater from the production of fiberboard. According to observations, colonies of this form are found in a variety of active sludges. The most compact and dense colonies of zoogles could be observed in the aerotanks of the citric acid plant at a load of about 3000 mg/g of ash-free sludge per day. It is interesting to note that the simplest ones were practically absent, however, the cleaning was intense. MickRocolonia shown in Fig. 3.1, b, on the contrary, is relatively rare. According to the literature, this form of colonies is observed in the presence of organic acids (which occurs with complete oxidation in aeration tanks). Such colonies are found in the treatment of effluents from the production of fiberboard and citric acid plant. At the same time, their presence in wastewater rich in nitrogen compounds (meat, fish, dairy production) is almost never noted. as well as on effluents with toxic compounds (plywood and furniture production, mining and processing plants).

Except *Z. ramigera*, the ability to flake is noted in representatives of the genera *Pseudomonas, Bacillus, Alcaligenes, Escherichia* and others. It depends on the composition of the medium. The mechanism of flakes formation is not completely understood. There is an opinion that this is a physicochemical process.

Z. ramigera grows in a wide temperature range from 9 to 37 ° C at a pH of about 7. It does not grow under anaerobic conditions, but tolerates these conditions well for about a month. At the same time, it uses starch, inulin, some primary alcohols, saturated fatty acids, etc. Asparagine, aspartic acid and glutamic acid it is able to use as the only source of carbon and nitrogen.

Cells Z. ramigera are able to accumulate long chains of polyphosphates and thereby help to remove phosphorus compounds from water. *Z. ramigera* utilizes phenol, cresol, benzene, toluene.

The shape of microcoloniums is very different and can serve as a characteristic of activated sludge. It is not yet precisely established whether the shape of microcolonies is a consequence of environmental influences or whether certain variants *of Z ramigera* take precedence when conditions change, which is characterized by a specific form of colony.

The complexity of studying an organism, which is characterized by development in combination with other species, does not allow for their accurate classification. The results of studies (Heukelekian H. and Littman M.) study of 14 variants of mucus-forming bacteria isolated from various active sludges are known. All of them during aeration formed flakes characteristic of activated sludge, but differed in the shape of microcolonia in a liquid medium during aeration. Thus, the authors showed that under the same conditions different variants of *Zoogloea ramigera* retained their characteristic shape of cotton, but at the same time, according to morphological signs, they attributed the isolated strains of bacteria to *Z. ramigera*. In the Berga identifier, the genus *Zoogloea* contains two main species: *Z. ramigera* and *Z. filipendula*. The latter species differs from the first by the presence of finger-like outgrowths and a slightly longer cell length, averaging about 4 μm, and in *Z. ramigera* - 3 μm. Fig. 3.2a-3.2b presents a typical type of flakes of activated sludge.

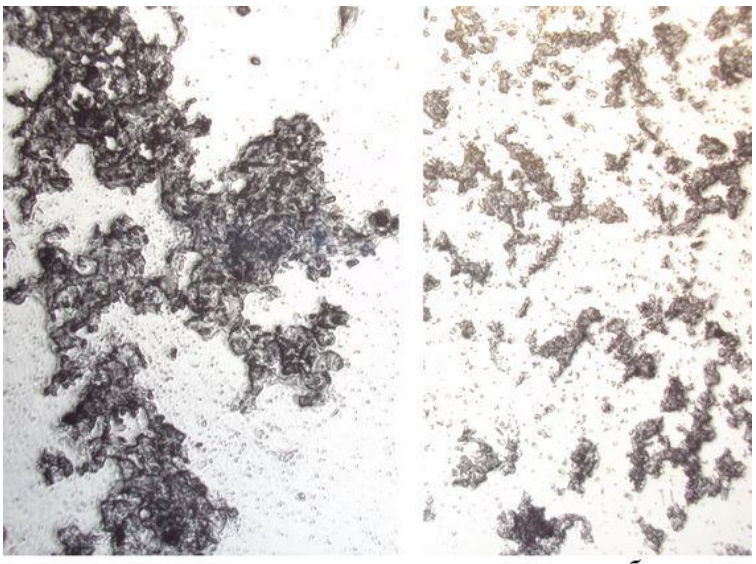


Fig. 3.2. Active sludge of municipal wastewater treatment plants

a) active sludge with a silt index of less than 100 cm^3/g;

b) active sludge with a silt index of more than 100 cm^3/g.

When describing the bacterial composition of any aerobic treatment plant, pseudomonas are certainly mentioned. Apparently, all natural organic compounds existing on Earth can be decomposed by one of the species of *Pseudomonas*. In the destruction of synthetic organic compounds, the first place also belongs to pseudomonads.

Various species of the genus Pseudomonas are able to cause the conversion of organochlorine compounds, including pesticides, restore the nitro group of nitroaromatic compounds with subsequent rupture of the benzene ring, use caprolactam as the only source of carbon and nitrogen. Some species of the genus *Pseudomonas* are able to destroy sulfur-containing compounds, in particular surfactants (surfactants) - salts of sulfuric acid esters and alkyl sulfonates.

Wide enzymatic possibilities allow some species of bacteria of the genus *Pseudomonas* to use compounds used as antiseptics or disinfectants, such as toluene, benzene, ethylbenzene, naphthalene. Representatives of the genus *Pseudomonas* destroy rubber, rubber, lubricating oils, absorb gaseous hydrocarbons.

Active destructors, often found in sewage treatment plants, include representatives of the genus *Bacillus*. Bacteria of this genus have a rod-shaped shape, spore-forming, most species are mobile, gram-negative, some of them are capable of flake formation. *Bac. subtilis* and *Bac. mesentericus* are, for example, among the most active destructors of caprolactam.

Actinomycetes play an important role in the destruction of hard-to-oxidize compounds, including hydrocarbons. Mycobacteria and nocardia related to actinomycetes have an ability to flake.

According to various authors, the dominant genera of activated sludge also include *Bacillus*, *Corinebacterium*, *Alcaligenes*, etc. In active sludges of wastewater containing flotation reagents, *Aeromonas liguefaciens, Enterobacter liguefaciens, Micrococcus cremoris, Bacillus mycoides, Achromobacter agile, Escherichia were isolated coli.*

According to VNIIsintezbelok (now JSC "GosNIIsintezbelok") in the wastewater of fodder yeast plants grown on oil paraffins, the bacterial population of activated sludge includes mainly representatives of the genera *Pseudomonas, Bacillus, Enterobacter* in approximately equal shares. At the same time, it should be

noted that at 8 plants of the specified profile, the composition of activated sludge was individual. Apparently, this can be explained by the fact that individual insignificant technological features at each of these plants led to a change in the composition of contaminants present in wastewater and, accordingly, to a variation in the bacterial population of activated sludge.

Filamentous active sludge bacteria are represented by *Sphaerotilus natans*. It is noted that they develop well on carbohydrate effluents and wastewater from dairy plants. Organotrophs receive energy by oxidizing sugars, some organic acids and alcohols during respiration. They belong to strict aerobes. They move with the help of a bundle of polar flagella and do not form spores.

For their development, bacteria of the genus *Sphaerotilus* need nitrogen compounds and grow better in the presence of organic nitrogen sources. Getting into the secondary sedimentation tank with a silt mixture, *Sphaerotilus natans* prevent the precipitation of activated sludge. As a result, there is a so-called "swelling" of activated sludge. Silt is carried into the reservoir, causing secondary pollution. Due to the removal, the amount of circulating activated sludge decreases and the dose of sludge in the aeration tank falls. For to combat the development of filamentous bacteria in the aeration tank, regeneration of activated sludge, alkalinization of wastewater to a pH of about 9 is used.

It is known that microorganisms are able to use almost any organic compound of natural origin, but in the vast majority of cases are not ready for the use of new synthetic substances, the amount of which is increasing every year. Microorganisms carry out the destruction of unnatural compounds in various processes of constructive and energy metabolism: using carbon, nitrogen, sulfur, phosphorus as food sources, oxidizing compounds to obtain energy, using only part of the substrate molecule, etc. Special mention should be made of cometabolism and "co-oxidation". Cometabolism is the ability of microorganisms to transform organic compounds without using them. Cometabolism is usually observed on

nutrient-rich media. The phenomenon of "co-oxidation" is that microorganisms that are unable to grow on a medium containing a certain organic compound as the only source of carbon are able to oxidize it along with other substances. Many hard-to-oxidize compounds are destroyed in the processes of cometabolism and "co-oxidation". For example, organochlorine nitrochloride compounds can only be used in the presence in the environment of nutrients suitable for the active growth of microorganisms. As a result of cometabolism, many analogues of DDT are destroyed.

Only the phenomena of cometabolism, co-oxidation or similarity of chemical bonds of new compounds and old ones cannot explain the fact that many completely new compounds eventually become available to microorganisms. In the process of destruction of hard-to-oxidize and toxic compounds, an important role is played by the processes of variability of microorganisms, both mutagenic (fixed in the structure of the DNA of the cell) and adaptive, which are lost during reseeding to media that do not contain the agent that caused the adaptation.

Along with adaptive variability among microorganisms, mutational variation is widespread, in which acquired new qualities are fixed genetically and transmitted to offspring. Mutations can be natural and induced. Wastewater often contains substances that are mutagens. For this reason, among the microorganisms of active sludges that purify industrial wastewater, there are bacteria that differ in one or more features from the corresponding classical species. Under the influence of mutagens, forms that were not previously found in nature can occur among microorganisms. It is very likely that among the newly emerged species there will be active destructors of new organic compounds.

Proposals for the selection of mutants for wastewater treatment have not yet received real application and are mainly promising, but the selection of strains of microorganisms capable of adapting to the active destruction of complex organic

compounds is currently being actively conducted all over the world and is already yielding practical results.

Particular consideration should be given to the adaptation of activated sludge microorganisms to phenols. Phenols were the first among organic compounds to be purified by specially selected cultures of bacteria. In small quantities, phenols are formed in the processes of vital activity of both plant and animal organisms, and therefore they cannot be considered among synthetic organic compounds. Nevertheless, monophenol - carbolic acid - is difficult to bacterial destruction and has long been used for disinfection. Diphenols: pyrocatechin, resorcinol, hydroquinone - decompose much easier. Once in the water, phenols give it an unpleasant odor, especially aggravated by chlorination. For this reason, the MPC of phenols in water is 0.001 mg/L. Such a low maximum permissible concentration requires a very strong dilution for waters containing phenols. Microorganisms capable of destroying phenols have been isolated by many researchers in different countries, including Russia. Among the microorganisms are bacteria of different species, fungi, yeast, actinomycetes. Thus, the ability to destroy phenols is widespread among microorganisms.

The most actively destroy phenols representatives of the genera *Pseudomonas*, *Achromobacter, Bacillus*.

Phenolic effluents cannot be diluted with household effluents, since in the presence of more accessible organic compounds, bacteria are passive to phenols.

The results of practical tests also show that the adaptation of activated sludge microorganisms to phenols occurs for a sufficiently long time and in some cases is up to 3-4 months.

Of great importance in the practice of biological purification is the destruction of sulfur-containing organic compounds, which are very diverse both in chemical composition and in their purpose. This group includes lignosulfonates

and methylsulfur preparations formed during the cooking of cellulose; drugs, pesticides, surfactants (surfactants) and many other compounds.

Of particular interest is the destruction of organic nitro compounds that are part of explosives, dyes, solvents, etc. 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. The 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.

Much attention is currently being paid to the study of the possibilities of using enzymes for wastewater treatment. As a source of enzymes, destroyed bacterial cells of microorganisms-destructors and extracts from cells are used. Experiments are being conducted on the treatment of wastewater containing fiber, caprolactam and other compounds.

According to most researchers, the leading role in the processes of destruction of organic substances contained in wastewater belongs to bacteria, permanent inhabitants of activated sludge and biofilm. The simplest are assigned a secondary role. However, they cannot be ignored, as only bacterial sludge is not able to provide a high degree of water purification. This is mainly due to the fact that in the absence of protozoa, intensive development of bacteria is observed. The density of the body of bacteria is close to one, and therefore, when the active sludge settles in secondary sedimentation tanks, bacteria form a stable organic suspension, which, together with purified water, enters water bodies, causing secondary pollution of it.

The role of protozoa is considered by most authors as twofold: providing a sanitary effect by eating bacterial microflora and an indicative function.

The simplest are more sensitive than bacteria to adverse environmental conditions, so all changes in the technological regime primarily affect the composition and number of protozoa: with satisfactory purification, a variety of

protozoa is observed with their relatively low biomass, with a deterioration in living conditions (weak toxicity, insufficient aeration), the number of protozoan species decreases, but their biomass often increases. The more unfavorable the conditions, the fewer species are observed in the active sludge.

With unsatisfactory biological treatment regimes, amoebas and colorless flagella predominate in the composition of activated sludge and there are practically no infusoria and even more so rotifers. For example, with a lack of dissolved oxygen in the aeration tank, the protozoa become transparent, the individuals increase in volume, and then the cells burst.

In the event of further aggravation of adverse conditions, the protozoa disappear. This leads to a sharp increase in the number of bacteria. Thus, an increase in the number of bacteria indicates not only the intensity of treatment, but may be a consequence and indicator of some toxicity of the effluent. The death of microflora can be observed with a high degree of toxicity.

The decrease in enzymatic activity proceeds more gradually. The ability of sludge to a sharp increase in enzymatic activity makes it possible to conduct the process of wastewater treatment with the same efficiency with significant fluctuations in the dose of sludge. But in any case, the dose of sludge in the aeration tank is set by the technologist depending on the concentration of contaminants in the wastewater, the aeration time and the required degree of purification. As a result of a sufficiently long contact (within 10 - 36 hours) of microorganisms with water in conditions of air aeration, biodegradation of organic impurities that were not removed at the previous stages of purification occurs. Briefly consider the features of biochemical oxidation of some 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.

3.1.2. Microbial destruction of complex organic compounds.

The appearance in the environment of previously unknown organic compounds induced in microorganisms the ability to destroy them. The causes and mechanism of this phenomenon have not yet been precisely established, but it is known that even such stable compounds as DDT are subject to gradual decay. This is very likely due to the fact that the bonds between atoms in molecules of natural and synthetic compounds are similar. For example, DDT has the same articulation of chlorine and carbon residues as the biosynthetic products chlortetracycline and fungal chlorophlavonin. In nature, trinitrotoluene and nitroglycerin are not found, but by the type of connection of the nitro group with the carbon skeleton, these compounds are similar to natural chloromycetin in nitropropioic acid. Apparently, enzymes inherent in a microbial cell are able in some cases to affect the usual chemical bonds of unusual compounds.

The phenomenon of microbial variability is widely known. It is enough to refer to the well-known fact of addiction of pathogenic microbes to antibiotics. There are also many examples of the adaptation of microorganisms to industrial wastewater and to the hard-to-oxidize and toxic compounds contained in them. It is known that in some cases, the culture of microorganisms adapted to synthetic organic substances by long-term cultivation on nutrient media with these substances as the only source of organic substances lost this ability when reseeded to universal media.

Along with adaptive variability among microorganisms, mutational variation is widespread, in which acquired new qualities are fixed genetically and transmitted to offspring. Mutations can be natural and induced. Wastewater often contains substances that are mutagens. For this reason, among the microorganisms of active sludges that purify industrial wastewater, there are bacteria that differ in one or more features from the corresponding classical species. Under the influence of mutagens, forms that were not previously found in nature can occur among

microorganisms. It is very likely that among the newly emerged species there will be active destructors of new organic compounds.

I. A. Rapoport (1970) proposed the use of mutational variability of microorganisms for the treatment of wastewater from chemical industries. He proposed several schemes for obtaining microorganisms with specified properties for the treatment of industrial wastewater, including the treatment of directly activated sludge with chemical mutagens in a volume of 0.1 to 0.01 of the total amounts of yale. At the same time, mutants that are not able to exist in the conditions of an aeration tank will die, and forms will remain, on the one hand, with an increased ability to destroy chemical pollutants, and on the other hand, quite resilient.

Proposals for the selection of mutants for wastewater treatment have not yet received real application and are mainly promising.

3.1.3. Microbial destruction of phenols

Phenols were the first among organic compounds to be purified by specially selected cultures of bacteria. In small quantities, phenols are formed in the processes of vital activity of both plant and animal organisms. For example, monophenol – carbolic acid – is difficult to bacterial destruction and has long been used for disinfection. Diphenols: pyrocatechin, resorcinol, hydroquinone - decompose much easier. Once in the water, phenols give it an unpleasant odor, especially aggravated by chlorination. For this reason, the maximum permissible concentration (MPC) of phenols in water is 0.001 mg/l. Such a low maximum permissible concentration requires a very strong dilution for waters containing phenols. Many developers have therefore proposed to mix phenolic waters with household waters, but in mixed runoff, phenols are difficult to destroy. This is due to the fact that microorganisms absorb primarily an easily accessible substrate, and not as difficult to oxidize as phenol.

Microorganisms capable of destroying phenols have been isolated by many researchers in different countries, including Russia. Among the microorganisms are bacteria of different species, fungi, yeast, actinomycetes. Thus, the ability to destroy phenols is widespread among microorganisms.

The most actively destroy phenols representatives of the genera *Pseudomonas*, *Achromobacter, Bacillus*.

N. T. Putilina (1952) identified several hundred microbial cultures, among which 10 of the most active ones were selected. 9 strains were assigned to the species *Bacterium cycloclastis* and one to the species *Chomobacterium sauremali*. The isolated strains were cultured in a special fermenter and introduced into the aeration tank. Their content in 1 ml was tens and hundreds of millions. After the phenol-destroying bacteria oxidized most of the phenols, the usual heterotrophic microflora, protozoa and even rotifers developed in the aeration tank. Aeration tanks worked steadily when received from 1000 to 3000 mg/l phenols. A lower concentration did not provide sufficient natural growth of microorganisms. The method has received practical application for wastewater treatment of coke-chemical industries. The residual concentration of phenols in the purified water was tenths of mg/L.

3.1.4. Microbial destruction of sulfur-containing compounds and surfactants

Sulfur-containing organic compounds are very diverse both in chemical composition and in their purpose. This group includes lignosulfonates and foul-smelling methylsulfur preparations formed during the cooking of cellulose; drugs, pesticides, surfactants and many other compounds. Among the sulfur-containing synthetic organic compounds, a special place is occupied by surfactants, since they practically transit through biological treatment plants into water bodies and soil. The production of surfactants around the world is growing steadily and only in Russia it has long exceeded 500 thousand tons per year. The resistance of many

surfactants to microbial effects makes it necessary to limit their use. In Russia and other countries, the production of so-called rigid, biologically difficult to destroy, detergents is prohibited.
Relatively easily, the so-called mild surfactants are destroyed, the basis of which are alkyl sulfates, alkyl sulfonates and alkylbenzene sulfonates , having the formula R-SO 4 Na, R-SO 3 Na and R(Ar)-SO 3 Na, respectively.) may be represented by an unbranched or branched hydrocarbon chain, (Ar) is a benzene ring.

In view of the enormous role played by surfactants in environmental pollution, much attention is paid worldwide to the issue of their destruction in natural conditions and in sewage treatment plants. All surfactants are tested for resistance before permission for practical use is obtained.

The main role in the destruction of surfactants belongs to bacteria. Algae practically do not break down alkylbenzene sulfonates, and among bacteria the ability to destroy them is widespread and inherent in many species of *the genus Pseudomonas*, individual species of the genera *Flavobacterium*, *Achromobacter*, *Alcaligenes*, *Bacillus*, *Serratia*, *Escherichia*, etc.

The resistance of detergents depends on their chemical composition. The most susceptible to microbial destruction are alkyl sulfates and alkyl sulfonates, relatively easily - alkylbenzene sulfonates with an unbranched alkyl chain. As the alkyl chain branches, the rate of destruction of surfactants decreases.

Of significant importance for the biological destruction of alkylbenzene sulfonates is the mutual arrangement of the sulfonate group and the alkyl chain in the benzene ring: the pair of compounds are destroyed faster than ortho- and meta-derivatives. The place of attachment of the benzene ring to the aliphatic chain does not significantly affect the destruction.

Cleavage usually begins at the methyl end of alkyl, then the bond between the benzene ring and the sulfur atom breaks to form pyrocatechin, which is destroyed by the type of meta- or orthoclement to pyruvic acid.

A method for the treatment of wastewater containing anionic surfactants using *strains of Pseudomonas sp.* 2T/1 and *Achomobacret eurydise* at the aerotank-aerofilter unit. The lower part of the structure is arranged in the form of an aeration tank, and the upper part is arranged in the form of a biofilter. When air blows a liquid rich in surfactants, a large amount of foam is formed. The foam rises to the loading of the biofilter and there is extinguished both mechanically and due to the destructive activity of microorganisms that form a biofilm.

Another example of microbial destruction of wastewater contaminants containing hydrogen sulfide, dimethyl sulfide, methyl mercaptan and other foul-smelling compounds is associated with the use of *thiobacillus thioparus thioparus thiobarus thiobarus* thion bacteria. Such cultures of bacteria were introduced into existing treatment facilities, where, together with other organisms, biofilms participated in biological treatment processes. The introduction of a culture of microorganisms improved the work of the biofilter.

3.1.5. Transformation of organic nitrogen compounds by microorganisms.

Organic nitro compounds are part of dyes, solvents, explosives, and other substances and 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 (Ukraine) 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. P. I. Gvozdyak and his colleagues found that caprolactam is used by all the studied strains of 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. For example, 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.

3.1.6. Biological processes in the aeration tank.

As already noted, the wastewater treatment process is carried out by a complex of living organisms belonging to different systematic groups. It involves bacteria, actinomycetes, fungi, algae, protozoa, worms, lower crustaceans, insects.

According to most researchers, the leading role in the processes of destruction of organic substances contained in wastewater belongs to bacteria, and the simplest are assigned a secondary role. However, they cannot be ignored, as only bacterial sludge is not able to provide a high degree of water purification. This is mainly due to the fact that in the absence of protozoa, intensive development of bacteria is observed. The density of the body of bacteria is close to

one, and therefore, when the activated sludge settles in secondary sedimentation tanks, bacteria form a weakly settling organic suspension, which in some cases can enter water bodies together with purified water, causing secondary pollution of water bodies.

The simplest are more sensitive than bacteria to adverse environmental conditions, so all changes in the technological regime primarily affect the composition and number of protozoa: with satisfactory purification, a variety of protozoa is observed with their relatively low biomass, with a deterioration in living conditions (weak toxicity, insufficient aeration), the number of protozoan species decreases, but their biomass often increases. The more unfavorable the conditions, the fewer species are observed in the active sludge. In the event of a further aggravation of adverse conditions, the protozoa disappear. This leads to a sharp increase in the number of bacteria. Thus, an increase in the number of bacteria indicates not only the intensity of purification, but may be a consequence and an indicator of some toxicity of the runoff. The death of microflora can be observed with a high degree of toxicity. Viable bacterial cells are preserved in the presence of phenols in a concentration of more than Z g/l, carbamide resin - 1.5 g/l, methanol - 0.4 g/l and even such a strong antiseptic as pentachlorophenol in concentrations up to 100 mg/l.

In addition to the sanitary and indicative role of protozoa and other representatives of microfauna, their importance as destructors of organic substances cannot be ignored. To characterize the order of transformation of organic substances, there is the concept of "trophic level", or the level of nutrition. Under natural conditions, the levels of organisms that synthesize organic matter (producers) and organisms that use ready-made organic matter (consumers) are distinguished.

Producers form the I trophic level, primary consumers, for example, herbivores or other phytophages, - II, predatory organisms that feed on

phytophages - III. When moving from one trophic level to another, the amount of biomass and energy contained in biomass decreases, since part of it is consumed in metabolic processes. By analogy with natural ecological systems in which there are no producers, organic can be taken as the first trophic level in the aerotank. By analogy with natural ecological systems in which there are no producers, organic ones can be taken as the first trophic level in the aeration tank. substances of incoming contaminants. The second trophic level will consist of bacteria, fungi and flagella, feeding saprophytically. Protozoa with a holozoic type of nutrition will belong simultaneously to the second trophic level, since they consume suspended substances that have entered the aerotank with wastewater, and the third, since they feed on bacteria. Predatory infusoria, worms and arthropods, sometimes present in the aeration tank, can be assigned to the third and fourth trophic levels, respectively. The ratio of organisms of different trophic levels in the aeration tank is determined by the technological regime: at high loads, organisms of the second trophic level predominate in the silt, at low loads - organisms of the third and fourth trophic levels.

If we denote the production of bacterial biomass through P_1, and the utilization rate of digested food *A* on the growth through *a*, then

$$P_1 = a_1 A,$$

Where *a* is the trophic coefficient. Yconsumes this coefficient to characterize the formation of biomass in systems consisting of several trophic levels, but can also be used to characterize the resulting biomass consisting of organisms of the same species. In this case, it becomes an analogue of the economic coefficient, which is defined as the yield of biomass per unit of limiting substrate, which can be determined from the equation:

$$y = \frac{m_t - m_0}{S},$$

where t_t is the dry matter mass of the cells in 1 ml of the culture that has entered the stationary phase; t_0 - the mass of dry matter of cells in 1 ml

immediately after infection of the nutrient medium; S is the concentration of the limiting substrate; (m_t — t_0) is the increase in biomass indicated in the previous equation by P.

The economic coefficient varies depending on the substrate used, the presence of nutrients, the presence of various growth factors in the nutrient medium and other causes. On average, aerobic heterotrophic microorganisms when growing on glucose have an economic coefficient of 0.2-0.5.

According to I. N. Pozmogova (1974), *candida tropicalis* yeast on a full-fledged medium at a temperature of 36 ° C showed an economic coefficient of 0.67, and in the absence of a nitrogen source on the same medium - only 0.20.

Under anaerobic conditions, various microorganisms (yeast, streptococci, lactic acid bacteria) had an economic coefficient on glucose of 0.1 and even 0 (the economic coefficient was measured using radioactive tracers). Biomass growth was carried out at the expense of other components of the medium, and sugar was used mainly as a substrate for energy. Very low economic coefficient in lithotrophic organisms. It is less than 0.1. In any case, the coefficients a and y are always less than 1, since part of the digested food is necessarily consumed in the process of metabolism of the body; they can be equal to 0 if the body is at rest (endogenous respiration).

Organisms of subsequent trophic levels use as food the biomass of organisms of the previous trophic level, therefore

$P_2=a_2P_1=a_2a_1A_1$.

Due to the fact that the coefficient a is always less than one, an increase in the number of trophic levels in the aeration tank necessarily leads to the fact that the final increase in active sludge decreases with an increase in the number of trophic levels.

At the same time, a situation may also be observed when the total biomass of organisms of high levels will be higher than the biomass of previous levels. This

is possible due to the fact that bacteria have a higher rate of reproduction than protozoa, and therefore not only the biomass of bacteria present at the moment is involved in the creation of the biomass of protozoa, but also the biomass of those cells that, due to consumption, death and other reasons, are not present in the aeration tank by a certain point in time.

Because of this, the amount of organic matter in the system is more correctly estimated by the amount of energy contained in it, since the energy stored in organic substances only dissipates during the transition from one trophic level to another, and therefore it is impossible for the biomass energy of the subsequent level to be higher than the previous one.

The amount of energy can be expressed in calories, joules, or in mg of oxygen, which is necessary for the complete oxidation of the organic matter of the contaminants to carbon dioxide and water. These values are interrelated: 1 mg O_2 corresponds to 3.4 calories of ila 17 joules.

In the practice of wastewater treatment, the number of contaminants is usually expressed in mg of oxygen necessary for their complete oxidation by chemical (COD) or biological (BOD) means. As a rule, BOD is always less than COD, the ratio of BIIK: COD (biochemical indicator) serves as an indicator of the ability of wastewater pollution to biological destruction. For domestic wastewater, the biochemical index is 0.75-0.80, for wastewater of many food industries - 0.6-0.8, for the oil refining industry - from 0.8 to hundredths of a unit.

It should be noted that the BOD indicator is not entirely reliable, since its determination does not take into account all organic matter available for biological destruction, and therefore in reality the true pollution with organic substances of wastewater is often higher than the analysis of BOD shows.

3.1.7. Features of the existence of microorganisms in the conditions of aeration tanks.

Wastewater treatment in aeration tanks is carried out according to the same principle as in natural water systems, but at the same time the conditions for the existence of living organisms in the aeration tank have a number of features. Individual species perform their inherent functions in the community, and different organisms can perform the same function.

The stability of the system as a whole depends on the number of species: the more diverse the species composition of the community, the greater the number of populations capable of duplicating each other's functions, the more stable the system.

The species composition of the population of activated silt is usually poorer than the composition of natural reservoirs. Often, the entire microfauna of the aeration tank is represented by two or three types of protozoa, and the number of trophic levels does not exceed three.

The conditions for the existence of communities in natural conditions are relatively stable, while after active aeration of wastewater in an aeration tank, it, together with silt (silt mixture), enters the secondary sedimentation tank, where aeration is absent and where the purified water and activated sludge are separated. Water from the secondary settling tank is sent to the reservoir, for disinfection or additional purification, the active sludge is partially returned through the pumping station to the aeration tank (circulating active sludge), and partially removed from the system (excess active sludge).

Thus, active sludge is not just in the aeration tank, but in the aerotank-secondary settling tank system, and, consequently, the conditions for the existence of activated sludge change in time and space, while under natural conditions they change only in time. The time of aeration of activated sludge in the aeration tank varies depending on the composition of the contaminants and ranges from about 2 hours to 2-3 days, for example, for domestic wastewater about 5-10 hours.

Thus, the first feature of the ecological system of the aeration tank is the instability of the conditions for the existence of activated sludge.

The second feature is associated with the artificial maintenance of the sludge dose in the aeration tank. Under natural conditions, the amount of biomass is determined by the amount of natural increase, which, in turn, depends on the concentration of the limiting factor, mainly on the content of organic substances in the water of the reservoir. In the aeration tank, the concentration of activated sludge (sludge dose) is artificially inflated by returning the sludge from the secondary settling tank to the aeration tank. At a concentration of incoming organic substances in the aeration tank of 300 mg / l, the maximum increase in biomass at a = 0.6 will be about 180 mg / l, while in the aeration tank a dose of silt is usually maintained at least 1.5-2.0 g / l, and usually 2.5-3.5 g / l.

The conditions of the existence of microorganisms in the aeration tank affect the formation of its biocenosis, which has a number of features that distinguish active sludge from biocenoses formed in natural conditions.

The instability of the conditions of existence, in particular changes in incoming contaminants both in quantity and composition, the different gas regime in the aeration tank and in the secondary sedimentation tank lead to the fact that bacteria with a wide ecological valence, the so-called eurybionts, predominate in the active sludge. Pseudomonas have the greatest "omnivorousness" of bacteria - they predominate among the bacterial population of active sludge. A wide range of enzymes, including constitutive ones, allows members of the genus *Pseudomonas* to adapt to various nutrients.

The formation of plankton of a natural reservoir is affected by the speed of the current. At a high flow rate, plankton is dominated by organisms with a short developmental cycle, since all other organisms will be carried out with a current of water. In the aerotunk-secondary sedimentation tank system, the zone of high speed of water movement is replaced by a sedimentation zone, so the rate of

reproduction of organisms is not a determining feature, but the breeding role belongs to the ability of bacteria to agglomeration and to deposition. Therefore, among the bacteria of active sludge, forms with a mucous capsule and other devices that contribute to the formation of cotton predominate. It is these bacteria that enter the aeration tank with circulating silt. Increasing the dose of sludge in the aeration tank compared to the natural increase also leads to a number of features of active sludge. Every bacterial cell under normal aeration tank conditions experiences starvation, as there are many more bacteria than there would be with the same amount of nutrients in vivo. This leads to a more complete absorption of incoming nutrients. According to L. I. Gunther (Research Institute kvov), the consumption of contamination with activated sludge corresponds to the formula:

r_t=795m+20.2 mg BOD_5;г/ч,

where ρ_τ is the consumption of pollution; μ is the specific growth rate. At μ = 0, the consumption of pollution corresponds to the main exchange. The maximum value of the μ for urban wastewater in the Günther experiments was 0.089 $^{h-1}$, ρ_τ at the same time it reached 90 mg of BOD_5 / g · $^{h-1}$. Thus, the higher the increase in active sludge, the more pollution is consumed, and vice versa. When creating an increased concentration of activated sludge in the aeration tank each unit of biomass, due to a lack of nutrients, works less actively and the amount of pollution consumed in the process of basic metabolism increases relatively. At the same time, an increase in biomass per unit volume leads to the fact that total consumption not only does not decrease, but even increases. In this way, two tasks are solved: increasing the consumption of pollution and reducing the growth of activated sludge.

The increase in the concentration of activated sludge in the aeration tank cannot be unlimited. With an increase in the dose of sludge, the conditions of its existence worsen: the amount of nutrients per unit of biomass decreases, the conditions for the mass transfer of nutrients and oxygen worsen, metabolic

products accumulate. All this leads to a decrease in the specific growth rate and a reduction in growth. Less and less excess activated sludge is formed, the residence time of the sludge in the aerotank-secondary settling tank system increases, the sludge ages, the number of dead cells grows in it. It loses activity. In flow systems operating on natural growth, the decrease in biomass growth will continue until the specific growth rate of the crop is equal to the rate of inflow of the nutrient medium. This is how the self-regulation of the system is carried out. In the aeration tank, where the dose of sludge is set artificially, self-regulation of active sludge also takes place. It is manifested in a change in the enzymatic activity of cells. The enzymatic activity of sludge with an increase in the load for several minutes can increase tenfold.

The decrease in enzymatic activity proceeds more gradually. The ability of sludge to a sharp increase in enzymatic activity makes it possible to conduct the process of wastewater treatment with the same efficiency with significant fluctuations in the dose of sludge. But in any case, the dose of sludge in the aeration tank is set by the technologist depending on the concentration of contaminants in the wastewater, the aeration time and the required degree of purification.

3.1.8. Biological treatment facilities. Aeration tanks.

Aeration tanks are one of the main facilities in the technology of biological wastewater treatment. In aeration tanks, activated sludge microorganisms come into contact with the purified water both in aerated conditions and in conditions of limited oxygen supply or in its absence when creating anaerobic zones.

It is known that, depending on the hydraulic scheme of operation, aeration tanks are classified into:

- aeration tanks - displacers (Fig. 3.3) with the so-called concentrated intake of dirty water and activated sludge, as a rule, at the end of the aeration tank and with a decreasing load on the active sludge along this treatment plant;

-aeration tanks - mixers (Fig. 3.4) with such a scheme of flows of dirty water and activated sludge in order to ensure the same load on the active sludge in the entire volume of the aeration tank;

- intermediate type aeration tanks (Fig. 3.5) with a dirty water supply dispersed along the structure and a concentrated intake of activated sludge with a cyclically changing load on active sludge along the structure.

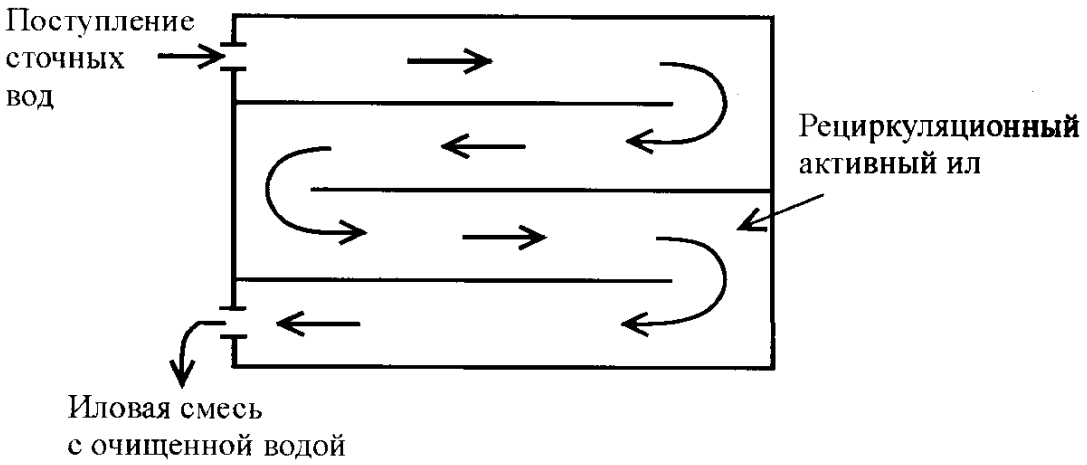


Fig. 3. 3. Scheme of wastewater movement in a four-corridor aeration tank-displacer.

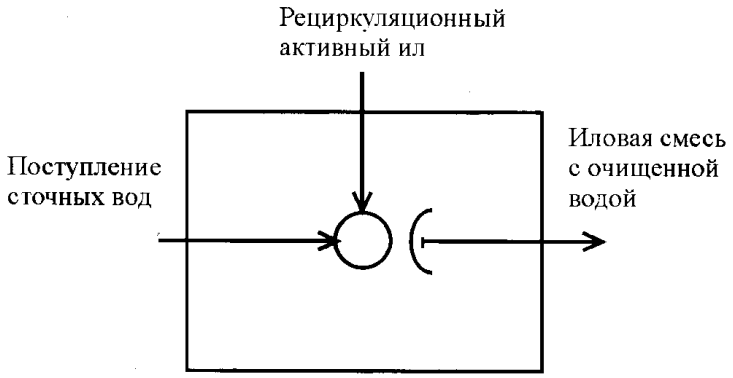


Fig. 3. 4. Scheme of the aeration tank-mixer with the central supply of wastewater and silt to the aeration zone.

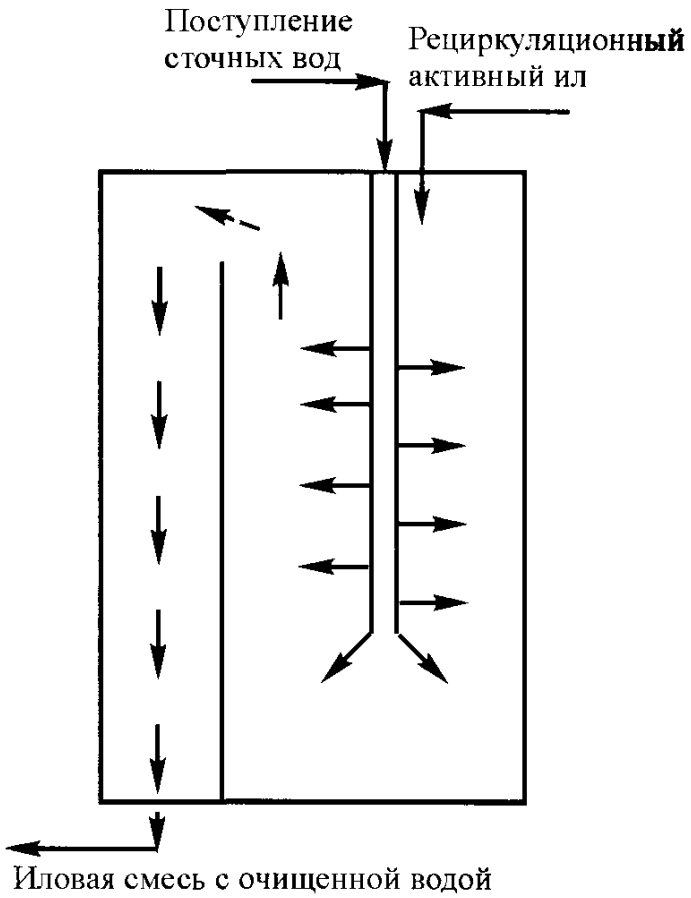


Fig. 3. 5. Scheme of wastewater movement in an intermediate type aeration tank: mixer-displacer.

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 aeration tanks-mixers in the treatment of highly concentrated industrial wastewater, similar in composition to domestic wastewater (food plants, beer plants, fish factories), as well as with uneven inflow and frequent volley overloads, was justified by Professor N.A. Bazyakina in 1948. the reason for the high loads on

active sludge throughout the 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.

Aeration tanks are also divided onthe type of aeration used into: aeration tanks with mechanical or the most common 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.

3.2. Comparative analysis of biological wastewater treatment with technologies of cultivation of biomass of microorganisms.

In Table. 3.1 the conditions under which both processes take place: the process of biological wastewater treatment and the process of cultivation of biomass of microorganisms are considered.

Table 3.1. Comparative characteristics of biological wastewater treatment and controlled biotechnological processes

Indicator affecting biomass growth	Biological treatment process	The process of cultivation of microorganisms
Composition of microflora	Composition of active sludge: bacteria, actinomycetes, fungi, algae, protozoa, worms, lower crustaceans and insects. The biomass of activated sludge microorganisms is never a monoculture, but is always a polyculture.	For various purposes of growing, the biomass of microorganisms in the fermenter can be both monoculture and polyculture.

Composition of the nutrient medium	The nutrient medium for microorganisms is wastewater supplied for treatment. Wastewater coming from the city sewer or discharged from various enterprises can contain a variety of elements and their connections in different aggregate states. Wastewater may contain toxicants and mutagens, which reduce and increase growth accordingly. Wastewater entering the aeration tank for treatment is characterized by the inconstancy of the composition and concentration of contaminants.	The nutrient medium for microorganisms is a balanced mixture of substrate, macro and microelements necessary to ensure the vital activity of the cultivated strain of microorganisms. Substrate, macro and microelements and their concentrations are selected on the basis of knowledge about the physiology and metabolism of this strain of microorganisms. The nutrient medium is fed into the fermenter rhythmically.
Dissolved oxygen content of culture liquid	The dissolved oxygen content at any point of the aeration tank should not be less than	Depending on the living conditions of the cultivated strain of microorganisms, the

	1.0–2.0 mg/dm^3. This is provided by various aeration systems or mixing.	supply of oxygen to the culture liquid varies. Either the supply of cysrogen to the culture liquid is carried out using aeration systems, or mixing.
Acidity of culture liquid	The acidity or alkalinity of effluents depends on the nature of production.	The acidity or alkalinity of the culture liquid depends on the cultivation conditions of the cultivated strain. The acidity of the nutrient medium is regulated by the supply of reagents.
Culture liquid temperature	The temperature in the aeration tank depends on the time of year and the temperature of the nutrient medium entering the aeration tank. The temperature of wastewater depends on the type of production.	The temperature of the culture liquid depends on the culture conditions of the cultivated strain. The fermenter maintains the optimal temperature for the growth of this strain.

With the same mechanism of the two processes under consideration, the conditions for their implementation differ significantly. If optimal cultivation

conditions are strictly observed in the process of biosynthesis, then during wastewater treatment, active sludge is in unstable conditions.

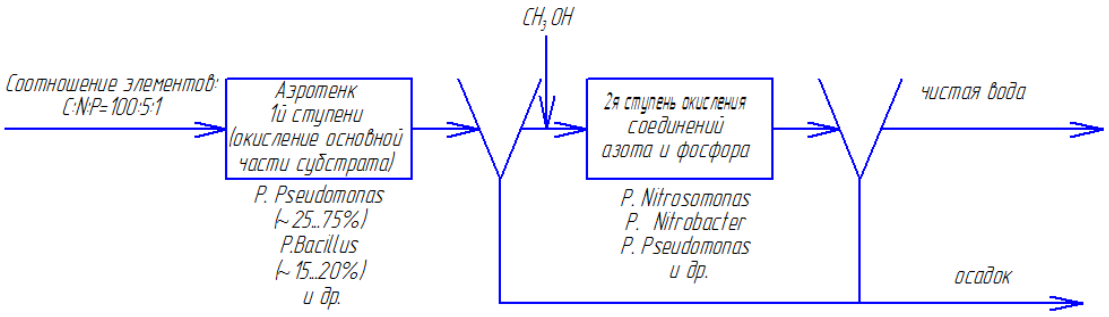
But it should also be borne in mind that in the process of cultivating the biomass of microorganisms, the constancy of the composition of biomass is most often strictly observed, then in the process of water purification we are dealing with a self-regulating ecosystem, more like a natural one.

Based on the experience of using technological developments of microbiological production, it is possible to intensify the process of biological wastewater treatment.

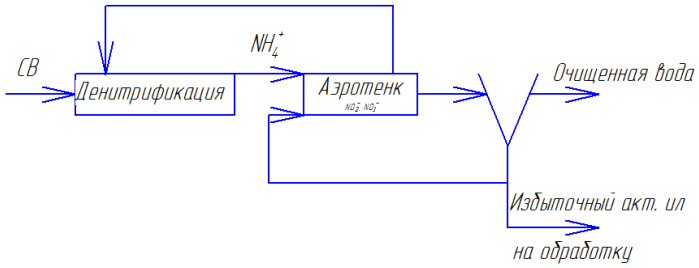
3.3. Wastewater treatment from biogenic* elements (nitrogen and phosphorus)

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. 3. 6 A,B).



(A)



B)

Fig. 3. 6. Schematic technological schemes for the removal of biogenic elements: A) two-sludge scheme; B) single-sludge scheme.

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:

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:

Mixers;

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.

The process of biological purification is not limited to the processes of oxidation of organic contaminants in the aeration tank. After the aerotanks, the 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. At the same time, various options for technological schemes of biological wastewater treatment are possible, for example, presented in Fig. 3. 7 a – 3. 7 b.

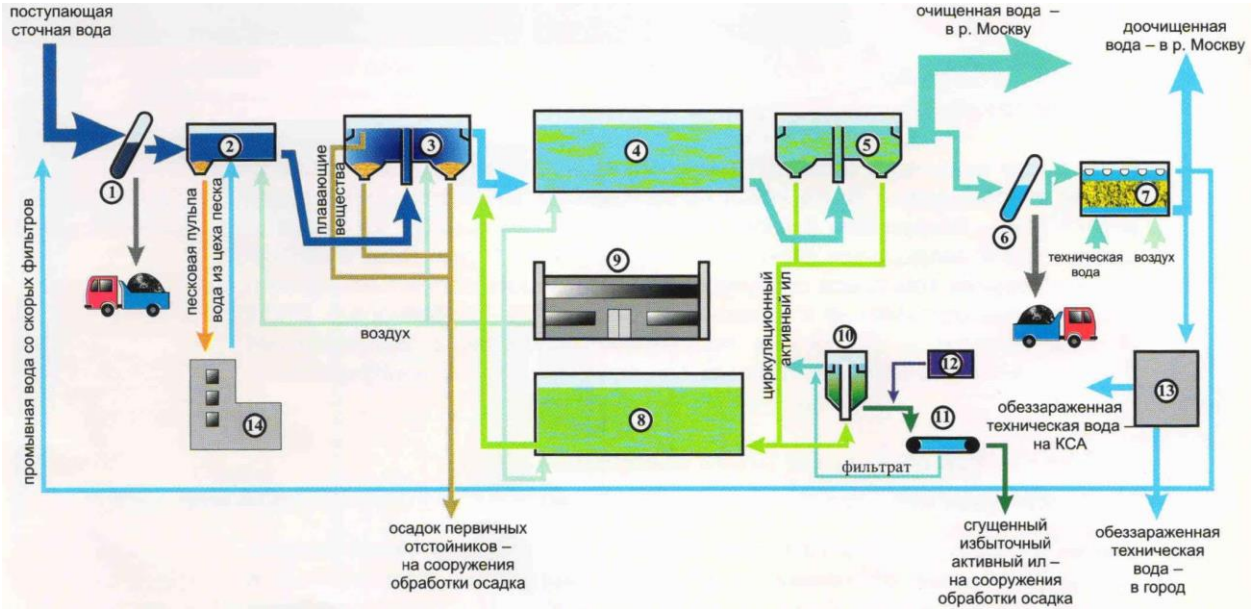


Fig. 3. 7 a. Scheme of wastewater treatment at a modern aeration station

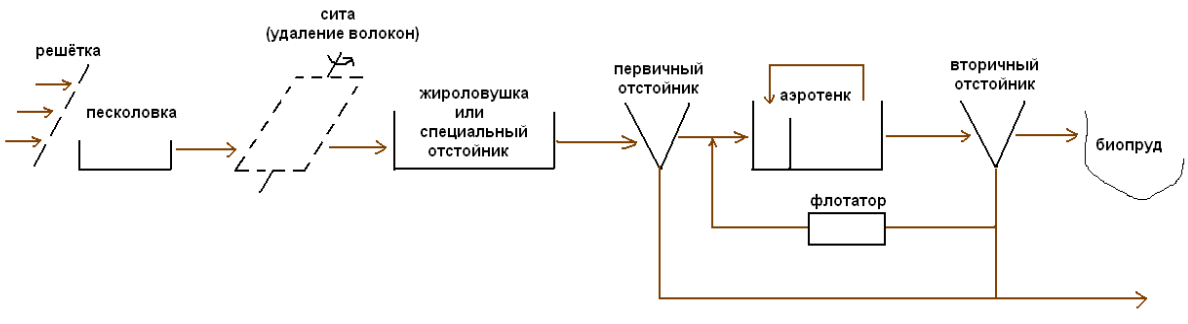


Fig. 3. 7 b. Scheme of biological treatment with regeneration of return activated sludge in the flotator.

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 typical scheme (Fig. 3. 8).

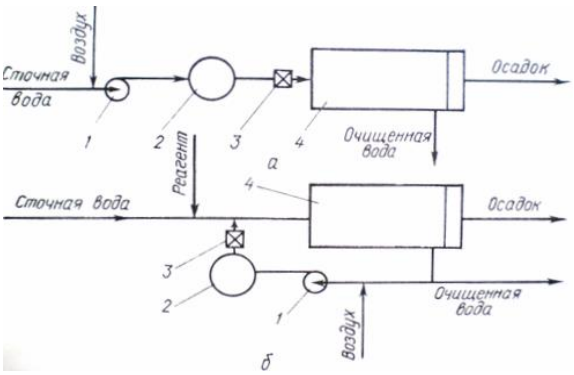


Fig. 3.8. Typical scheme of flotation technology

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. 3. 8).

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 plants are common as with saturation of the entire flow of purified wastewater with air (Fig. 3. 8, a) and with the saturation of part of the purified water (20-50%) with air and mixing it with wastewater entering the purification, i.e. with the recirculation of part of the purified liquid (Fig. 3. 8, 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.

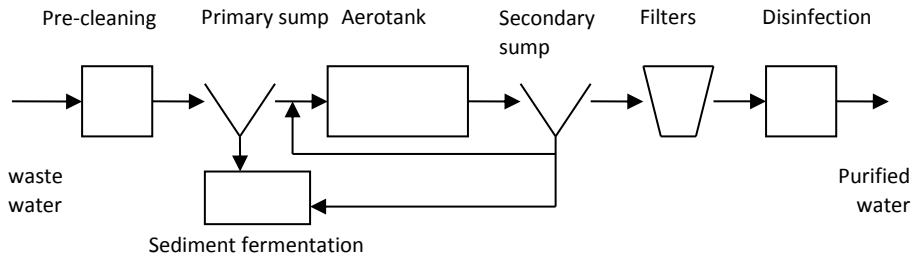
In the initial period of development of the use of biological methods, the requirements for the quality of wastewater treatment were reduced to achieving a concentration of BODfull and suspended substances (EXPLOSIVE) at the outlet of treatment facilities in the range of 15-20 mg/l, as well as a certain 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 BODN 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.

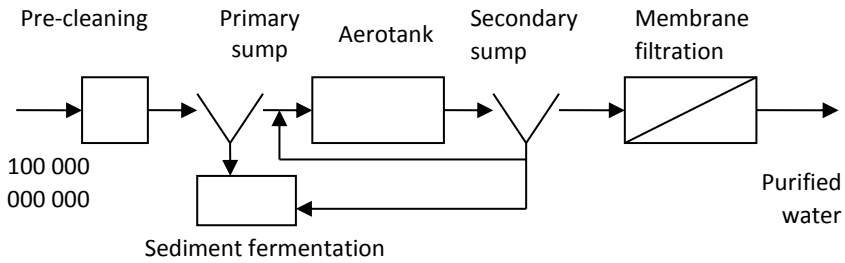
Initially, the use of membranes in wastewater treatment schemes was limited to post-treatment. Ultrafiltration, microfiltration or reverse osmosis plants were used under very strict discharge requirements or when direct water reuse was necessary. High capital and operating costs and insufficient knowledge 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.

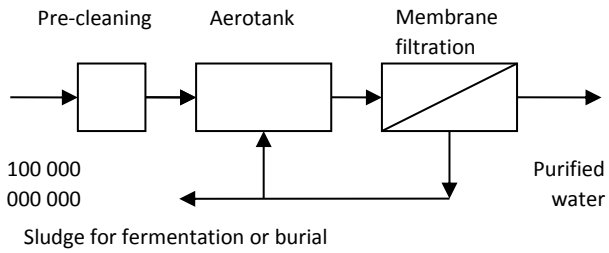
The development of membrane technologies has come from their use exclusively for tertiary wastewater treatment to direct integration into systems with activated sludge - membrane bioreactors (ICBMs). In Fig. 3. 9 illustrates the evolution of the incorporation of membrane technologies into biological treatment processes.



(a)



b)



c)

Fig. 3. 9. Evolution of the introduction of membrane technologies in the processes of biological purification.

In Fig. 3. Fig. 9, and the traditional scheme of biological wastewater treatment is presented. At the first stage (Fig. 3. 9, b) the membranes were used as an element of post-treatment of wastewater after a 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. 3. 9, (c) membrane separation is useddirectly in the process of biological purificationinstead of secondary sedimentation tanks.

The action of the bioreactor is based on the principles of biotechnology and technology for the separation of aqueous suspensions on ultrafiltration membranes.

The membrane bioreactor consists of an aerotank and a membrane module with ultrafiltration or microfiltration membranes. The treated wastewater first enters the aeration tank. In this case, the silt mixture formed in the aeration tank circulates through the membrane module. Ultrafiltration membranes serve to increase the concentration of activated sludge in the aeration tank and achieve deep wastewater treatment. In this case, the aeration tank is operated with a high concentration of activated sludge, so its dimensions are about 2-3 times smaller than the size of a conventional aeration tank.

The membrane module includes 10-20 cassettes with membranes. Each cassette contains about 5 to 15 bundles of membrane fibers. The membrane is made in the form of a cylinder with an outer diameter of about 2 mm and a length of up to 2 m. At the same time, the surface of the cylinder is an ultrafiltration membrane with a pore size of 0.02–0.1 μm.

Each bundle consists of about 100-1000 fibers and is equipped with a common branch pipe for the removal of purified liquid. This pore size does not

allow active sludge microorganisms to penetrate through the membrane and this allows the active sludge to be separated from the wastewater.

To do this, a pressure difference (approximately 0.01~ 0.06 MPa) is created between the inner cavity of the membranes and the space of the membrane block. In this case, the sludge mixture is filtered through the surface of the membranes from the outside to the inside. As a result, the concentration of activated sludge in the membrane biorector unit and in the aeration tank increases, which contributes to the intensification of the process of biological wastewater treatment and a decrease in the volume of the aeration tank by 2-3 times.

In this case, the purified water enters for disinfection, and the active sludge contained in the membrane tank is maintained in suspension by an aeration 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. Replacing the gravitational method of separating the sludge mixture makes it possible to increase the concentration of activated sludge in the bioreactor to 10-20 g / l, which is noticeably higher compared to a conventional aeration tank (3-4 g / l).

High concentrations of activated sludge make it possible to operate the bioreactor in low load mode, which creates a reserve of oxidizing capacity, increases the resistance of the biocenosis of activated sludge to fluctuations in the composition of wastewater and peak loads, and ensures a stable quality of treatment. On the other hand, high concentrations of activated sludge multiply the oxidizing capacity of the structure as a whole, which makes it possible to purify highly concentrated wastewater with a high content of organic substances.

During the transition from the gravitational method of separation of the

sludge mixture to membrane filtration, profound changes in the structure of the biocenosis of activated sludge are observed. The age of sludge in ICBMs is usually about 20-25 days, and sometimes more. At the same time, the main part of the activated sludge is represented by a slow-growing microflora, which most effectively decomposes hardly oxidized organic substances in wastewater. The predominance of slow-growing microflora can significantly reduce the growth of activated sludge, and, consequently, reduce the necessary capacity of equipment for dehydration of excess activated sludge.

The size of the flakes of activated sludge in ICBMs is several times smaller than in common aeration tank designs. Such dispersion of activated sludge leads to an increase in the area of contact of microorganisms with wastewater, increasing the efficiency of sorption by active sludge of inert substances, heavy metals, microcontaminants.

The advantages of membrane bioreactor technology are as follows.

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.

Increasing the resistance of the bioreactor to volley discharges of bioresestive substances characteristic of industrial facilities of local water disposal.

The ability to increase or decrease productivity without changing the technological process.

A decrease of about 25-50% in the weight and size characteristics of capacitive structures, since the required amount of activated sludge is in a smaller volume at a higher concentration.

Obtaining a small amount of excess activated sludge, which significantly

affects the cost of its mechanical dewatering and disposal.

Reduction by about 50-75% of the area occupied by the equipment.

Ensuring high microbiological safety of treated effluents. The removal of activated sludge from the system to the tank with purified water is excluded.

Of particular note is the retention of all suspended solids and part of the soluble components of wastewater in the bioreactor, which ensures a very high quality of the treated water, meeting the most stringent requirements for discharge or directly for reuse. The ability to detain bacteria and viruses ensures the relative sterility of the outgoing water, simplifies the final disinfection systems and eliminates the related hazards associated with by-products. Disinfection. 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 ICBMs 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 ICBMs 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.

3.4. Biological purification of water and soilsoils from oil pollution

Pollution of soil and soils with oil and oil products in most cases is anthropogenic in nature and is associated, first of all, with unorganized economic activity. Oil and oil products, getting into the soil and soils, inhibit the vital activity of microorganisms and plants, which ultimately leads to the alienation of contaminated areas and the impossibility of their use for economic activities. However, certain types of microorganisms, as was established by our compatriot V.O. Towson, can oxidize oil hydrocarbons. Further studies conducted in various domestic and foreign organizations, and especially in France and the USSR, finally confirmed that individual microorganisms can develop on media where the only source of carbon is oil hydrocarbons. At the same time, it was found that the oxidizability of different classes of hydrocarbons varies greatly.

In the processof research conducted mainly in our country, it was found that the most universal sources of nutrition are normal paraffins. Hydrocarbons are also well consumed, the molecules of which consist of a long chain with terminal branches of cyclic or acyclic structure. It was also found that aromatic compounds are oxidized only by certain types of microorganisms and at the same time the presence of side radicals with a straight chain increases them. Digestibility. Yeasts

of some genera, in particular Candida, Torullopsis and others, quite well oxidize normal paraffins, as well as aromatic hydrocarbons.

At the same time, bacteria isolated from oil-contaminated soils and soils grow better on high-boiling fractions of oil and worse on low-boiling fractions (in the range of 100 - 200 ° C).

The above provisions point to complex mechanisms of oxidation of petroleum hydrocarbons, the diversity of which cannot be considered in this work.

The results of numerous studies of both domestic and foreign scientists in this direction were the basis for the development of various biological preparations for the oxidation of petroleum hydrocarbons present in soil, soils or water as pollutants. A lot of biological preparations have been developed, including various combinations of oil-oxidizing microorganisms. In addition, especially recently, drugs have also appeared, in which, along with microorganisms, there are food sources for them. Consider as an example only certain types of drugs.

The drug "Putidoil" is known, designed to purify the soil and water from oil pollution. This drug is produced on the basis of a natural bacterial strain Pseudomonas putuda - 36. The drug, along with certain advantages, has a number of significant drawbacks.

The drug "Putidoil", which is dry biomass in its initial state, must be "dispersed" when applied to the soil or water, which in the field is in some cases a difficult task associated in particular with heating water to about 20 - 28 degrees, as well as with aeration of a suspension of bacterial biomass for about half a day.

When using this drug, its low effectiveness was noted. In addition, the depressant effect of this drug on the natural microbial biocenosis was noted.

The bacterial preparation "Naftox" is also known, which allows, in a number of favorable cases, to clean the soil from petroleum products and create certain

prerequisites for the subsequent use of cleaned soils and improve the state of the environment.

The essence of the method is to use the natural bacterial strain Mycobacterium Sp - 5 kB to clean the soil from petroleum products. Bacteria of the genus Mycobacterium have, according to the developers of this method, a number of advantages over other bacteria in the processes of microbiological oxidation of petroleum hydrocarbons in the soil. These bacteria, along with high oxidative capacity, contribute to the emulsification of petroleum products in the soil. These bacteria, along with high oxidative capacity, contribute to the emulsification of petroleum products in the soil. and the case of cultivation in aquatic environments. At the same time, mycobacteria are able to assimilate not only normal alkanes, but also phenol, benzoic acid, naphthalene, cyclohexane, higher fatty acids.

The drug "Naftox" is obtained according to the technological scheme adopted for the production of biomass of nitrogen-fixing bacteria. The technology of obtaining is as follows. Neutralized to pH 6.8 - 7.0 sterile peat in plastic bags is inoculated with a liquid culture of oil-oxidizing bacteria with the simultaneous introduction of a source of carbon and energy, for example, n- alkanes in an amount of 1 - 2% of the weight of dry peat, mixed and incubated at room temperature. The drug "Naftox" is obtained with a humidity of 55 - 60%.

Along with the above advantages, the drug "Naftox" like other similar drugs do not make it possible to get a guaranteed effect of soil cleaning in any predicted time due to many adverse factors affecting the vital activity of microorganisms introduced into the soil.

The literature describes dozens of ways to protect soils and soils from petroleum products using various biological preparations. In domestic practice, the drugs "Devoroil", "Lestan" and others are well known. The composition of such

drugs most often includes several cultures, among which, as a rule, bacteria of the genus Pseudomonas, Alcaligenes, Rhodococcus, etc. are used.

The drug "Devoroil" allows you to implement a purification technology based on the use of microbial associations that actively dispose of oil hydrocarbons, and allows you to clean the soil and water from petroleum products in a fairly short time.

The drug is obtained by cultivation in fermenters under conditions of intensive aeration on media containing sources of carbon, nitrogen, phosphorus, potassium and trace elements.

Trace elements that make up the drug "Devoroil" are isolated from nature. The non-toxicity and non-pathogenicity of these microorganisms has been established. The technology of using this drug, like many others, is based on the spraying of dried biomass using mechanized means.

When using "Lestan" (according to Ivanov V.N., Stabnikova U.V. and others) for the treatment of soil contaminated with hydrocarbons (UGV), in the form of a pulp, the purification efficiency was 90 - 95% with an average oil degradation rate of 69 - 72 mg / kg per day, which far exceeded the results obtained in the control - when tilling the soil without "Lestan" - the purification efficiency - 15.7%, the rate of oil degradation - 9 mg / kg per day (Table. 3.2-3.4).

The drug "Lestan" can also be used to purify water from oil products. 3.2) indicate an increase in the rate of oil degradation by 20-30% in water samples containing "Lestan". The efficiency of purification and the rate of oil degradation depends on the dose of "Lestan" injected into the purified water (Table. 3.3). Increasing the dose by 10^4 times (from 1 mg / l of water to 10 g / l) made it possible to increase the efficiency of purification in 30 days from 63.3 to 93.3%, and the rate of oil degradation by 1.5 times.

Table 3. 2. Using "Lestan" to clean the soil in the form of pulp*

Sample	Oil content in the soil sample, mg/kg	Efficiency of oil degradation,%	Rate of oil degradation, mg/kg per day
Control 1 (no soil and no "Lestan")	23,07	12,9	10
Control 2 (with soil without "Lestan")	23,34	15,7	9
Control 3 (with "Lestan" and without soil)	124,00	95,3	72
Sandy loam soil	204,00	92,3	70
Loam	249,00	90,6	69
Arctic soil	125,00	95,3	72

* Initial total hydrocarbon content in samples – 2650 mg/kg

Table 3. 3. Use of "Lestan" for water purification.*

Sample	Oil content in the sample, mg/kg	Efficiency of oil degradation,%	Rate of oil degradation, mg/kg per day

Control 1 (fresh water without "Lestan")	320	65,9	21
Control 2 (sea water without "Lestana")	345	63,3	20
Fresh water with "Lestanom"	184	80,4	25
Sea water with "Lestanom"	123	86,9	27

* The initial total content of hydrocarbons in water is 940 mg/ l.

The effect of the dose of "Lestan" on the process of purification of water from hydrocarbonsis presented in Table 3. 4.

Table 3. 4. The effect of the dose of "Lestan" on the process of water purification from hydrocarbons.*

Introduction of "Lestan",mg/kg	Oil content in the sample, mg/kg	Efficiency of oil degradation,%	Rate of oil degradation, mg/kg per day
1,0	347	56,1	15
10,0	290	63,3	17
100,0	268	66,1	17
1000,0	200	74,7	20

10000,0	48	93,9	25

* Initial total hydrocarbon content in water – 790 mg/l

A number of microbial preparations are known to be recommended for cleaning soil and water contaminated with oil. Brief information about them is given in Table. 3.5.

Table 3. 5. Brief information about biological preparations for cleaning soil and water from oil hydrocarbons (according to Ivanov V.N., Stabnikova E.V., etc.)

Name of the drug	Brief description
NoggiesBiodetox	Dry mixed cultures of microorganisms are harmless to humans and animals for cleaning soil and groundwater from hydrocarbons. In the soil (up to a depth of 0.4 m) is introduced in the form of foam with nutrients and surfactants. To purify groundwater, the drug is injected through wells, groundwater is pumped out, purified in a bioreactor and returned to the aquifer
NoggiesHorrepat	For decomposition in the soil of fuel oil, diesel fuel, gasoline, kerosene phenols, formaldehyde, coal oil; introduced into the soil in the form of foam
Putidoil	To clean the environment from oil
Cytocultur	Bacterial compositions for cleaning the environment from aromatic hydrocarbons
Microbe Inc.	Commercial strains for soil purification from biphenol, cresol, pentachlorophenol

Konsan	Bacterial preparation with nutritional supplements for soil cleaning

The positive difference between "Lestan" and other drugs is its stability in extreme temperature conditions, as well as emulsifying and foaming ability. As a result of the studies, it is possible to recommend the drug "Lestan" for the treatment of soils and water bodies from oil pollution in order to accelerate their purification from oil hydrocarbons.

There are many different ways to neutralize soils from petroleum products, patented both in Russia and abroad.

The biological method has significant drawbacks, for example, a long duration (up to 2-3 months) and does not give full confidence in achieving a guaranteed effect. Although there are a number of examples of obtaining a positive application of this method. For example, during long-term tests of this method of treating contaminated soils and soil, the Laboratory for Processing and Biotechnological Waste Disposal of JSC "GosNIIsintezbelok" under the leadership of Ksenofontov B.S. conducted successful tests of the use of a biological preparation based on bacteria of the genus Pseudomonas for the purification of soil and sewage sludge after washing cars. However, the noted shortcomings, in particular the lack of confidence in the guaranteed achievement of a positive result, do not make it possible to widely use this method of cleaning the soil and soils from oil pollution.

In conclusion, it should be noted that the problem of neutralization of soil and soils from petroleum products has passed various stages of development and is currently at the stage of pilot testing. The described drugs, as well as the methods of their use, have significant drawbacks associated with the fact that some of the microorganisms in the sprayed biological preparation may already be dead, and

living microorganisms, getting into the soil, carry out their vital activity in suboptimal conditions associated with both the imbalance of nutrients and the suboptimal moisture content in the soil.

At the same time, it should be emphasized that the developers of biological products, as a rule, declare better indicators of the effect of cleaning the soil and soils from petroleum products than is usually achieved in practice. This appears to be due to the conduct of tests under more favourable conditions than those most commonly observed in a real practical situation. These circumstances to a certain extent gave rise to disbelief among buyers of biological products in achieving a guaranteed effect of cleaning the soil and soils within the planned period.

One of the banal reasons for the absence or small size of the effect of soil and soil cleaning is sometimes the work in the cool season, for example, due to the lack of funding for these activities in the warm period. Other, no less frequent reasons are the difficult availability of the cultivated soil area due to off-road and waterlogging, as well as the inability for various reasons to make the necessary nutrients for the normal functioning of microorganisms introduced into the soil or soil.

Comparing the technological methods of biological purification of soil and soils with the already developed technology of biological water purification, it should be noted that the first problem is at the stage of solution, and the second is at the stage of improvement. In our opinion, a comprehensive solution is also possible, when the active sludge of biological treatment facilities of industrial waters, mainly oil refineries, adapted to the oxidation of petroleum products, is introduced into contaminated soil or soil in the form of a suspension. At the same time, the transportation of a sludge of activated sludge can be carried out both through pipelines and with the help of special vehicles.

In the case of remoteness of the objects on which it is necessary to carry out biological cleaning of the soil or soils, active sludge is supplied in the form of dried biomass with a moisture content of not more than 10%. The technology of obtaining dry biomass of activated sludge with a humidity of not more than 10% was developed in the 80-90s of the twentieth century in JSC "GosNIIsintezbelok". This technology includes the following main stages: A suspension of excess activated sludge from secondary sedimentation tanks of biological treatment plants with a concentration of approximately 0.8 – 1.0% for absolutely dry substances (DIA) is thickened using a pressure flotation apparatus to 2.5 – 3.5% DIA and the condensed concentrate is sent for further thickening to a vacuum evaporation unit. The resulting condensed sludge of activated sludge with a concentration of approximately 8 - 10% according to the DIA is fed into a spray dryer. The resulting biomass of activated sludge has a humidity of not more than 10%. The shelf life of such biomass is at least 6 months.

The disadvantage of the above technology is that some microorganisms die in the process of dehydration. This, of course, is a disadvantage of this technology, but given the fact that active sludge is a waste, it can be considered part of the dead biomass as a substrate for the vital activity of the remaining living microrganisms. Naturally, there are other more gentle ways to dehydrate microorganisms, including activated sludge. First of all, this refers to the method of drying the suspension of microorganisms. Freeze-drying or other methods can be used to keep the vast majority of microorganisms alive when drying.

The use of excess activated sludge of biological treatment facilities mainly of oil refineries as a preparation for cleaning soil and soils from oil pollution will reduce the price of biological preparations of this type within certain limits. In addition, this technical solution will contribute to the utilization of such multi-

tonnage waste as excess active sludge biological treatment facilities of Russian refineries, the capacity of which in some cases has even increased in recent years.

The above-described technical solutions for cleaning soil and soils using microorganisms do not exhaust, of course, the entire possible arsenal of approaches to solving this problem, which is very complex and multifaceted. And in this aspect, apparently, combinations of various methods of cleaning soil and soils from petroleum products will be used to increase the complexity of the task being solved.

In recent years, the production of batches of biomass is carried out in smaller volumes than it was before. At the same time, it should be noted that there is no significant decrease in demand for microbiological preparations for the treatment of oil-contaminated soil and water areas, and at some points there is an increase in demand. In this regard, there is interest in considering the industrial technology for obtaining biomass of oil-oxidizing microorganisms, developed earlier and intended for the production of mainly feed protein from petroleum paraffins.

The essence of the industrial technology for obtaining biomass of oil-oxidizing microorganisms, mainly yeast, developed in JSC "GosNIIsintezbelok" is as follows. Selected in the process of selection, the most productive strain of yeast (according to the protein content in yeast cells), the only source of carbon of which were oil paraffins, is cultivated sequentially in special devices for growing microorganisms - fermenters.

It is necessary to describe in more detail the design and principle of operation of one of the most important devices used in biotechnological practice. Fermenter is an apparatus for deep cultivation (cultivation) of microorganisms in a nutrient medium under conditions of sterility (non-sterile processes are also used), intensive mixing, continuous aeration with sterile air (in the case of a sterile process) and constant temperature. The fermenter, as a rule, is a sealed cylindrical

vessel - a housing equipped with a unit for supplying sterile air and an electric stirrer (Fig. 40). Inside the fermenter along its body and perpendicular to it are fixed narrow metal strips - bumpers to increase the efficiency of mixing. The volume of fermenters intended for laboratory research, most often, is from 1 to 30 liters, for experimental and industrial experiments - 0.05-5^{m3}, industrial use - 50-400 m3. At the enterprises of the microbiological industry, fermenters with a working volume of up to 400 m 3 were used to obtain biomass of fodder yeast on petroleum hydrocarbons.

If necessary, the fermenter is equipped with devices for measuring and regulating the pH of the medium, temperature, the concentration of dissolved oxygen in the culture liquid, carbon dioxide in the outgoing air, a foam level alarm and nodes for mechanical or chemical defodying. With a continuous sterile process of culturing microorganisms, the fermenter is equipped with sterilizable tanks for storing components of the nutrient medium and pumps for their continuousrapid supply to the fermenter (Fig. 3.10). Fermenters are used in industry in the microbiological production of fodder yeast, antibiotics, enzymes, vitamins, amino acids, etc.

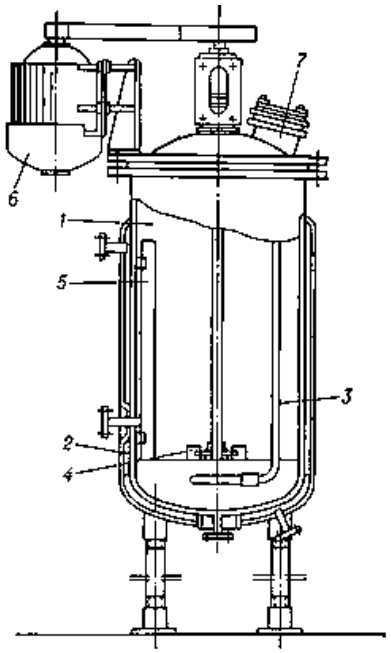


Fig.3.10. Fermenter with mechanical aeration system for sterile process: 1 — body; 2 — steam jacket; 3 — bubbler; 4 — agitator; 5 — bumper; 6 — electric drive; 7 — loading hatch.

The work of the fermentation department in a biotechnological enterprise, as a rule, is carried out as follows. First, the selected culture is sown in the smallest fermenter (working volume of 1 - 10 liters) from the flask, in which the strain selected for industrial cultivation is located in the form of a pure culture, i.e. without the presence of foreign microorganisms. Further, after increasing the biomass, microorganisms in the form of a suspension are introduced into the next by volume fermenter, for example, with a volume of 100 liters, and so on up to a fermenter with a working volume of 50 m^3. All these fermenters are called pure culture apparatuses, since they should not contain foreign microflora, but only microorganisms of the strain selected for industrial cultivation. From the fermenter of a pure culture with a working volume of 50 m^3 a suspension of microorganisms (yeast) is sent to the main apparatus for growing microorganisms - a fermenter with a working volume of 400 m^3. In this large fermenter, as in other fermenters, along with a pure culture in the form of a selective strain, sources of nitrogen, phosphorus, potassium and others necessary for the nutrition of the cells of microorganisms, substances, including trace elements, such as iron, are supplied.

At the initial stage of industrial production of oil-oxidizing microorganisms, as well as in later years, the yeast strain used and the nutrient medium for its cultivation are in a certain sense the secret of production (KNOW - HOW). In this regard, the information provided, including on nutrient media, is in most cases approximate.

For example, for the cultivation of yeast on paraffin oil, the following composition of the nutrient medium (kg) can be used:

H – oil paraffins13.0;

Superphosphate (or phosphoric acid)3.0;

Ammonia water4.5;

Potassium chloride0,6;

Magnesium sulfate0,3;

Water (circulating) up to 1000.

When growing yeast on such a nutrient medium, it is possible to yield bimass up to 90 - 98% of the amount of paraffin mass used in this case, provided that there is no limit on oxygen. One of the main technological characteristics of the process - the yield of biomass depends not only on the composition of the nutrient medium, but also on other reasons, including the perfection of the design of the fermenter, which provides the necessary conditions for heat and mass transfer in the cultivation of microorganisms. An increase in biomass yield can be achieved using various new technological techniques that contribute to the improvement of the technology for obtaining biomass of oil-oxidizing microorganisms.

When obtaining yeast biomass in industrial conditions, fermenters with mechanical aerators made in the form of turbine agitators were used and are still partially used today. Such aerators make it possible to effectively mix the environment in which microorganisms are grown, as well as to suck in air from the environment, which is a source of oxygen, a necessary component for growing microorganisms in aerobic conditions.

The fermentation stage is central among the stages of industrial production, representing a set of sequential operations from the introduction of inoculata into a pre-prepared and thermostated medium to the completion of the processes of growth, biosynthesis or biotransformation.

Since in industrial biotechnology there are 2 types of processes - the accumulation of biomass and the accumulation of valuable substances that arise during the growth and subsequent development of culture, the nature of the construction of production over time also changes. Unicellular biomass is grown in a continuous way in chemostat type apparatuses, and all the processes of the second group are carried out periodically, when all the necessary phases of cell development and biosynthesis occur in the same apparatus in the production cycle. The processes of the two types under consideration differ in the requirements for the degree of asepsis, which is due to their volumes. Therefore, in the production of protein substances, a sufficiently high, but not 100% degree of asepsis is limited, providing the latter with the selection of a cultivation regime suitable for the producer, but unfavorable for possible foreign strains.

The technological design of the processes of industrial biotechnology is largely determined by the ratio of the producer microorganism to oxygen. When using aerobic cultures, the fermentation equipment and the norms of the technological regime are selected in such a way that mass transfer (the transfer of oxygen from the gas to the liquid phase) ensures the supply of oxygen to the cells in quantities necessary and optimal for this culture.

The industrial use of facultative anaerobes does not pose the task of absolutely eliminating oxygen from the environment, so processes of this type (fermentation) are technologically simpler than aerobic ones. In the initial phase of these processes, it is only necessary to remove oxygen from the gas phase above the culture fluid, which can be achieved by introducing an inert gas or simply displacing the air with carbon dioxide released by cells during metabolism.

The technological design of strictly anaerobic processes is more complicated than for fermentation processes, since in this case it is necessary to completely

exclude the possibility of oxygen entering the gas, and from there into the liquid medium.

Issues of thermostating of the fermentation process (supply or removal of heat during fermentation) are very acute in a number of biotechnology industries. Under aerobic conditions, microbiological synthesis proceeds with significant heat generation, which causes the need to remove heat from large-volume devices (hundreds and thousands of cubic meters). Technological requirements for the heat dissipation rate are very stringent due to the narrow temperature optimum of culture growth. The most acceptable method of heat dissipation in practice - cooling with water through coils, jackets, and other devices - is complicated by a small temperature difference between the contents of the bioreactor (32-34 ° C for Candida yeast) and cooling water (20 ° C), the temperature of which in the hot season is even higher. Therefore, a developed gas exchange surface is created in the reactor, the speed of movement of liquids increases, etc.

The use of these fermenters with a working volume of 400^{m3} allows you to get up to 30 - 45 tons of yeast biomass per day. The performance of the fermenter depends on many reasons, including the quality of the paraffins used, the added special biostimulants and other substances necessary for conducting an intensive regime of growing microorganisms, etc.

From the fermenter, a suspension of microorganisms (yeast) with a biomass concentration of approximately 1.2 - 1.8% of absolutely dry substances (DIA) is sent for thickening by two-stage separation. After separation, the concentration of yeast biomass in the suspension increases to about 7 - 10% DIA, and when using certain technological techniques, for example, preheating the yeast suspension before separation to a temperature of 70 - 90^0C, the concentration value rises to 12 - 14% ACB. After two-stage separation, the yeast suspension is fed to a vacuum evaporation unit in which the liquid phase evaporates and, accordingly, further

concentration of the solid phase to 16 – 20% DIA. The final stage of biomass dehydration is drying, after which the dried biomass contains no more than 10% moisture. The resulting biomass with such moisture can be used as a biological preparation for soil neutralization, including from petroleum products.

The technologies described above, associated with the introduction into contaminated soil, along with undoubted advantages, have significant disadvantages. The main disadvantages of such technologies are that when microorganisms are introduced into the soil, a significant part of them dies in the first days of their stay in contaminated soil.

A more effective technique in some cases is the creation of favorable living conditions for indigenous microorganisms. This leads to an increase in the number of microorganisms capable of oxidizing petroleum products. Such technologies of soil neutralization have recently become somewhat widespread. Further experience of their use will give a more objective assessment of their effectiveness.

In general, assessing the experience of using biotechnological methods of soil cultivation, it should be noted that in emergency situations it is not effective, since the rate of oxidation of petroleum hydrocarbons is quite slow. Under these conditions, mechanical and physicochemical methods of soil and soil purification are more suitable. One of the most effective ways to clean soils and soils in emergencyconditions is flotation.

3.5. Solid-phase fermentation in wastewater sludge treatment technologies

Fora variety of precipitate treatment methods, solid-wool fermentation in the form of composting is simple and affordable. It is well known that the solid-phase fermentation process taking place in this case depends to a large extent on the composition and properties of the sewage sludge.

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.

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

Table 3.6 gives the characteristics of the composition of some types of precipitation.

Table 3.6. Nutrient content in different types of sludge at wastewater treatment plants

Type of sediment	Nitrogen, %	Phosphorus,% P_2The_5	Potassium, % K_2O
Primary	2,4 – 2,9	1,1 – 1,6	-
Precipitate condensed on the filter	2,9	2,8	
Activated sludge	3,0 – 5,6	2,8-7	0,56

Precipitate after fermentation, mixed	1,8 – 5,8	1,2-3,3	0,14 – 0,4

The presence of heavy metals in sediments makes it difficult to use them as fertilizers. Heavy metals can not only cause intoxication of bacteria in the process of sediment stabilization, but also have a toxic effect.

In agriculture, a common method of recycling various wastes is their natural use as a fertilizer, for example, to form the soil, restore its structure on waste lands, increase the content of nutrients in the ground. The use of sewage sludge as a fertilizer causes the need for stricter compliance with sanitary standards, control of the composition of both the applied sediments and the composition of the soil. In order to ensure the safety of the use of sewage sludge as a fertilizer when it is applied to the soil, the regulations in force, for example, in the EEC countries, do not allow cattle to graze on pastures for 6 weeks from the date of introduction of sewage sludge into the grass stands. The use of sediment in most cases significantly increases the yield of grass, legumes, corn, cabbage, cereals. Wastewater and the sediments generated during its treatment can be used in forestry and forest park management, and also taking into account strict control over the presence of toxic ingredients in them.

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

As practical directions confirming the effective use of sewage sludge as a fertilizer, consider the use of excess activated sludge (microbial biomass) of microbiological industries, in particular plants for the production of protein-vitamin concentrates (BVK) and sediments formed during the treatment of manure effluents.

At the BVK plants at the stage of wastewater treatment, the main amount of waste is generated in the form of excess activated sludge (microbial biomass) in the amount of 6-9% of the volume of BVK production.

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

Analysis of the chemical compositionof dry micro-organic biomass is given in Table. 3.7.

Table 3. 7. Chemical composition of dry microbial biomass

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

Phosphorus	2,0-3,0

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

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

In addition, the most important stage in the preparation of excess activated sludge for use as a fertilizer is its preliminary thickening. Experimental studies with activated sludge selected from various biological treatment plants have shown that the thickening of excess activated sludge is influenced by many factors, including the mode of bio-oxidation of wastewater. At the same time, the production of well-settled flakes of activated sludge formed due to the flocculation of microorganisms is not always a controlled stage. The latter leads to the fact that in some cases the flakes of activated sludge are poorly separated from water or are not separated at all (swollen active sludge).

To separate activated sludge from water, sedimentation processes are used in most cases, and further thickening is carried out by repeated settling of sludge or its flotation. The method of flotation thickening of activated sludge is very promising. The most widely used method of pressure flotation is the so-called DAF systems. The method of pressure flotation is based on the fact that air dissolved under pressure in water, released in large ring or rectangular containers containing suspended sludge, forms small bubbles that attach to silt particles and rise to the

surface with them. The resulting foam layer of sflotirated activated sludge is mechanically removed through the sludge collector. At the same time, it is possible to obtain a sludge concentration of up to 3 - 5% ACB. With the simultaneous use of coagulants, the effect of lifting larger flakes to the surface and, accordingly, a higher thickening effect is ensured.

In the field of flotation condensation, a large number of works have recently appeared devoted to both the theoretical substantiation of the process and the practical implementation of this method.

The degree of thickening of excess activated sludge achieved after flotation does not allow, due to the high humidity of the obtained microbial biomass, to effectively dispose of it. In this regard, the suspension of excess activated sludge is centrifuged or filtered. Technological tests of thickening of excess activated sludge, in particular at the Novopolotsk plant of BVK (Belarus), according to the flotation - centrifugation scheme, showed that the resulting condensed product contained up to 8 - 10% of DIA microbial biomass. This made it possible in the future to obtain microbial biomass with moisture (8-10%), *which* could be transported and mixed with any filler, for example, peat, and to obtain a mixture for composting.

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

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

The use of activated sludge biomass obtained with a growing time of 5 to 15 hours makes it possible to drastically reduce the content of heavy metals in activated sludge and more effectively use the adsorption properties of activated sludge during its thickening. In this case, active sludge obtained during wastewater treatment of any industries can be used.

The process of thickening the resulting mixture of active sludge - peat is carried out by settling. The interaction of peat particles with microorganisms of activated sludge leads to the formation of sufficiently large aggregates that positively affect the process of thickening the mixture of peat - active sludge. In this case, it is most preferable to use in this mixture as components of upper and lowland peat in a ratio of 1: 1 to 1: 5, respectively. With this choice of the ratio of upper and lowland peat, the best aggregation of peat particles with activated sludge microorganisms is observed.

Of particular importance is the content of heavy metals in the soil. Regulation of the values of the concentration of ash elements, including heavy metals, in the proposed method makes it possible to maintain the MPC of heavy metals in the soil established by the Ministry of Health of the Russian Federation, while when applying fertilizer obtained by a known method to the soil, there is no such regulation of ash elements and, therefore, not in all cases the MPC in the soil is maintained.

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

Experience options:

1. Control (without fertilizers)

2. N_{146}* P_{140}* K_{277}*

3 . MB** 300 kg/ga

4 . MB 600 kg/ga

5. МБ 300 кг + P_{33} K_{228}

6. Straw 5 t / ha

7. Soloma 5 т/га + N_{146} P_{140} K_{277}

8 . Soloma 5 t/ga + MB 300 kg/ga

9 . Soloma 5 t/ga + MB 600 kg/ga

10. Straw 5 t/ha + MB 300 kg + P_{22} K_{226}

11. Transition peat 58 t/ha (19 tons of dry matter) + N_{146} P_{140} K_{277}

12. Peat-silt compost 50 t/ha (19 tons of dry matter) + K_{223}.

* - the value of the lower index - the amount of this element in kg per 1 ha;

** - MB – microbial biomass of activated sludge.

Potato yield and starch content in tubers are given in Table 24.

From those given in Table. Figure 3.8 shows that peat-silt compost at its lower cost may have a greater effect on crop accumulation.

Economic studies have shown that 1 ton of wet microbial biomass when used as a fertilizer can provide additional income by obtaining an increase in yield.

Table 3.8. Yield and starch content in potato tubers in the control experiment and with the addition of various fertilizers

№ p/n	Experience option	Average yield, c/ha	Increase		Starch content,%
			c/ga	%	
1	Control	62,3	-	-	17,09
2	N_{146} P_{140} K^*_{277}	103,6	40,4	63,9	17,90
3	MB ** 300 kg/ga	87,9	24,7	39,1	16,42
4	MB 600 kg/ga	96,2	33,0	52,2	18,05
5	МБ 300 кг + P_{33} K_{228}	109,9	46,7	73,9	18,70
6	Straw 5 t / ha	79,6	16,4	25,9	19,51
7	Soloma 5 т/га + N_{146} P_{140} K_{277}	115,5	52,5	83,1	14,00
8	Soloma 5 t/ga + MB 300 kg/ga	89,2	26,0	41,1	12,31
9	Straw 5 t/ha + MB 600 kg	98,7	35,5	56,2	17,09
10	Straw 5 t/ha + MB 300 kg + P_{22} K_{226}	80,3	17,1	27,1	17,76
11	Transitional peat 58 t/ga+ N_{146} P_{140} K_{277}	101,9	38,9	61,2	17,76
12	Torfo -ilovă compost 50 t/ga + K_{223}	97,2	34,0	58,3	14,80

*- the value of the lower index - the amount of this element in kg per 1 ha.

** MB - microbial biomass.

Thus, as a result of the tests, the experimental data obtained showed that the microbial biomass produced by BVK is a valuable component of fertilizers for various crops.

When obtaining peat-silt fertilizers in large volumes, it is necessary to use special equipment in compliance with certain technological requirements.

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 in fertilizer consists in rapid development under favorable conditions first of mesophilic microorganisms (t_{min} = 10 - I5 ° C, t_{max} = 35 - 47 ° C, t_{opt} = 30 - 45 ° C), and then thermophilic microorganisms (t_{min} = 40 - 45 ° C, t_{max} = 80 ° C, t_{opt} = 55 - 75 °C). When composting under conditions of forced aeration, it is possible to create conditions for the predominant development of actinomycetes 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 - 8 months.

However, the solid-phase fermentation process can be accelerated by storing the shoulders under a canopy or indoors, and by stirring the compostable mass as the sludge process is attenuated by an enhanced aeration device. Selective cultures of microorganisms can be used to intensify the process. For example, a culture of thermophilic actinomycetes is grown in the laboratory on the Kosmachev environment: 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, the pH of the medium is 7.2 - 7.5 and is introduced into the embedded burt, where: the height of the shoulder is 2.5 - 3.0 m, the width is at least 4 and, the length is arbitrary, the minimum weight of the shoulder is 200 tons.

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%;

correlation 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°.

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

Preparation of peat-silt compost in the field can be carried out according to the following technology (Fig. 3.11). Dehydrated precipitate by a screw or screw pump 2 from the map is piped along with ammonia water to the mixer 6. The powdered peat crumb with a layer of mineral additives is fed into the mixer 6.

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

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

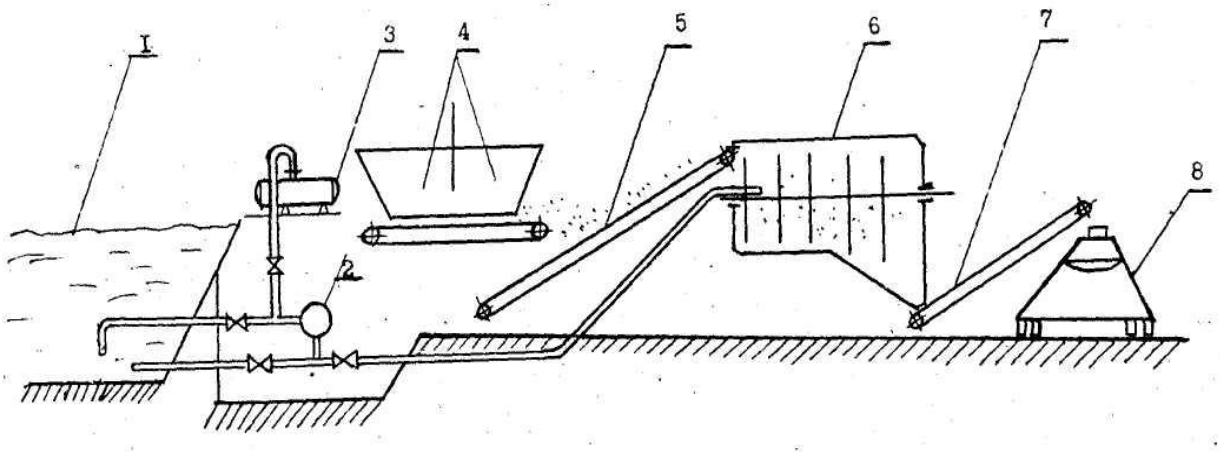


Fig. 3.11.. Technological scheme of fertilizer preparation using silt from maps

For peat-manure composts, both top and lowland peat are used. Depending on the degree of decomposition and humidity of peat, certain ratios between peat and manure are established. Slaughterhouse waste, manure and feces are mixed with peat, which absorbs ammonia well. The liquid component is added by filling furrows 15 - 20 cm deep at a distance of 1 m from each other. The humidity of the compost should be 60 – 70%. Compost is laid in piles with a width of 8 -10 m and a height of 1.5 - 2 m. Components are laid in layers of 5 - 10 cm. The acidity of peat is reduced by the addition of lime. After 2-3 weeks, the first mixing with an excavator is carried out and after about 2 more weeks - the second mixing. At the beginning of the process, the temperature in the shoulders rises to 60 - 65 ° C, and then drops to 25 -30 ° C. The fermentation process lasts about 2 months.

3.6. Treatment of sewage sludge with pre-fermentation in methane tanks

The technology of fermentation of sewage sludge in methane encases has become widespread in the practice of wastewater sludge treatment. The technological scheme of sediment treatmentpresented in Fig. 3.12 is quite often used in practice. This technological scheme (Fig. 3.12) includes a receiving tank 1, a methane tank 2, an intermediate tank 3, a gas tank 4, a settling tank 5, a chamber

6, a sand trap 7, a sedimentation compactor 8, a filter press 9, reagent treatment unit 10, dewatered sludge collector 11.

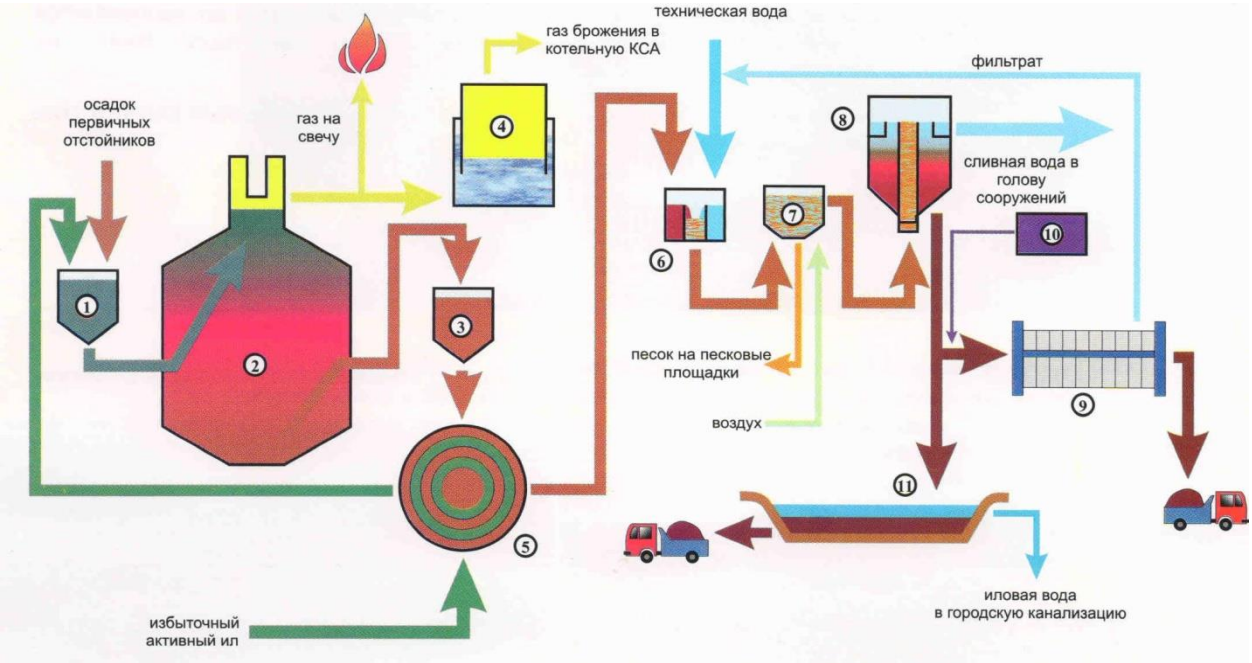


Fig. 3.12. Technological scheme of wastewater sludge treatment

Of particular interest is the stage of sediment fermentation, which is carried out in methane tanks of various designs. In early practice, methane tanks were often used, which are round tanks buried in the ground, for example, with a diameter of 24 m of monolithic reinforced concrete with a rigid spherical coating and a conical bottom. Each such methane tank is equipped with a propeller agitator, a steam injector and an emergencyeliva pen system (Figure 3.13).

Fig. 3.13. Methane tanks in the form of reinforced concrete tanks buried in the ground.

In the latest practice, round methane tanks are more often used in the form of ground tanks, for example, with a diameter of 18 m with a conical monolithic bottom, a flat ceiling and walls ofprefabricated, pre-stressed reinforced concrete (Fig. 3.14). Each methane tank is equipped with an injector and an emergency overflow system. To mix the sediment in the methane tanks, propeller agitators are installed or mixing is carried out using gas lifts.

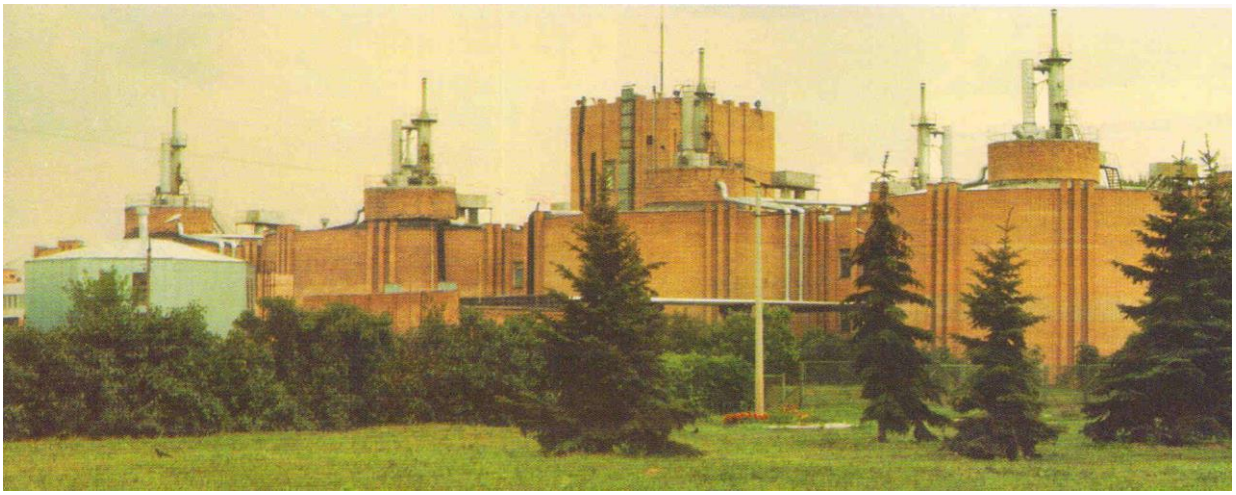


Fig. 3.14. Methane tanks in the form of above-ground tanks

Methane tanks work, as a rule, according to a flow-through scheme. They support the thermophilic fermentation process at a temperature of +50 ... + 53 ° C. The sediment is heated by sharp steam using a steam jet injector. The mixture of sediment and excess activated sludge loaded into the methane tanks has a humidity of about 95... 96% and ash content 36... 38%, unloaded sediment - 97.3% and 44%, respectively. The dose of loading according to the actual humidity is 12-16%. Further, the fermented sediment passes the stages of treatment according to the above scheme (Fig. 3.12). At the same time, the fermented precipitate is first washed with subsequent compaction. Washing is carried out in special tanks by mixing it with industrial water in a ratio of 1: 3. To intensify the washing process, the mixture is bubbled with air. Approximately half of the sediment entering the washing and sealing facilities is subjected to preliminary filtering on the washing and sealing facilities. mechanized grilles with gaps of 8 mm.

The detained garbage is taken to a special training ground. The washed fermented sludge is distributed over radial sludge compactors of the gravitational type with a diameter of 33 m, similar in design to sedimentation tanks. The duration of settling is within 15-20 hours.

Compacted washed fermented sludge with a humidity of 95-96.5% is sent to the mechanical dewatering department and to the sludge sites. Drain water is in the head of the structures. Dewatering of the sludge is carried out in two ways - mechanical on thefir presses (Fig. 3.15) and drying in natural conditions on silt sites.

Fig. 3.15. General view of the filter press.

Previously, the precipitate is subjected to reagent conditioning with flocculants. Optimal flocculant flow rate and pressing mode is provided by a computer control system according to the parameters set by the operator. The possibility of sludge dehydration ranges from 69-72%.

The gas released during fermentation is diverted to the gas network for subsequent combustion, usually in the local boiler house. To maintain the required gas pressure in the network there are gas tanks with a capacity of about 2... 3 thousand^{m3} each. The yield of biogas from 1 m3 of the loaded mixture is 5... 6 m^3.

3.8. Installations for microbiological air purification

The problem of combating air pollution in the context of increasing technological activity is becoming increasingly acute, including in the areas where biological treatment facilities are located. In the air of large industrial cities, including in the zone of urban treatment facilities, contains a huge amount of

harmful substances. At the same time, the concentration of many toxicants exceeds the permissible levels. In this regard, treatment plants are installed at treatment plants to purify the resulting waste gas flows.

It should also be noted that sewage treatment plants, as a rule, are located in industrial zones of cities. At the same time, it should be noted that enterprises of various industries, waste disposal plants, etc. also contribute to air pollution.

Modern technologies for air purification include, as a rule, the use of physicochemical methods, which are not always effective and very expensive.

Microbiological methods for the removal of household and industrial contaminants are intensively used in the field of water and soil purification, and in the field of atmospheric protection began to be used quite recently and are considered the most promising. One of the main advantages of biological methods is their low, compared to other methods, cost. This applies to both capital investment and operating costs. In addition, biological methods are distinguished by simplicity and reliability. In these cases, there is no need for increased pressures and temperatures.

Microbiological methods of air purification from harmful impurities of domestic and industrial origin using biofiltration have been developing noticeably in recent years. These methods are based on the natural ability of microorganisms that form a biologically active film on the surface of a solid porous carrier to extract impurities of organic and inorganic volatile substances, including organic substances of artificial origin, from the air passing through this carrier, to oxidize and decompose them to water and carbon dioxide.

A real revolution in the field of microbiological air filtration technologies occurred in the early eighties of the last century, when the idea of using a highly active microbial filter was born, consisting of a durable housing with shelves with a biologically active catalyst placed in it, on the surface of which a biofilm is formed, irrigated with a nutrient solution circulating inside the biofilter housing.

Biochemical purification methods are known to be based on the ability of microorganisms to break down and convert various compounds such as aliphatic, aromatic, heterocyclic, acyclic and other various compounds without forming dangerous by-products. It is known thatthe microorgans of the snake utilize ammonia, oxidize sulfur dioxide, hydrogen sulfide and dimethyl sulfoxide. The resulting sulfates are utilized by other microbes.

The vast majority of toxic air pollutants can be destroyed by monocultures of microorganisms, but it is more effective to use mixed cultures that have greater catalytic potential. To destroy hard-to-recycle compounds, in some cases it is advisable to adapt microorganisms to such substrates and only after that introduce them into the working body of existing installations.

The decomposition of substances occurs under the action of enzymes produced by microorganisms in the environment of purified gases. With frequent changes in the composition of the gas, microorganisms do not have time to adapt to the production of new enzymes, and the degree of destruction of harmful impurities becomes incomplete. In this regard, biochemical systems are most suitable for the purification of gases of constant composition. At the same time, it is necessary to strictly monitor the temperature, humidity and acidity of the environment.

The essence of the cleaning process can be described as follows. Microorganisms in the process of their vital activity absorb and destroy the substances contained in the gaseous medium, as a result of which there is an increase in their mass. In this case, the efficiency of purification is largely determined by the diffusion from the gas phase into the biological film and the uniform distribution of gas in the nozzle layer. Such filters are used, for example, to deodorize the air. In this case, the gas stream to be cleaned is filtered under direct flow conditions with an irrigated liquid containing nutrients. After the filter, the liquid enters the settling tanks and is then re-fed for irrigation.

It should be noted that biofilters are sometimes used to purify waste gas streams from ammonia, phenol, cresol, formaldehyde, organic solvents of paint and drying lines, hydrogen sulfide, methyl mercaptan and other organosulfur compounds.

The *disadvantages* of biochemical methods include:

1. low speed of biochemical reactions, which increases the size of the equipment;
2. high selectivity of strains of microorganisms, which complicates the processing of multicomponent mixtures;
3. labor intensity of processing mixtures of variable composition.

For biological air purification, three types of installations are used: *biofilters, bioscrubbers* and *bioreactors with a washable layer*. Table 3.9 gives a classification of biological air purification plants (according to I. B. Utkin et al., 1989).

Table 3.9. Classification of biological air purification plants (according to I. B. Utkin and others)

Installation Type	Working fluid	Water mode	The main stage of removing impurities from the air	Source of mineral salts
Trickling filter	Filter layer – microbiological cells immobilized on natural carriers	There is no water circulation	1. Desorption by the material of the filter layer 2. Destruction by microbial cells	Filter layer material

Bioscrubber	Water, active sludge	Water circulation	1. Absorption in the absorber with water 2. Destruction in the aeration tank with activated sludge	Mineral salts are introduced into water
Bioreactor with a washable layer	Microbial cells immobilized on artificial carriers	Water circulation	1. Diffusion through the aqueous film to microorganisms 2. Destruction in the biological layer	Mineral salts are introduced into water

The conceptual scheme of the installation for biological air purification was proposed in 1940 by Pruss. The first biofilter in Europe was built in Germany relatively recently - in 1980 Three years later, in 1984, about 240 installations were functioning and were in the process of launching only in germany. The main element of a biofilter for air purification, like a water-purified biofilter, is a filter layer that sorbs toxic substances from the air. Further, these substances diffuse in dissolved form to microbial cells, are included in them and are subject to destruction.

Purification of polluted air using modern biofilters, the scheme of one of which is shown in Fig. 3.16, allows to achieve a high degree of purification up to 85-

97%, for example, when neutralizing exhaust gas-air emissions from organochlorine substances.

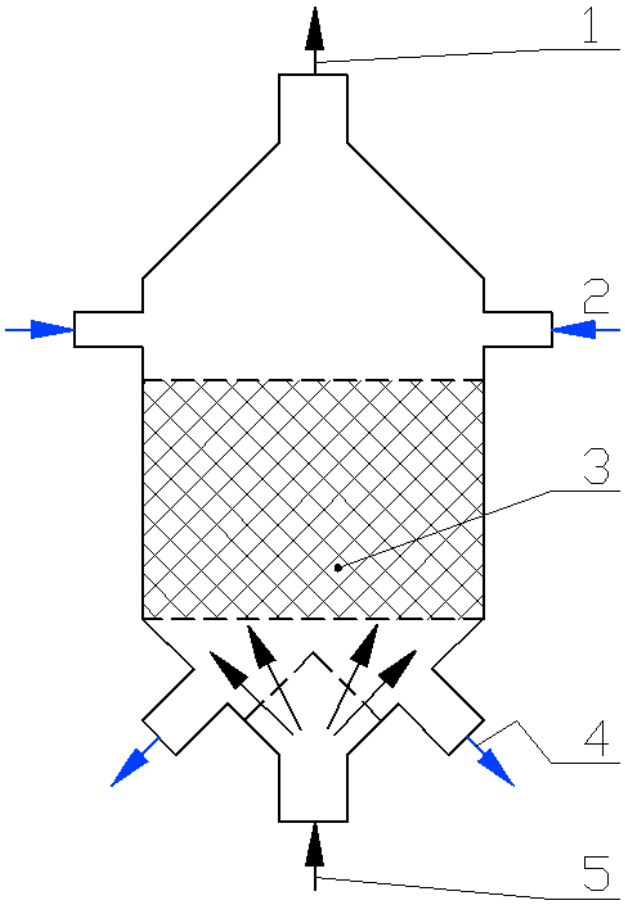


Fig. 3.16. Diagram of a biofilter for cleaning polluted air

1- purified gas stream; 2 – irrigating liquid; 3 – filter loading; 4 – dirty (spent) liquid; 5- contaminated gas stream.

It should be noted that the described biotechnologicalmethods of air purification are at different stages of development, but they are being improved and are becoming more widely used. At the same time, the basis for their improvement is the development of the basics of microbiology and biotechnology.

In this regard, achievements in these areas will undoubtedly lead to progress in thosechnologies of air purification using microorganisms.

Test questions for section 3

1. What elements are called biogenic?
2. What are the main features of the biological method of extracting phosphorus from wastewater?
3. What is the essence of the processes of nitrification and denitrification in the technology of biological wastewater treatment?
4. What types of flotation apparatus are used to isolate microorganisms?
5. What is the role of protozoa in the processes of biological water purification?
6. What is the essence of the microbiological technology of soil purification?
7. What are the advantages and disadvantages of microbiological purification of contaminated gases?
8. What is the role of extracellular polysaccharides in the cultivation of activated sludge microorganisms?
9. What are the main features of anaerobic treatment of sewage sludge?
10. What are the main problems of sediment disposalfrom wastewater?

4. Basics of microbiology and technology of biological wastewater treatment

4.1. General information on microbiology of wastewater treatment

The method of biological treatment is based on the ability of some types of microorganisms under certain conditions to use pollutants as their food. Many microorganisms that make up the active sludge of a biological treatment plant, being in the wastewater, absorb pollutants into the cell, where they are under the influence of enzymes . undergo biochemical transformations. In this case, organic and some types of inorganic pollutants are used by the bacterial cell in two ways:

Biological oxidation in the presence of oxygen to harmless products of carbon dioxide and water: Organic matter + O2 (in the presence of enzymes) = > CO2 + H2O + Q The energy released is used by the cell to ensure its vital activity (movement, respiration, reproduction, etc.).

Synthesis of a new cell (reproduction):Organic matter + N + P + Q (in the presence of enzymes) = > NEW CELLThe intensity and depth of the processes depends on the qualitative composition of the activated sludge, the diversity of

forms and species of microorganisms, their ability to adapt (adapt) to the specific composition of pollutants of the wastewater and the conditions of the process.

Conditions of the process

the presence in the wastewater liquid and the optimal ratio of organic carbon, biogenic elements (nitrogen and phosphorus) and trace elements (sulfur, manganese, iron, cobalt, etc.);

compliance with the maximum permissible concentrations of pollutants;

absence of toxic substances for microorganisms in the wastewater liquid;

sufficient oxygen and aeration intensity;

optimal temperature regime;

load on silt by the amount of pollutants;

contact time of sludge and wastewater;

design features of structures and biological scheme of purification;

and so on.

An important factor affecting the process of biological treatment is the content of heavy metals in wastewater.

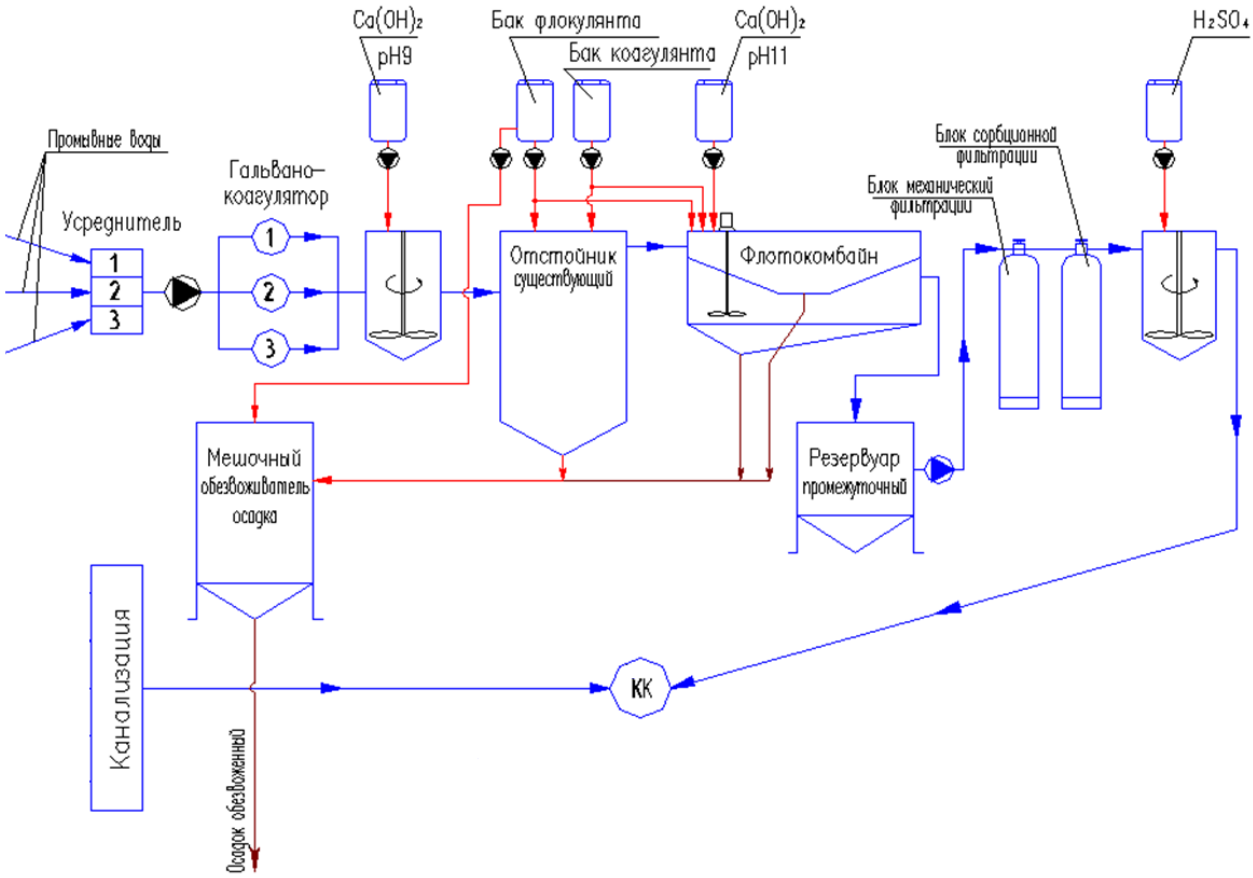
To solve these problems, various both physicochemical and biological methods of purification are used. Flotation treatment is also used in the practice of wastewater treatment of galvanic plants from ions Cu^{2+}, Zn^{2+}, Fe^{2+}, Ni^{2+}.

In the proposed method, flotation cleaning is carried out in a flotation combine, in which flotation, gravity and filtration processes are simultaneously carried out, which allows cleaning to be carried out with higher efficiency than when using each of the above methods.

Experimental testing of the efficiency of technological processes of wastewater treatment was possibleon four options.

Analysis of existing cleaning methodsand revealed the most promising ones. A total of four options for cleaning technology were considered.

Technological scheme of purification (option 1), presented in Fig. 4.1, includes the following stages: averaging of effluents (3 averagers), pH adjustment; galvanocoagulation (3 galvanocoagulators), lime treatment, settling with the addition of a coagulant and flocculant to the settling tank, flotation purification with the addition of a coagulant (aquaaurate), flocculant and lime in the form of a finely dispersed suspension to the receiving chamber and further post-treatment in 2 successively installed filters with loading in the form of a sorbent AC and coal and finishing adjustment of pH.



QC – control well

Fig. 4.1 - Flowchart for wastewater treatment (option 1)

After averaging and neutralization, the purified water is fed to galvanocoagulation, where the water is pre-purified from heavy metals and other dissolved contaminants. Then the water flows by gravity for treatment with lime milk up to a pH value of 9. A number of heavy metals have a deposition pH close to 9. At the same time, at pH values significantly greater or less than 9, these metals can go into a dissolved state. To accelerate the deposition of flakes, a coagulant and flocculant are additionally supplied to the water. After the first stage of reagent treatment, water enters a vertical sedimentation tank, where precipitated contaminants treated with reagents are precipitated.

Next, the water flows by gravity into the flotation combine, where it is treated with lime milk to a pH value of 11. At this stage, metals with a solubility point close to pH = 11 fall out of the water. To accelerate deposition, a coagulant and a flocculant are fed into the flotocombine. As a result, the second stage of reagent treatment takes place in this apparatus, as a result of which flakes of insoluble contaminants are formed, precipitating or popping up in the flotation combine.

After flotation, the purified water enters the post-treatment stage, which proceeds in mechanical and sorption filters. As a filter material in mechanical filters, the AC sorbent is used - natural aluminosilicate. In sorption filters, activated carbon and activated crushed anthracite are used as a load. Then the pH is corrected, and the purified water is discharged into the sewer.

In the process of using this scheme, it became clear that it was advisable to use it in the form of various options. The technological scheme of purification according to the second option differs from the first in that the ozonation stage is additionally present in the scheme.

This scheme (according to the second option) includes the following stages: averaging of effluents with pH adjustment, galvanocoagulation, ozonation, lime treatment, settling with the addition of coagulant and flocculant to the settling

tank, flotation purification with the addition of a coagulant (aquaaurate), flocculant and lime in the form of a finely dispersed suspension to the receiving chamber and further post-treatment in 2 successively installed filters with loading in the form of ac sorbent and coal and finishing pH adjustment.

The refinement of this wastewater treatment scheme is based on the introduction of ozonation, the mode of which for the specific amount of ozone is 1 g / m$^{of\ 3}$ effluents. The mode of two-stage reagent treatment with subsequent settling and flotation is similar to the first version of the technological scheme. Post-treatment of wastewater is sequentially carried out in a filter with an AC sorbent, and then in a filter with coal loading. The final stage of wastewater treatment is the adjustment of the pH to a neutral value.

The technological scheme of purification according to option 3 includes the following stages: averaging of effluents, lime treatment, settling with the addition of coagulant and flocculant to the settling tank, flotation cleaning with the addition of a coagulant (Aqua-Aurate), flocculant and lime in the form of a finely dispersed suspension to the receiving chamber and further post-treatment in 2 successively installed filters with loading in the form of AC sorbent and coal and finishing pH adjustment.

The purification process scheme according to option 4, in contrast to the previous option, includes an ozonation step. Thus, the composition of the technological scheme option 4 includes the following stages: averaging of effluents, ozonation, lime treatment, settling with the addition of a coagulant and flocculant to the settling tank, flotation cleaning with the addition of a coagulant (Aqua-Aurate), flocculant and lime in the form of a finely dispersed suspension to the receiving chamber and further post-treatment in 2 successively installed filters with loading in the form of ac sorbent and coal and finishing pH adjustment.

The cleaning process was simulated in the laboratory according to all four options. After the research, an analysis of the source and purified water was carried out.

The results of the analyzes in the form of diagrams are presented in Fig. 4.2-4. 9. Analyzing the results presented in the diagrams (Fig. 4.2 – 4. 9), it is recommended to use the technological scheme according to option 1.

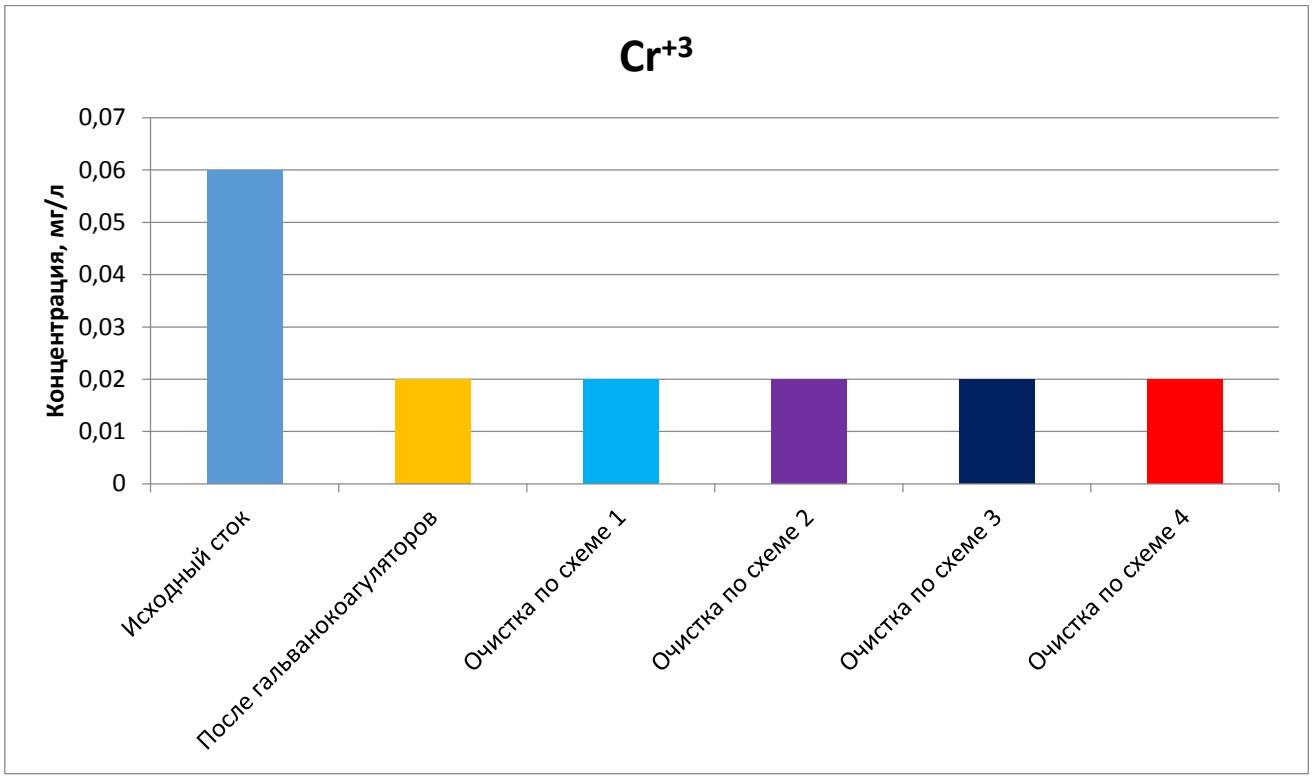


Fig. 4.2 - Experimental data on the concentration of Cr^{+3} chromium in various technological schemes of wastewater treatment

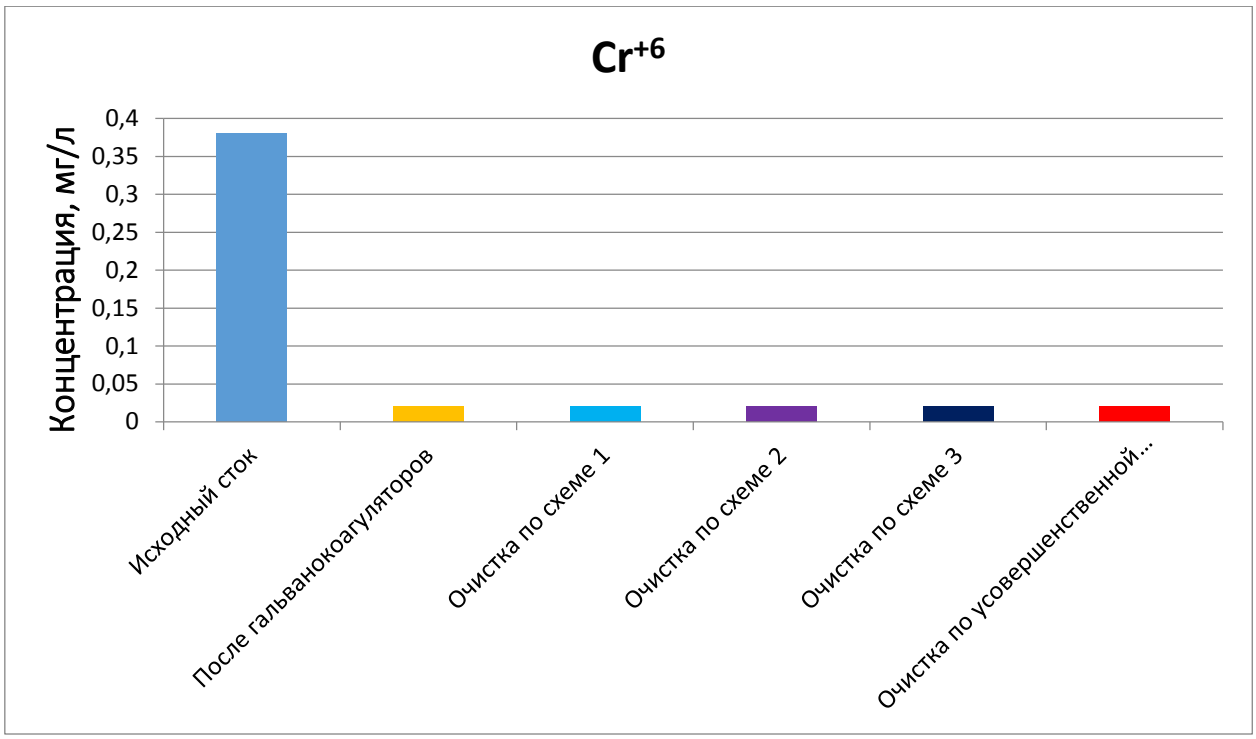


Fig. 4.3 - Experimental data on the concentration of Cr^{+6} chromium in various technological schemes of wastewater treatment

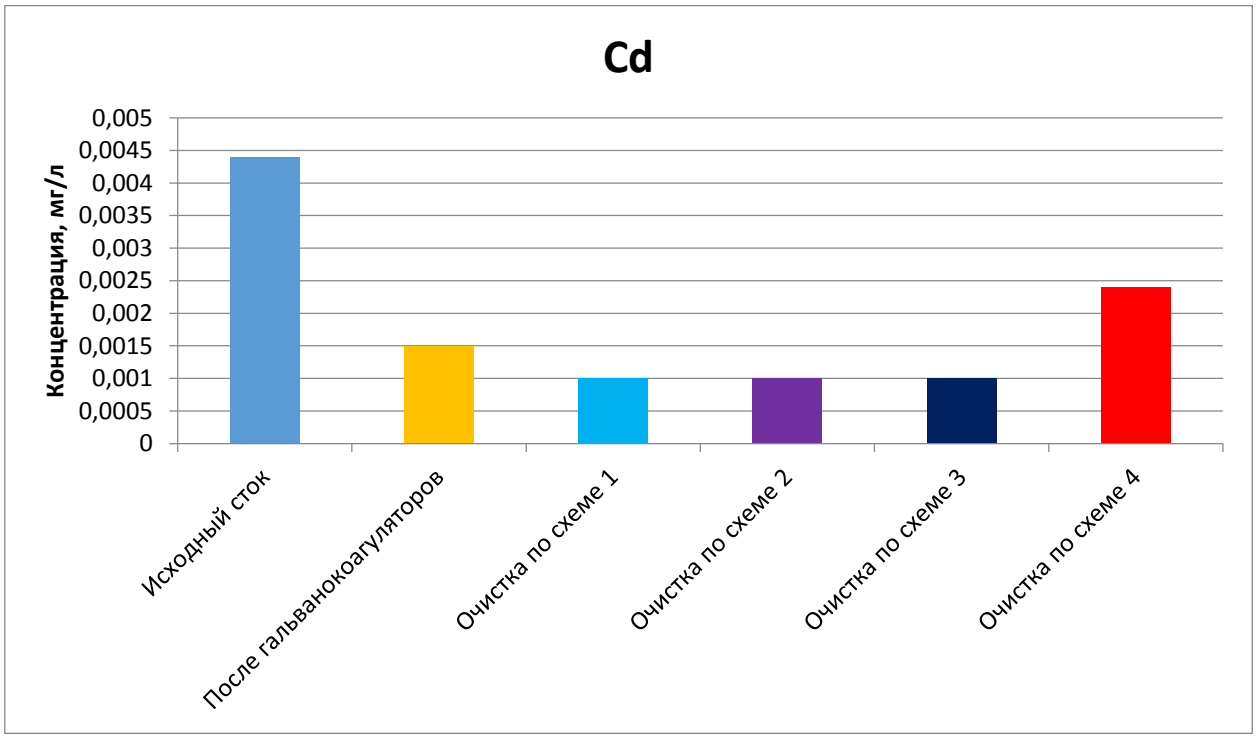


Fig. 4.4 - Experimental data on the concentration of cadmium Cd in various technological schemes of wastewater treatment

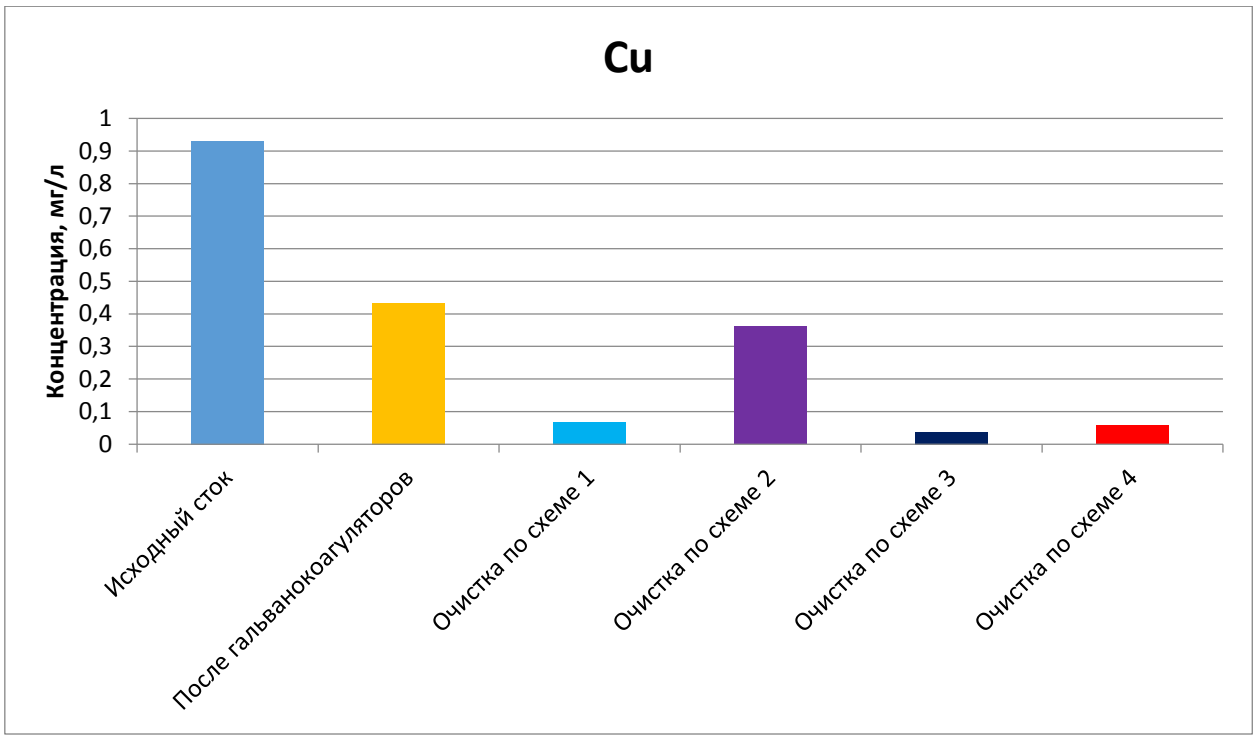


Fig. 4.5 - Experimental data on copper Cu concentration in various technological schemes of wastewater treatment

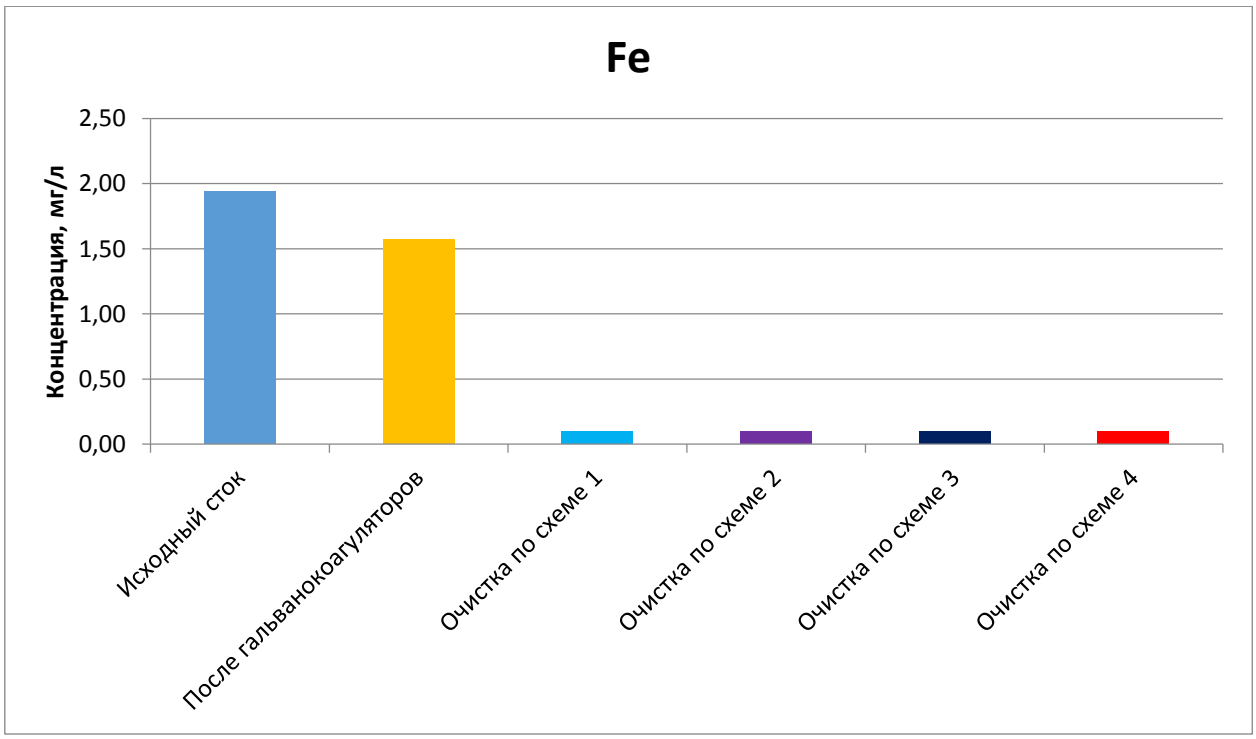


Fig. 4.6 - Experimental data on the concentration of iron Fe in various technological schemes of wastewater treatment

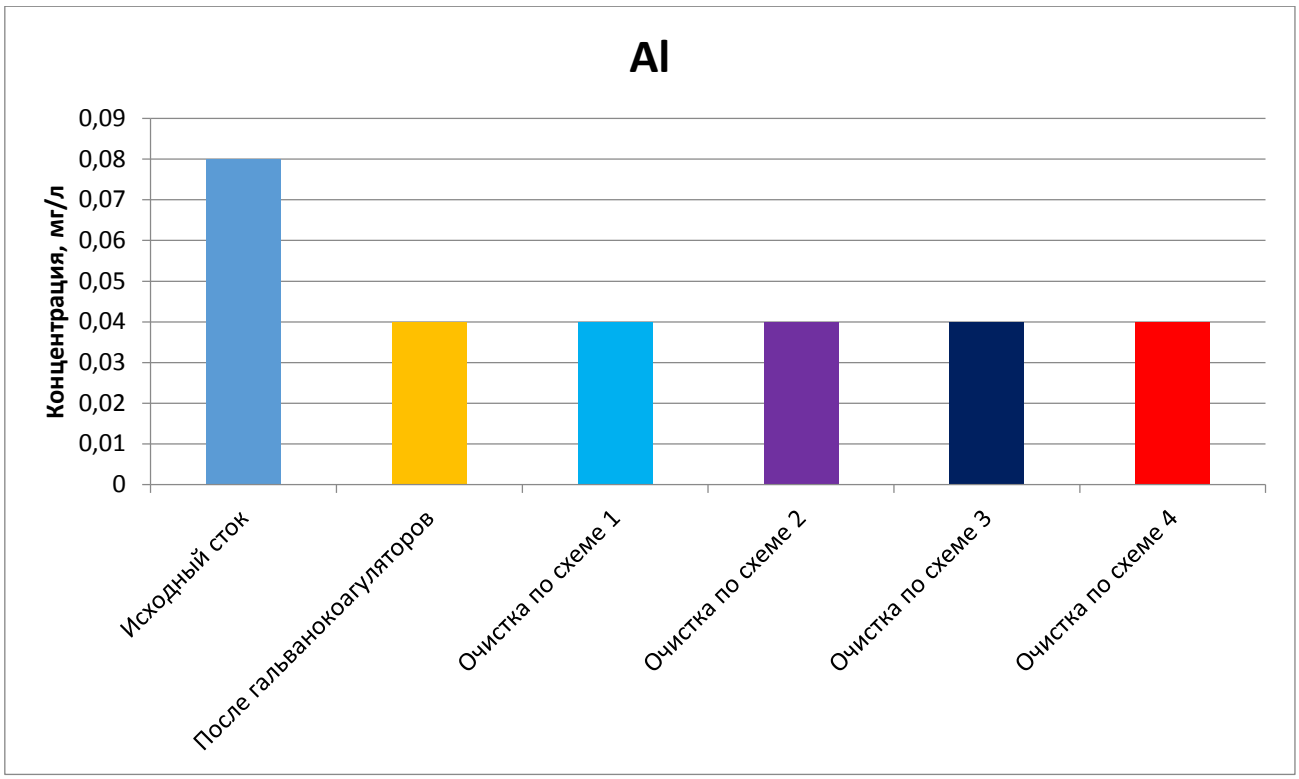


Fig. 4.7 - Experimental data on the concentration of aluminum Al in various technological schemes of wastewater treatment

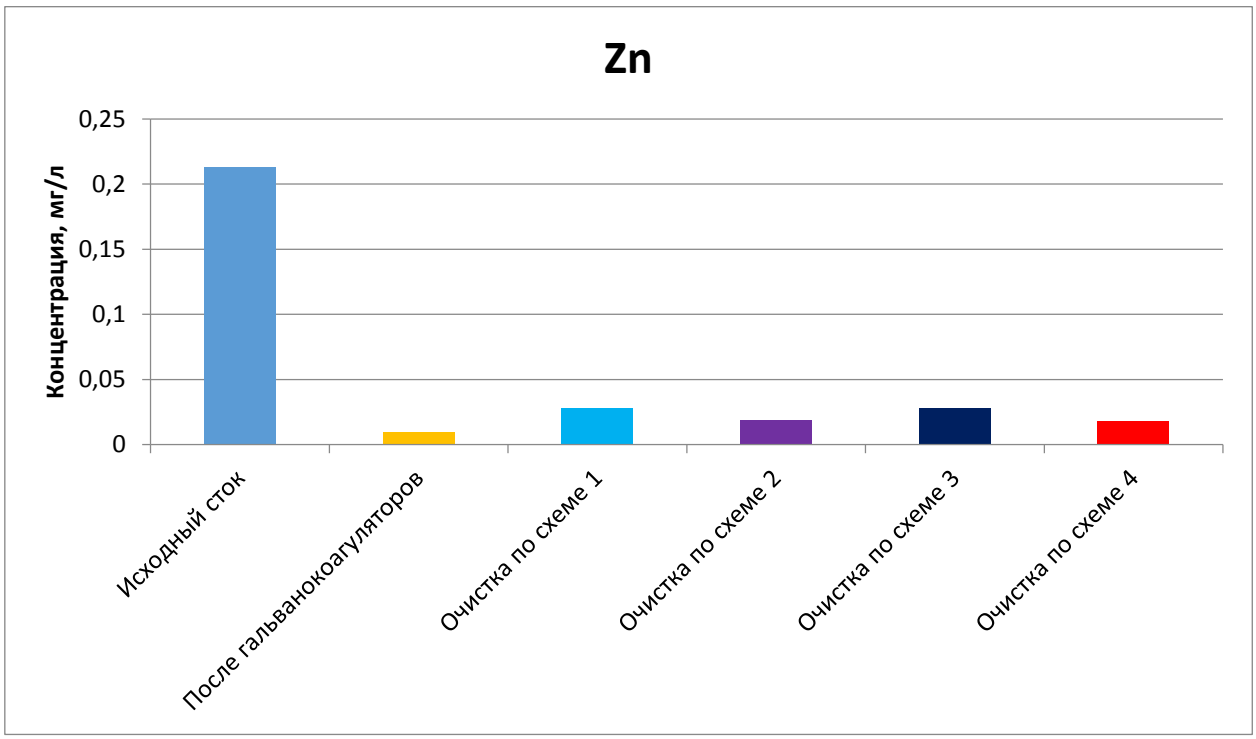


Fig. 4.8 - Experimental data on zinc Zn concentration in various technological schemes of wastewater treatment

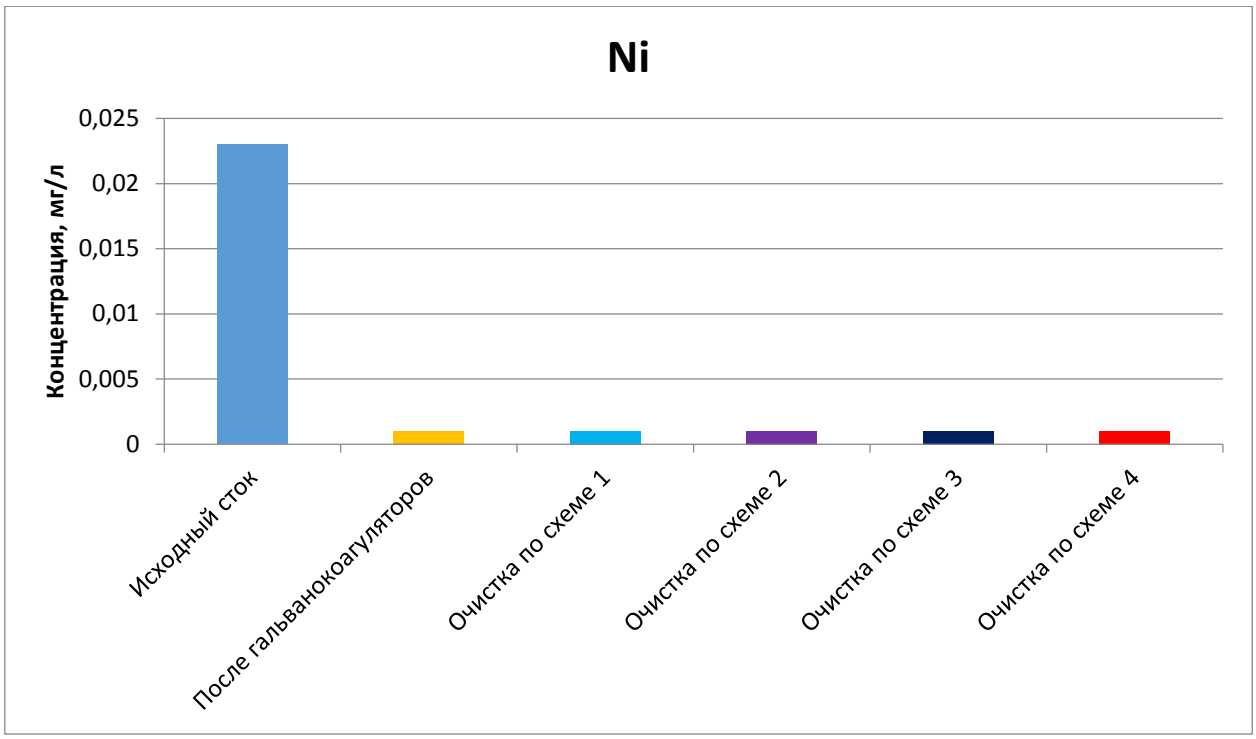


Fig. 4.9 - Experimental data on nickel Ni concentration in various technological schemes of wastewater treatment

The options considered are, of course, not universal, and therefore in each case, when choosing an option, experimental studies should be carried out, which, of course, is a costly measure. However, the results obtained in this case are a certain guarantee of success in the further practical implementation of the developed technological scheme for the treatmentof industrial wastewater at the next stage by biological means.

To intensify the processes of ion flotation, it seems expedient to consider a multi-stage model of ion flotation, which can be represented as a sequence of the following states of the system (Fig. 4.10):

- state A - colligend and collector ions and gas bubbles exist autonomously;

- state B - the formation of a sublate as a result of the interaction of the collector and the colligend;

- state C – formation of the flotation complex of the collector-gas bubble;

-state D – formation of the flotation complex ion colligendum-collector-gas bubble;

- state E - the formation of a foam layer containing colligend and collector ions and gas bubbles;

- state F - the formation of a foam containing colligende and collector ions without gas bubbles (sublate concentrate).

Mathematic description of the flotation process presented in Fig. 4.1 0 may be represented by the following system of equations (1):

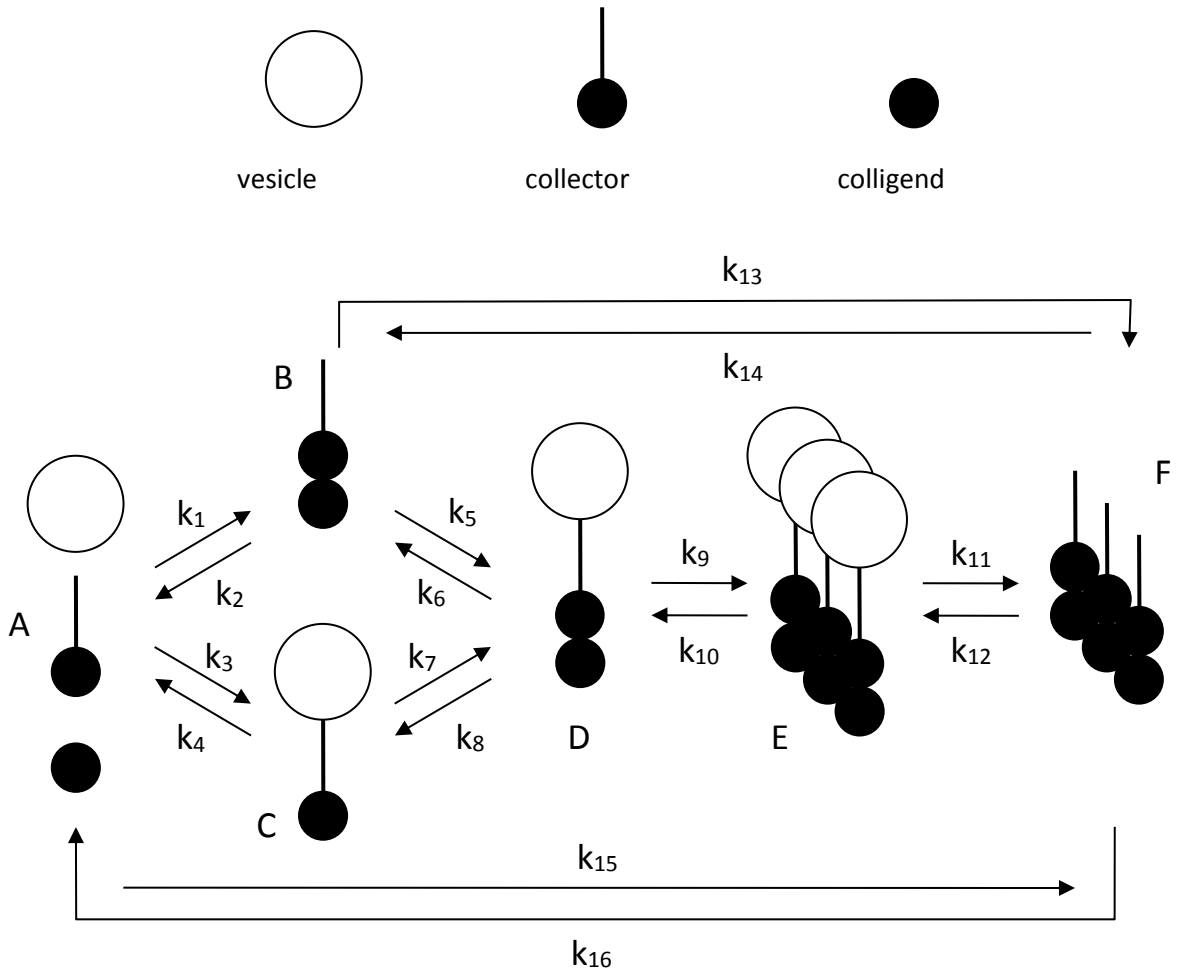


Fig. 4.1 0. Scheme of multi-stage model of ion flotation

$$\begin{cases} \frac{dC_A}{dt} = -k_1 C_A + k_2 C_B - k_3 C_A + k_4 C_C - k_{15} C_A + k_{16} C_F; \\ \frac{dC_B}{dt} = k_1 C_A - k_2 C_B - k_5 C_B + k_6 C_D - k_{13} C_B + k_{14} C_F; \\ \frac{dC_C}{dt} = k_3 C_A - k_4 C_C - k_7 C_C + k_8 C_D; \\ \frac{dC_D}{dt} = k_5 C_B - k_6 C_D + k_7 C_C - k_8 C_D - k_9 C_D + k_{10} C_E; \\ \frac{dC_E}{dt} = k_9 C_D - k_{10} C_E - k_{11} C_E + k_{12} C_F; \\ \frac{dC_F}{dt} = k_{11} C_E - k_{12} C_F + k_{13} C_B - k_{14} C_F + k_{15} C_A - k_{16} C_F. \end{cases} \quad (4.1)$$

The proposed system must satisfy at least two conditions, namely, at an initial point in time, the concentration of the colligend in the first step is equal to the initial concentration in the solution and at any given time the sum of the colligend concentrations for all stages is equal to its initial concentration.

Such a system, as a rule, is solved using numerical methods. For practical cases, as our calculations have shown, it is quite possible to use simplified calculations according to the schemes presented in Fig. 4.11 - 4.12. In this case, the first scheme can be used for a flotation machine without an air conditioning chamber, and the second - using air conditioning chambers.

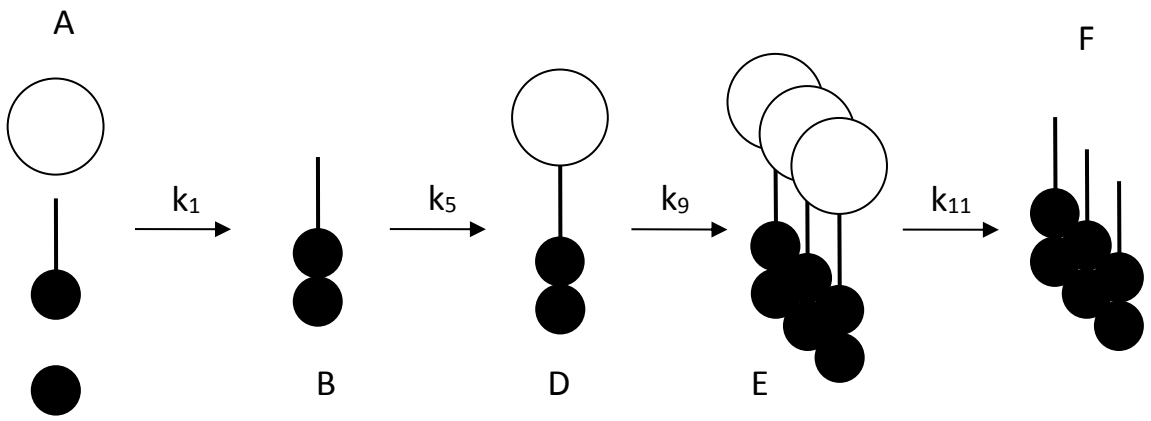


Fig. 4.11 - Simplified model of ion flotation (flotation machine without air conditioning chamber).

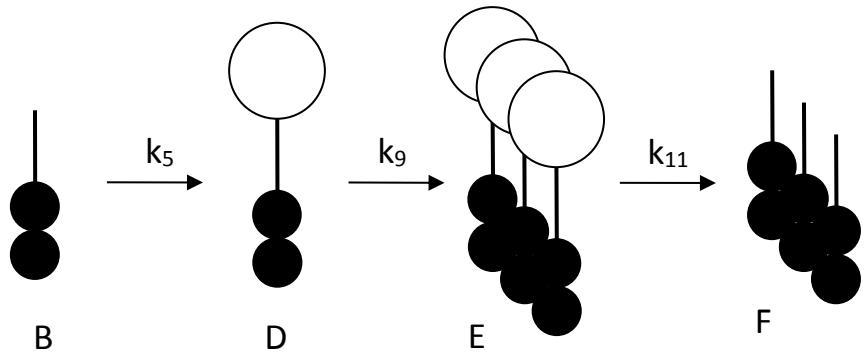
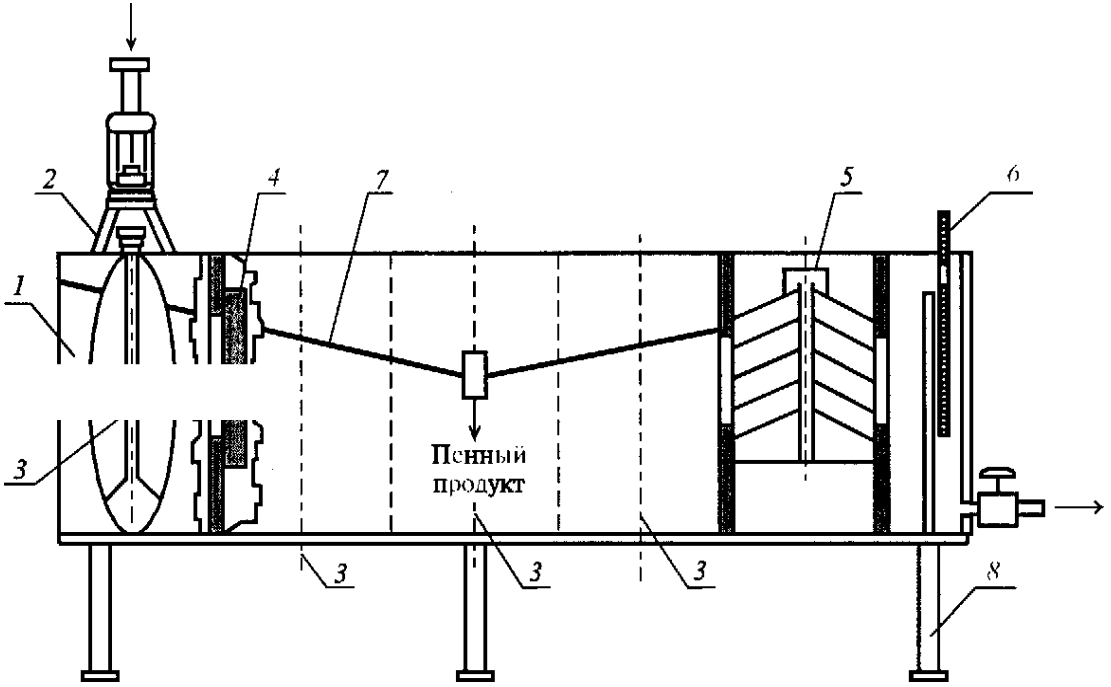


Fig. 4.12. Simplified scheme of the ion flotation process in a flotation machine with a conditioning chamber (Fig.4.13)

The scheme of the mechanical flotation machine of our development is presented in Fig. 4.13. If necessary, the first chamber in the course of dirty water supply can be used as a conditioning chamber in it.



Assuming that the collector is full of coigendomrea system will take care of

Fig. 4.13. Combined mechanical flotation machine:

1 – building; 2 – aeration unit: 3 – impellers; 4 – grid; 5 – plate illuminator; 6 – gate;7 – foam gutter; 8 – frame with stand.

Of greatest practical interest is the flotation process without a conditioning chamber, which is described by a system of equations (2).

$$\begin{cases} \frac{dC_B}{dt} = -k_5 C_B; \\ \frac{dC_D}{dt} = k_5 C_B - k_9 C_D; \\ \frac{dC_E}{dt} = k_9 C_D - k_{11} C_E; \\ \frac{dC_F}{dt} = k_{11} C_E. \end{cases} \quad (4.2)$$

Solving the system of equations (2), we will take the following initial data on the example of the extraction of nickel from wastewater.

C_0 = 0.9 mg / l - the concentration of the extracted substance in the initial solution;

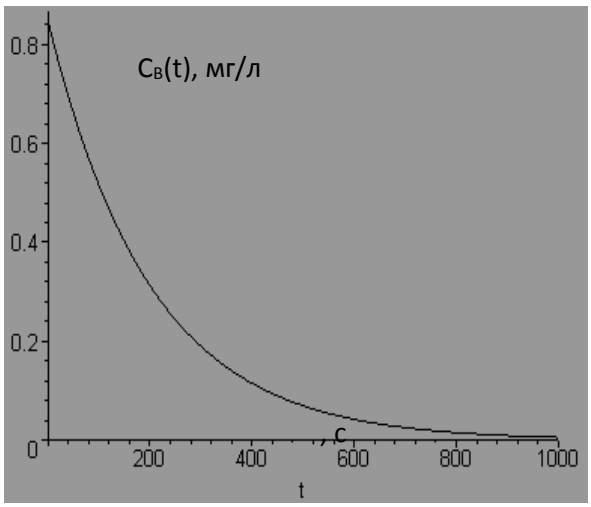
k_5=0,005 c^{-1};

k_9=0,15 c^{-1};

k_{11}=0,001 c^{-1}.

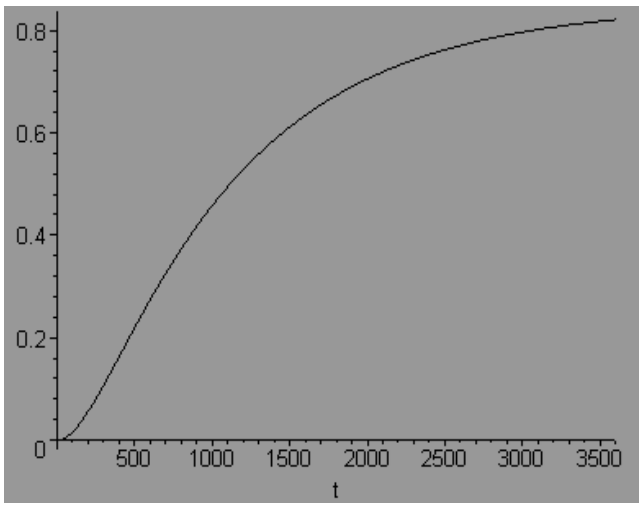
At t=0 $C_B = C_0$; $C_D = C_E = C_F = 0$.

Solutions of the system of equations (4. 2) in graphic form are presented in Fig. 4.14.



А)

C_B(t), мг/л



Б)

C_E(t), мг/л

Fig. 4.14. – Kinetic relationships of the concentration of colligendum ions based on the solution of the system (4. 2):

(a) the dependence of the colligend concentration on time in the clarified liquid C_B(t);

B) the dependence of the concentration of colligend on time in the foam product

The efficiency of extraction of individual metals from wastewater, obtained by calculation and determined experimentally, is presented in Table 1. A comparison of the calculated and experimental values shows a slight discrepancy not exceeding about 7%, which makes it possible to use the calculated data to assess the effectiveness of wastewater treatment, including metal, using ion flotation.

Table 4. 1. Indicators of extraction of individual metals from wastewater using ion flotation

No p/n	Metal	Concentration of metal in wastewater, mg/l	Flotation time, min	Estimated cleaning efficiency,%	Experimentally determined cleaning efficiency, %
1	Chrome (general)	2,2	15,5	97,7	91,4
2	Lead	4,4	15,5	96,9	89,6
3	Nickel	3,5	15,5	98,4	92,7
4	Tungsten	2,9	15,5	97,8	93,3
5	Cobalt	4,1	15,5	96,5	89,6

It should also be noted that this possibility makes it possible to determine the concentration of the recovered substance at each of the process stages in question at any given time without conducting expensive experiments, which is especially important when designingwastewater treatment systems. In addition, it

is possible to find a time-limiting stage, affecting the course of which it is possible to reduce the overall time of the process of extracting contaminants, including metal ions.

In some cases, the following solution is also of interest:

$$C_c = C_0(1+\frac{k_3}{k_1-k_3}e^{-k_1 t}+\frac{k_1}{k_3-k_1}e^{-k_3 t})$$

$k_1 = \frac{3\frac{Q}{S}\Gamma_m}{RHC_0}$ according to [2, p.22] and

following [3]have]

$k_3 = \frac{V_П}{H}$

$$C_c = C_0(1+\frac{V_П}{H(\frac{3\frac{Q}{S}\Gamma_П}{RHC_0}-\frac{V_П}{H})}e^{-\frac{3\frac{Q}{S}\Gamma_m}{RHC_0}t}+\frac{\frac{3\frac{Q}{S}\Gamma_m}{RHC_0}}{\frac{V_П}{H}-\frac{3\frac{Q}{S}\Gamma_m}{RHC_0}}e^{\frac{V_П}{H}t}\sim$$

It is known that

$\frac{\Gamma_m}{C_0} \sim \frac{S\gamma_0}{\eta}$

η – dynamic viscosity

γ – bubble braking coefficient

$\gamma = \frac{\partial\delta}{\partial C}\Gamma_0 Pe^{-1/2}D^{-1}\mathrm{Re}^{-1/2}(c.41)$

или

$\gamma = \frac{2}{3}\frac{\partial\delta}{\partial\ell}\Gamma_0 Pe^{-\frac{1}{2}}D^{-1}(c.40)$

$\Delta\delta \sim \pi\eta U\sqrt{\mathrm{Re}}$

$\frac{\gamma_0}{\eta} \sim 10$; and then and at the same time $S \sim 10^{-6}$ *м* $\frac{\Gamma_m}{C_0} \sim 10^{-5}$

$k_1 = \frac{3\frac{Q}{S}\Gamma_m}{RHC_0} \approx \frac{3*10^{-1}*10^{-5}}{10^{-3}*1} \approx 3*10^{-3}$

$\frac{Q}{S} = 360\frac{м^3}{м^2 ч} = 6\frac{м^3}{м^2 мин} = \frac{6}{60}\frac{м^3}{м^2 с} \approx 0{,}1$

$k_3 = \frac{V_П}{H} = \frac{2*10^{-1}}{1} = 2*10^{-1}c^{-1}$

The obtained values of constants make it possible to obtain solutions to the above system of equations, which describes quite well the experimental ones with a deviation of not more than 10-15%.

This case is of particular importance for the treatment of wastewater from surfactants.

The presence of fat in wastewater together with surfactants further aggravates the conditions for the oxidation of organic contaminants by microorganisms.

Our tests and the introduction of flotation technology for wastewater treatment at food industry enterprises have shown that in this way it is possible to extract surfactants from water to residual concentrations of about 1.5 - 2.5 mg / l, and fats - up to 15-20 mg / l or less. At the same time, the initial concentration of surfactants, as a rule, was in the range of 10 - 30 mg / l, and fats - about 1700 - 2000 mg / l.

In the process of testing this technology, it was also revealed that in some cases there is poor flotation of fats and surfactants.

The development of the theoretical foundations of flotation as a multi-stage process led to the creation of combinedflotation machines and apparatuses. At the same time, combined flotation machines and mechanical devices have been developed to purify wastewater from hydrophobic easily flotated substances, for example, fats and surfactants. Therefore, microbubbles interact most effectively with flotated particles. Therefore, microbubbles interact most efficiently with flotation particles. Therefore, for a method of deep jet aeration of wastewater has been developed for the implementation of this technical solution (Fig. 4.1 5) consisting in the supply of wastewater under pressure through a jet aerator. Such a device with a jet aeration system includes a pipe 1, through which the jet is supplied to the liquid volume. At the top of the device is the distribution and supply chamber 2 of the starting fluid through the branch pipe 3 and the distribution chamber for supplying to the pipe 1 through the nozzle 4, and the sucked air through the openings 5. A jet of liquid with a gas trapped by the surface of the liquid is fed directly into the volume of the liquid. The amount of air sucked from the atmosphere is regulated by a shut-off valve installed on the atmospheric air intake line. In the case of an increased content of sucked air, its reduction is achieved by closing the shut-off valves. In this case, the resulting

mixture of wastewater with air moves in cramped conditions through a pipe 1.5 - . At the outlet of the tubular aerator, air is dispersed to the smallest bubbles, which form stable flotocomplexes with hydrophobic substances, for example, fats, floating into the upper layer of the liquid. In this case, coalescence of mineralized bubbles with larger, unloaded air bubbles occurs. The bubbles coalesce, which leads to an increase in the diameter of the air bubble and, as a result, to an increase in the speed of lifting the flotological complexes of the particle (droplet of oil or fat) - the bubble. Small mineralized bubbles due to the low rate of surfacing may not reach the upper boundary of the foam layer and will be carried away by the flow of purified liquid diverted in the horizontal direction. To increase the rate of surfacing of such mineralized bubbles, it is necessary to reduce the height of their rise. To implement this technique, a thin-layer settling unit has been developed, the distance between the shelves of which is 1-. The above technical solutions are implemented in a combined flotation machine of the mechanical2,0 м10 смtype (Fig. 4.16) and in a flotation column with a thin-layer clarification unit (Fig. 4.17).

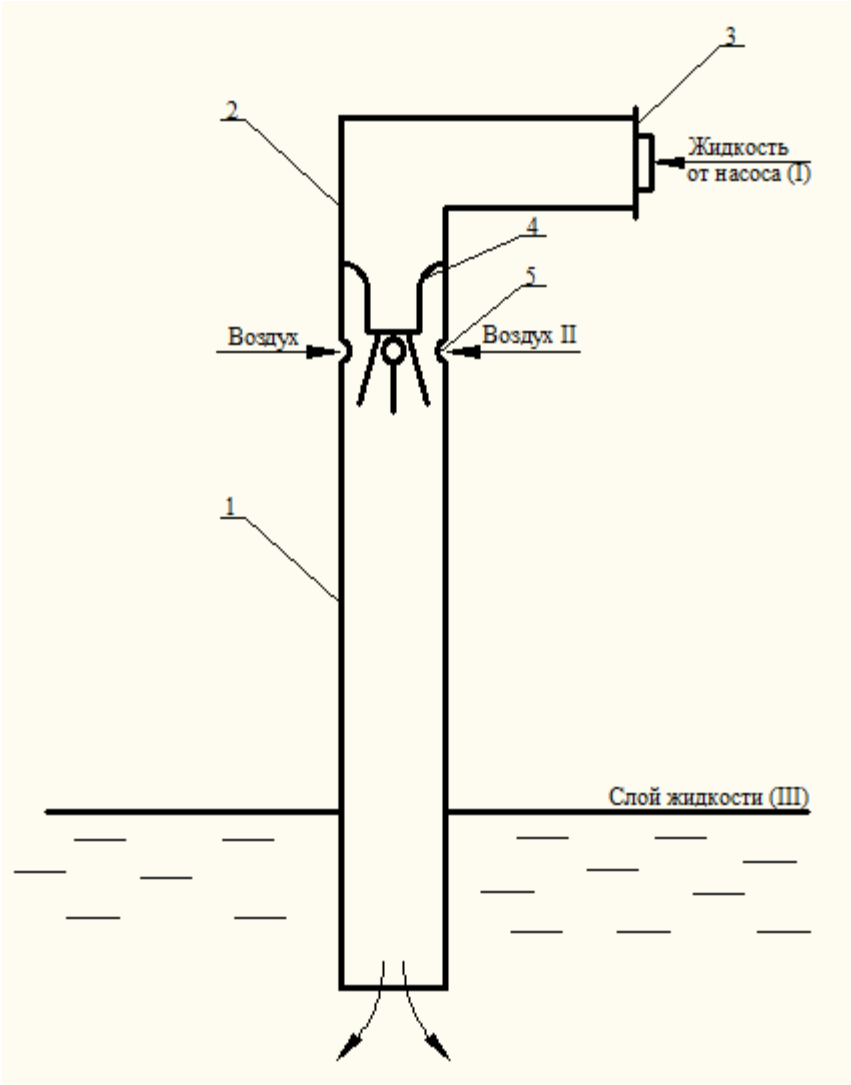


Fig. 4.15. Scheme of deep jet aeration of liquid

1 – aerator body; 2 – collector; 3 – branch pipe; 4 – nozzle; 5 – hole for air suction.

The scheme of the combined flotation mechanical machine is presented in Fig. 2.

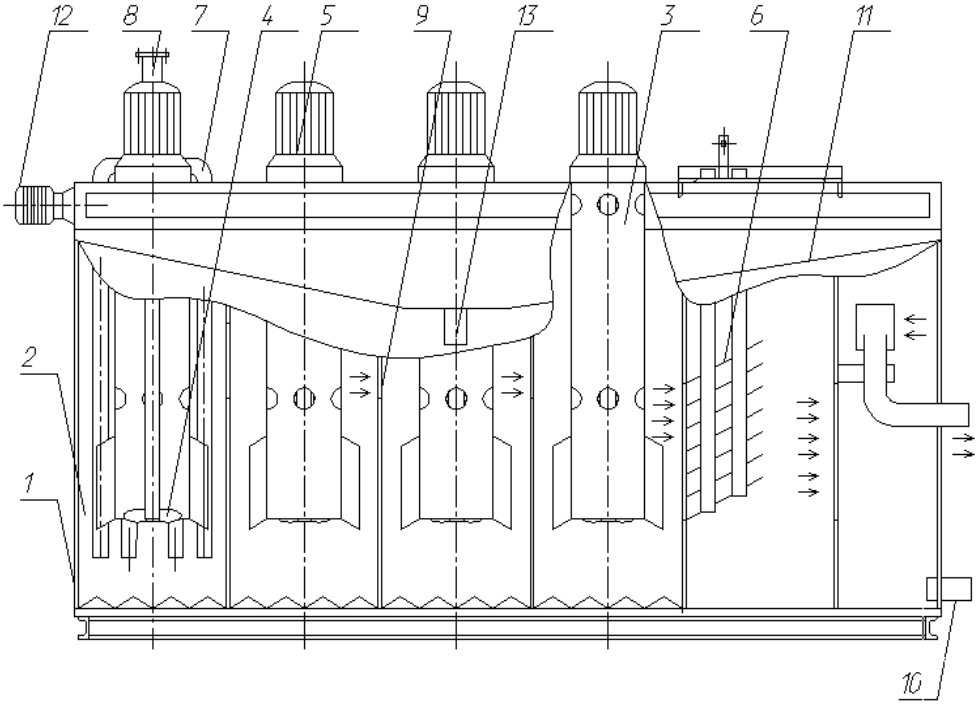


Fig. 4.16 – Diagram of a flotation combined mechanical machine (FKMO) with inlet flow.

1 - body, 2 - working space, 3 - casing pipe, 4 - impeller, 5 - electric motor, 6 - thin-layer clarification unit, 7 - device for jet supply of inlet flow, 8 - inlet pipe, 9 - partition with window, 10 - outlet pipe, 11 - foam gutter, 12 - electric pennode, 13 - branch pipe for the output of the foam product.

The combined flotation apparatus is aflotation column developed by nami (Figures 4.17, 4.18), which consists of a body 1, inside of which an aeration chamber for feeding pulp 4 and a grate 5 are installed.

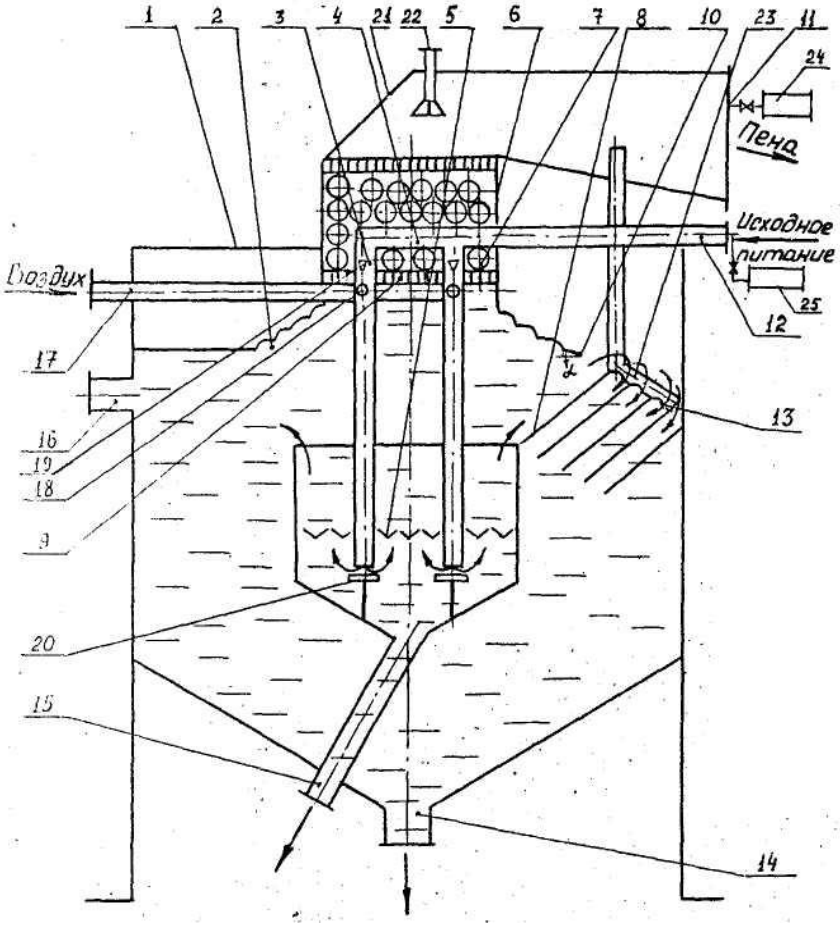


Fig. 4.17. Flotation column

1 - body, 2 - aeration chamber, 3 - jet aerators, 4 - aeration chamber for pulp supply, 5 - grille, 6 - flotation device, 7 - movable hydrophobic nozzle 8 - thin-layer settling unit, 9 - limiting mesh, 10 - narifles, 11 - branch pipe for removing foam product, 12 - branch pipe for pulp supply, 13 - a set of shelves, 14 – a branch pipe for the output of clarified liquid (chamber product), 15 – a branch pipe for draining flushing liquid, 16 – a branch pipe for supplying flushing liquid, 17 – a branch pipe for air supply, 18 – a hole, 19 – a nozzle, 20 – reflectors, 21 – foam tray, 22 – an irrigating nozzle, 23 – a branch pipe for draining gas or air bubbles accumulating in the upper part of the shelves, 24 – a pump, 25 – a compressor.

A flotation device 6 is installed above and coaxially above the chamber 2, in the upper part of which there is a movable hydrophobic nozzle 7, and in the lower part there is a thin-layer separation unit 8.

In this case, the hydrophobic nozzle is held by restrictive meshes 9, below which on the inner conical part of the flotation device 6 there are riffles 10 of a hydrophobic material, for example, fluoroplastic.

On the outside of the body 1 of the flotation column, branch pipes are installed respectively for the output of the foam product 11, the pulp supply 12, the output of the clarified liquid (chamber product) 14, the supply of the washing fluid 16, the exhaust of the washing fluid 15, the air supply 17. The thin-layer settling unit 8 installed in the lower part of the flotation device 6 includes a set of shelves 13 made in the form of v-shaped elements (Fig. 4). Located inside the device 2, the jet aerators 3 are vertically mounted cylindrical tubes, in the upper part of which there are holes 18, above which nozzles 19 are installed. At the same time, reflectors 20 are located under the lower ends of the jet aerators 3, made in the form of flat square or round plates.

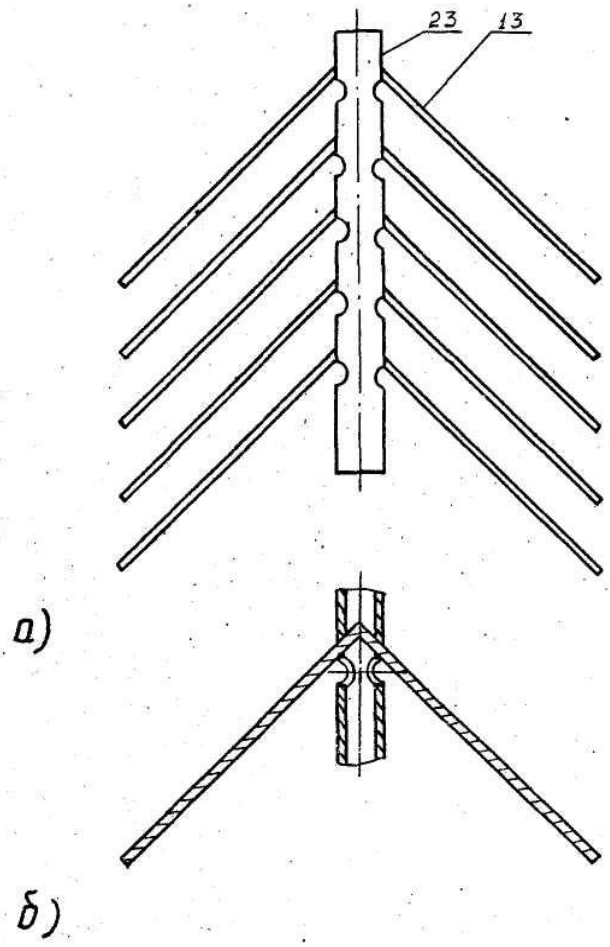

23
13
а)
б)

Fig. 4.18. V – shaped elements of the thin-layer sump unit

13 - a set of shelves, 23 - a branch pipe for removing gas or air bubbles accumulating in the upper part of the shelves.

Above the device 6 is a foam tray 21, in the upper part of which an irrigating nozzle 22 is installed, made in the form of a filter (shower sprayer), and in the lower part - a branch pipe 23 for removing gas or air bubbles accumulating in the upper part of the shelves 13.

The initial power supply may be carried out with a simultaneous supply of pressurized air from the compressor 25.

The discharge of the foam product may also be carried out under a vacuum created by the pump 24.

The flotation column works as follows. The original pulp or finely dispersed slurry through the inlet pipe 12 through the collector 4 enters the jet aerators 3, into which air is also sucked or supplied under pressure through the openings 18, the amount of sucked air being determined by the rate of the water jet or slurry flowing through the nozzle 19. At the same time, due to the rarefaction that occurs at the velocities of water flow or a finely dispersed suspension above about 15 m / s, air (or gas) is sucked up to the smallest bubbles and their contact with suspended particles of mineral or organic nature occurs. At the same time, to create a uniform and effective aeration in the entire volume of water or a finely dispersed suspension, the required number of aerators, as shown by experimental studies, is 4 - 8 per . In the case of using aerators less than 4, the efficiency of aeration and flotation decreases, and in the case of using aerators more than 8, the flotation effect does not increase.$1\ м^2 1\ м^2 1\ м^2$

The liquid jet leaving the aerators at high speed is further dispersed, falling on the reflectors 20. At the same time, additional crushing of air (or gas) bubbles occurs, to smaller sizes reaching sizes of the order of 0.1 - , and an intensive process of adhesion of bubbles with particles of the solid phase and drops of hydrophobic substances, for example, such as oils, fats, etc. For a more complete extraction of particles of a wide range of size, lattice 5 with a live section of 15 - 30% is used. This range was determined on the basis of studies conducted. With a live section area of less than 15%, the efficiency of aeration and flotation drops sharply, and with a live current area of more than 30%, the achieved positive effect does not change.$0{,}5\ мм$

The resulting bubble-particle flotation complexes (a drop of oil) rise upwards, forming a foam layer in the flotation device 6, which is in contact with the hydrophobic surface of the

nariflenium 10 of the inclined part of the confusor and further with a hydrophobic nozzle 7, made, for example, of fluoroplastic balls with a diameter of 5 - .10 мм

At the same time, the angle of the confusor α (Fig. 3) in the range of 20 - 70 ° was selected on the basis of the studies conducted. At confusor angles of less than 20°, it is very difficult to lift the foam product, which leads to a sharp increase in the residence time of the foam in the flotation column, the precipitation of fleeted particles from it and, as a result, to a decrease in the degree of extraction of the target product. In the case of using a confusor with an angle of more than 70 °, the effect of contact of the inclined hydrophobic surface with the foam and, accordingly, with the gas bubbles is reduced and, accordingly, the effect of compressing the volume of the foam layer decreases. The selected limit of the confusor is checked when testing a new column sample.

Due to the contact of the foam (foam layer) with hydrophobic materials of this form, there is an intensive coalescence (adhesion) of gas bubbles with each other and, as a result, a decrease in the foam layer in volume and an increase in the concentration of the target product in the foam. Further, the foam layer, passing through the nets 9, enters the foam tray 21, where it is irrigated with water supplied through the irrigating nozzle 22. At the same time, hydrophilic and poorly retained particles in the foam are washed out, which fall into the aeration zone of the device 2. In this case, the resulting foam product is spontaneously dumped on the inclined tray I I or suctioned using a vacuum pump 24.

The discharge of the clarified liquid (chamber product) takes place in the flotation device 6, in which the foam product is concentrated due to the coalescence of gas bubbles. The clarified liquid is further purified by settling in a slow flow between the shelves 13 of block 8. When settling in a thin layer 20 high, thin bubbles are separated, both loaded with particles or drops of oil and unloaded, which then accumulate in the upper part of 50 ммthe v-shaped elements representing shelves 13.

The accumulating bubbles are then, due to the lifting force due, among other things, to the airlift effect, discharged through the branch pipe 23 into the foam product located in the tray 21. The clarified liquid (chamber product) after the thin-layer settling unit is removed from the flotation column through the branch pipe 14.

Experimental data on the efficiency of wastewater treatment from fats using Praestol 655 as a reagent when using flotation machinesof various types are presented in Table 4.2.

Table 4.2. The efficiency of wastewater treatment for the extraction of fats in various machines without and with the addition of flocculant Praestol 655 (dose of Praestol 18 mg / l).

Type of flotation machines and apparatus	Fat concentration, mg/l		
	Original	Ultimate	
		No Added Flocculant	With the addition of Protostol flocculant
Mechanical FKMOs	1500-2000	40-60	20-30
Pneumatic FPM	1500-2000	50-80	35-60
Pressure	1500-2000	30-40	20-25
Inkjet	1500-2000	60-80	30-50

Data on the effect of the dose of Praestol 655 on the efficiency of wastewater treatment from fats in the flotation column apparatus with a working volume $1{,}5\ м^3$ are presented in Table 4.3.

Table 4.3. Effect of the dose of Praestol 655 on the efficiency of wastewater treatment from fats in a flotation column apparatus with a working volume (fat concentration in the source water 1227 mg / l; wastewater aeration intensity 0.5 m$1{,}5\ м^{33}$ / m^2 min)

Dose of Praestol 655 (mg / l)	Flotation time, min	Concentration of fats in purified water, mg/l	Cleaning efficiency, %
0	5	156	43,9
3	7,5	73	59,4
6	10	69	71,6
9	12,5	51	81,6
12	15	37	86,7
15	17,5	22	92,1
18	20	19	93,2
21	22,5	18	93,5

24	25	18	93,5
27	30	1,8	93,5

The dependence of the efficiency of wastewater treatment on surfactants on the flotation time in the flotation columnapparatus is presented in Table 4.4.

Table 4.4. Dependence of the efficiency of wastewater treatment on surfactants on the flotation time in the flotation column apparatus (working volume)$1{,}5\ м^3$

Flotation time, min	Concentration of surfactants, mg/l		Cleaning efficiency, %
	in the source water	in purified water	
2, 5	10,6	0,64	94,0
5	6,5	0,25	96,2
7,5	6,5	0,27	95,8
10	8,0	0,32	96,0
12,5	8,0	0,36	95,5
15	6,5	0,24	96,3
17,5	10,6	0,43	95,9
20	10,6	0,58	94,5
22,5	10,6	0,52	95,1

The experimental data presented in Table 1-3 indicate the possibility of achieving a high degree of purification through the use of flotation equipment using various types of flotation machines and devices, including column type. The cleaning efficiency can also be increased using, for example, vibration effects, which can lead to an increase in the efficiency of fat extraction

and surfactants by about 30-50%. This option is possible when using the equipment described above, supplemented by a vibration unit.

4.2. Monitoring the state of activated sludge and disruption of biological wastewater treatment processes

Microorganisms are an effective indicator for determining the quality of activated sludge. To carry out bioindicator control, hydrobiological analysis of the water-sludge mixture is carried out by microscopy. Structural features of the biocenosis of activated sludge are determined, the organisms of which have the ability to respond (qualitative change and quantitative distribution of individual groups) to the composition and properties of active sludge. treated wastewater, as well as on life support conditions. The numerical predominance of a particular component of the biocenosis serves as an indicator of the stability and efficiency of the technological process of wastewater treatment. This method makes it possible to determine the deviations of microorganisms and the change in the species composition of the biocenosis from the normal state, and according to the degree of such deviations, not only to determine the state, but also to predict the timing of the prospect of changing the normal course of the technological process of biological wastewater treatment. Specific operations to monitor the state of activated sludge are presented in a number of regulatory documents, including the MND F SB 14.1.92-96. Methods of sanitary and biological control. Methodological

guidelines for hydrobiological control of filamentous microorganisms of activated sludge (Appendix 1). Timely control allows to avoid in some cases a violation of the biological treatment regime and a decrease in the effectiveness of wastewater treatment, including the swelling of activated sludge.

Research work carried out by various developers 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 residuesat the bottom, including at the stage of separation of activated sludge from purified water. It should be emphasized that the effectiveness and reliability of treatment largely depends on the quality of the deposition stage, 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 coalesce into aggregates around an organic or mineral carrier. Coalescence is performed by exopolysaccharides. This type of growth is most common in the implementation of the technological process of wastewater treatment.

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.

4.3. Wastewater treatment using immobilized microorganisms

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 themicro-organisms on the carrier (Table 4.5).

Attached organisms are more resistant to the action of toxicants, multiply faster than in suspension, and are characterized by increased metabolic activity.

Table 4.5. Possibilities of wastewater treatment with the help of immobilized microorganisms-destructors

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., activated sludge	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-Methylstyrene	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 is always of interest. 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 kapron carrier and fibrous polymer material was also studied. Rhodococcus is well sorbed on the surface of both carriers. However, the fibrous polymeric material is populated by microorganisms preferably than the kapron carrier "via". This significant advantage of the fibrous polymeric material over the carrier of "via" lies in the fact 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 flow rate of 0.30 l / h with a COD purification efficiency of 76.9% (Table 4.6). Diesel fuel is oxidized by 98%. With an increase in the flow rate of wastewater to 0.45 and 0.8 l / h, the oxidation efficiency of the pollutant decreases to 91.4% and 78.1%, respectively.

Table 4.6. Oxidation of diesel fuel in water by destructor microorganisms immobilized on a fibrous polymer material

Diesel fuel concentration, mg/l (Source Water/Purified Water)	Flow rate, l/ h	COD, mgO2/l	Oxidation efficiency of diesel fuel, %	COD cleaning efficiency, %
1625/32,5	0,30	511/118	98,0	76,9
1625/140,0	0,45	511/165	91,4	67,7
1625/355,0	0,80	511/212	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 growth rate of bacteria 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 almost does not change. The decrease in the oil content in the versions with claydite 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 environmental protection .

Test questions

1. What is the essence of biological wastewater treatment?
2. Approximate composition of activated sludge.
3. The role of protozoa in the processes of biological wastewater treatment.
4. The role of bacteria in biological wastewater treatment processes.
5. Basics of wastewater treatment technology from biogenic elements.
6. Basics of nitri-denitrification processes.

7. Methods for removing phosphorus substances from wastewater.
8. Influence of filamentous bacteria on the deterioration of biological wastewater treatment processes.
9. Evolution of the introduction of membrane technologies in the practice of biological wastewater treatment.
10. Intensification of biological wastewater treatment processes using immobilized microorganisms.

4.4. Intensification of biological treatment and modern technologies removal of biogenic elements

Achieving the requirements for the quality of wastewater treatment, including nutrients, at the level of mpc for fishing bodies is a strict economic

necessity. At the same time, most treatment facilities in our country are designed only for the oxidation of organic pollution. At the same time, such treatment facilities were built 35-45 years ago and are still operating. In this regard, the need for reconstruction is due to the fulfillment of the requirements of the Government of the Russian Federation. Responsibility for the choice of the technological scheme of reconstruction falls on local water utilities or companies operating treatment facilities.

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 the best available technologies (BAT) for the 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.

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. 4.19 – 4.27.

A/O (anaerobic-oxide) process

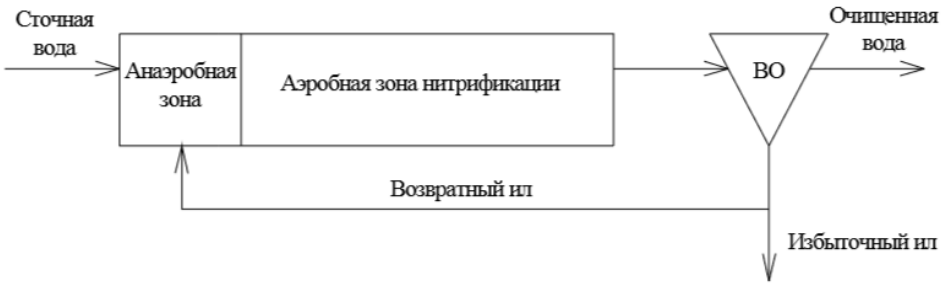


Fig. 4.19. Schematic diagram of A/O (anaerobic-oxide) process of nitrogen and phosphorus removal

According to the scheme presented in Figure 19 , the return sludge is mixed with incoming wastewater and fed into an anaerobic reactor, then the wastewater undergoes aerobic treatment and enters 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)

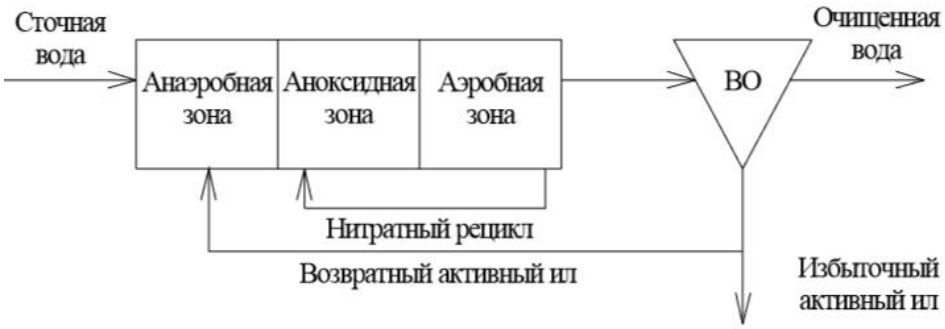


Fig. 4.20. - Schematic diagram A2/O of the nitrogen and phosphorus removal process

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. UCT process.

The 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).

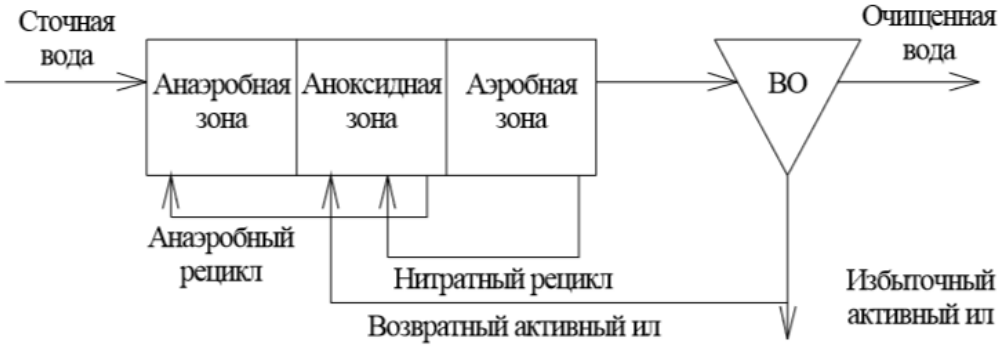


Fig. 4.21. Circuit Diagram of the UCT Process

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.

To stabilize the nitrification process in wastewater treatment, it is important to stabilize and increase the number of nitrification bacteria and increase their activity. A study was conducted at the ItC JSC Mosvodokanal (Nikolaev Yu.A., Grachev V.A., Mikhailova Yu.V.) on the possibility of applying the technology of bioaugmentation of activated sludge by nitrifying bacteria in relation to the purification of nutrient elements from wastewater in Moscow, depleted organic matter.

It is well known that nitrification bacteria have a low growth rate. In the process of nitrification, 98% of nitrogen is oxidized to nitrates, the rest of the amount is part of the cellular biomass. This property, according to the authors, can be considered as useful in terms of minimizing the growth of activated sludge. Low growth rates of nitrifications lead to the fact that heterotrophic microorganisms that oxidize organic matter have advantages in competing for space (can displace activated sludge from biomass). slow-growing nitrifiers) and for oxygen (as more quickly consuming it). Increasing the sludge retention time in the system (SRT) may require an increase in aeration or sedimentation area, which is irrational, given the high energy costs for aeration and the territorial limitations of water treatment plants. One alternative to improving the efficiency of purification is *bioaugmentation* technology, which can effectively improve the quality of treatment in systems with activated sludge (AI) without significantly increasing the volume of the tank. The point of the technology is that in order to improve nitrification or remove other contaminants, certain cultures of microorganisms specialized to remove certain pollutants are added to the main process. When adding Such microorganisms in the main AI reactor can increase the rate of water purification from the "target" compound, or work effectively under conditions that would otherwise be unfavorable to remove the target compound (e.g., too low SRT or temperature, toxicant inflow). In addition to improving nitrogen removal, bioaugmentation may have other advantages, such asimproving sludge flocculation; improvingthe removal of suspended solids; removing hazardous pollutants. Studies have shown that bioaugmentation can not only ensure continuity of the cleaning process and reduce the load on facilities, but also increase the resistance of AI to the effects of toxic compounds. First works on the use of augmentation for improving and/or restoring a particular process describes technology as the process of introducing externally desiredmicroorganism cultures. As it turned out, this approach is ineffective, since the acquired cultures can lose

activity during storage or when in new reactor conditions for them, and the cost of the necessary cell mass may be too high for permanent use. In the future, this approach was abandoned, as alternative and more rational schemes appeared. New options proposed to enrich activated sludge by building up the necessary microorganisms insidethe technological process. This approach was used by specialists of the Engineering and Technology Center (ETC) of Mosvodokanal JSC to develop a method to improve the stability of ammonium wastewater treatment. The purpose of the study was to determine the effect of the reactor-enricher (bioaugmentator) on the efficiency of nitrification in the presence of high concentrations of ammonium (i.e. exceeding the potential of a bioreactor) and the resistance of the nitrification process to a toxicant - thiomochevene.

The choice of the direction of research is not accidental, since the potential of using bioaugmentation technology to solve the tasks is obvious. Most large water treatment plants direct the resulting sediments to the stage of anaerobic digestion. This is done to reduce the dry matter exported to landfills and to obtain methane as a high-calorie energy carrier. As a result of the process of methane decay of organic matter, there is an intensive release of ammonium nitrogen into the liquid phase. The content of ammonium nitrogen in the drain water is high (up to 400-1000 mg / l), which provides up to 50% of the load coming from the city wastewater. At the same time, often among the components of incoming wastewater there are compounds toxic to nitrification bacteria that disrupt the stage of biological treatment at treatment plants. However, nitrification is only one of the stages of biological treatment, allowing to get rid of the ammonium nitrogen contained in the wastewater. The result of nitrification is the formation of oxidized forms of nitrogen in the form of ions NO_2^-, NO_3^-. It is possible to talk about the effectiveness of biological treatment only by getting rid of wastewater from all forms of nitrogen, as well as phosphorus, which are biogenic elements that cause eutrophication of water bodies and their flowering. Slowing down and even

reversibility of the eutrophication process is fundamentally possible by stopping the access of nitrogen and phosphorus to water bodies. To date, There is a large amount of information about the experience of introducing technologies for the treatment of nutrients for wastewater of various compositions. However, the literature review did not reveal technologies that combine bioaugmentation of activated sludge by nitrifying bacteria together with schemes for removing biogenic elements from wastewater depleted with easily degradable organic matter. In addition, examples of application or at least study of bioaugmentation in relation to wastewater treatment in Russia are unknown. Accordingly, the study of the technology of bioaugmentation of activated sludge by nitrifying bacteria in relation to depleted easily degradable organic wastewater, which includes most urban wastewater in Russia, has a high degree of novelty.

According to the authors of the study on increased ammonium loads (up to 50 mg $N\text{-}NH_4$ / l), the technology of the University of Cape Town did not ensure the removal of ammonium to the MPC standards for fishing reservoirs. The use of a bioaugmentator reactor ensured a decrease in the ammonium concentration from 50 to 0.4 mg of $N\text{-}NH_4$ / l, while increasing the resistance of nitrifying active sludge bacteria to thiomaceous tooxicant.

4. Process Modified UCT (University of Cape Town)

Fig. 4.22. 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 (- in honor of the developer Barnard, den - denitrification, pho - phosphorus extraction).

Fig. 4.23. Circuit 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

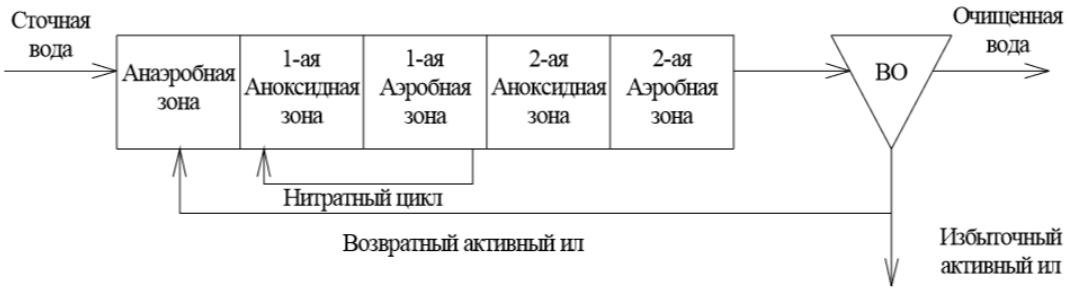


Fig. 4.24. Schematic diagram of the Modified Bardenpho process

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 (or JHB) process.

Fig. 4.25. JHB Process Diagram

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. 4.26. 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. 4. 27. Schematic diagram of the VIP process

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 - SCS, the removal of phosphorus from household wastewater is carried out by a combined method - biological and chemical. UCT (University of Cape Town) technology is used for biological disposal. Chemical removal is also used - ferrous sulfate Ferix-3, (10% aqueous solution). In this case, 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 commonoptions in Russia and abroad are 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 NO2 or NO3.

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.

Aeration tanks of the block for the removal of biogenic elements of the Lyuberets treatment facilities (according to JSC Mosvodokanal) consist of 4 corridors, with division into zones (Fig. 4.10).

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 2 and 3 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 4.7).

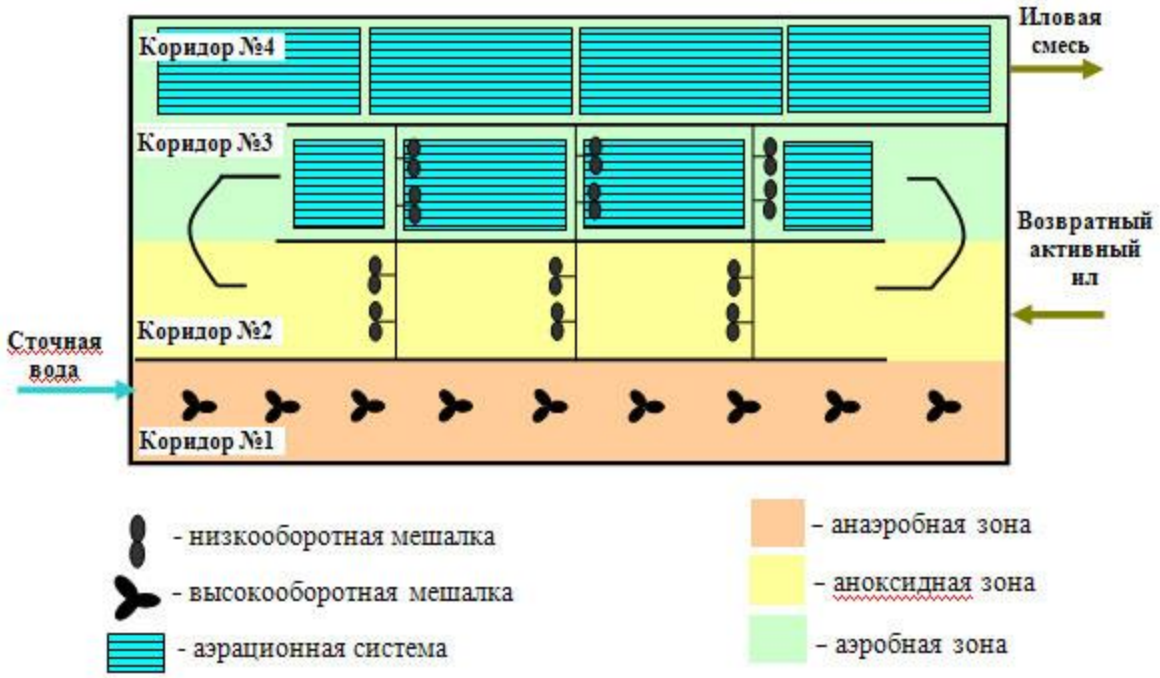


Fig. 4.28. Scheme of the aeration tank of the biogenic element removal unit

Table 4.7. Efficiency of removal of biogenic elements in aeration tanks (according to JSC Mosvodokanal)

Name of indicators	Unit	Average value for 2013	Project significance	EU Regulations
Suspended solids	mg/l	6,4	8,0	35
BOD5	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)

Presented in Table. 4.7 The data indicate the effectiveness of the technological solutions used for the removal of nutrients.

To stabilize and intensify the nitrification process inwastewater treatment, it is important to maintain and even increase the number of nitrifying bacteria and increase their activity. With this tool, the Engineering and Technology Center (ITC) of JSC Mosvodokanal conducted a study on the possibility of using the technology of bioaugmentation of activated sludge by nitrifying bacteria in relation to the purification of nutrient elements from wastewater in Moscow, a depleted organic substance. For the first time in world practice, a new technology was investigated that combines a bioaugmentator reactor with nitrifying bacteria and a removal technology nutrients according to the Cape Town process. At increased ammonium

loads (up to 50 mg N-NH4/ l), the technology of the University of Cape Town did not provide ammonium removal to the MPC standards for fishing bodies. The use of a bioaugmentator reactor reduced the ammonium concentration from 50 to 0.4 mg of N-NH4/ l, while increasing the resistance of nitrifying active sludge bacteria to tooxicanthu-thiomochevina.

The specialists of the ITC JSC Mosvodokanal assess the results of their work as promising and stating at the same time that a strategy has been developed for the use of bioaugmentation, as a way to improve nitrification, for low-load, easily degradable organic wastewater treatment facilities.

An effective way to intensify the biological method of removing biogenic elements is acidification (prefermentation) of raw sludge as a method of stabilizing wastewater treatment from nutrients. The acidification process increases the volatile fatty acid content of the wastewater, allowing for a more stable removal of phosphorus in aeration tanks operating under the University of Cape Town (UCT) scheme.

It is known that the concentration of readily available organic matter determines the stability of the process of biological removal of phosphorus fromwastewater. Wastewater of most Russian cities is characterized by a low content of this indicator. One of the methods of increasing the proportion of readily available organic matter is to carry out the process of acidification (prefermentation) of raw sediment. In this regard, the possession of readily available organic matter in the wastewater entering the treatment is one of the key factors determining the quality of the biological phosphorus treatment process. According to a number of developers, for an effective phosphorus removal process, a BOD ratio of$_5$: total phosphorus in the incoming water is more than 20: 1, the ratio of KPK: total phosphorus - more than 45: 1 . The concentration of an easily

degradable organic substrate according to COD related to volatile fatty acids in the anaerobic zone should be at least 25 mg / l.

To implement biological dephosphatization in low-concentrated effluents, one of the methods of increasing the content of easily accessible organic matter is the process of acidification (prefermentation). It should be explained that preferencing is a specially organized process of formation of soluble, biologically readily available organic matter (volatile fatty acids) by anaerobic treatment in primary tanks of suspended or precipitated organic matter contained in municipal and industrial wastewater, with the aim of using the obtained PLCA to increase the efficiency ofthe removal of biogenic elements.

To denote the process, the terms "acidification" and "prefermentation" are used equally, but there is a tendency to use the term "acidoficification" more frequently in the Russian-language literature, and "prefermentation" in the English-language literature. This process can be implemented both on the main wastewater treatment line in primary sedimentation tanks equipped with a sludge recycling system, and on a separate line in crude sludge prefermentation reactors with different recycling, mixing and staging schemes.

Even before carrying out such work, when they were needed, when creating a microbiological industry in the USSR, in the 70-80s of the twentieth century, employees of JSC GosNIIsintezbelok were developed, including Korotchenko N.I., Vorobyeva G.I., Ksenofontov B.S. and others, and later introduced (1985) a method for using activated sludge as an additional substrate for growing microorganisms. This method of utilization of activated sludge as a substrate for growing microorganisms can be considered a prototype of the acidification process, the essence of which is almost the same, namely, the decay products of the substance of the sewage sludge are a nutrient medium for the cultivation of microorganisms.

An example of the industrial implementation of the acidification process according to literature data can serve as foreign treatment facilities in the cities of KalgAri and Summerland (Canada), Self's Point and Saint Maris (Australia).In Russia, biological treatment of nutrients, and, accordingly, acidification, is much less common. An example of the introduction of acidofication (prefermentation) at domestic industrial facilities is much less common. An example of the introduction of acidification (prefermentation) at domestic industrial facilities is Zhet to serve the city of Sestroretsk.

When introducing the best available technologies in the Russian water sector, acidocation is considered as one of the methods of increasing the efficiency of wastewater treatment from nutrient elements and is taken into account when designing the construction and reconstruction of sewage treatment plants, for example, in Samara and in the village of Uva (Udmurtia).

At Mosvodokanal, the University of Cape Town (UCT) process aimed at the joint removal of nitrogen and phosphorus has been implemented at the biogenic element removal unit of the Luberetsky Wastewater Treatment Plant. Urban wastewater in Moscow is characterized by a low content of easily accessible organic matter, so the urgent task is to increase the stability of biological treatment of phosphorus. In this case, one of the methods of increasing the proportion of easily accessible organic matter is the process of acidification (prefermentation) of the primary sediment. As it was shown earlier, the incoming wastewater and the primary sediment of the Moscow treatment facilities have an averagecidification potential. This allows us to consider acidification as an appropriate method of increasing the content of available organic matter in the water entering the biological treatment.

Along with those described above, traditional methods of intensification of biological wastewater treatment are still relevant.

Onthe operation of biological wastewater treatment systems accumulated in our country and abroad, the study of the kinetics of biochemical processes, the creation of perfect structures of structures and devices, the development of adequate mathematical models and methods for optimizing the structural and technological parameters of treatment systems, made it possible to bring the effectiveness of the biological method to a fairly high level.

Some methods of intensifying the process of biological wastewater treatment are currently carried out as before (2nd half of the twentieth century), for example, by increasing the concentration of activated sludge in the aeration zone, using technical oxygen, ozone, powder and granular sorbents, the use of mutants, ultrasonic and electromagnetic treatment of wastewater and activated sludge, fixed biomass, etc.

1. Increasing theconcentration of activated sludge

The efficiency of the biochemical wastewater treatment process largely depends on the concentration of activated sludge in the aeration tank. Most of the currently used mathematical models of biochemical wastewater treatment in aeration tanks suggest an inversely proportional relationship between the required duration of wastewater aeration and the concentration of activated sludge. Its increase is one of the possible ways to intensify the work of aerotanks, allowing to create high loads per unit volume of the structure.

Studies have shown that with an increase in the concentration of active andla to 25 g / l, it is possible to increase the oxidative power of the aerotenca according to the BODf to 8 - 12 kg / m3 day and, as a result, it is possible to reduce the period of aeratsii by about 2 times at relatively low loads on active sludge (0.5 -0.8 kg / kg of sludge per day).

However, along with an increase in the oxidative power of the aeration tank, with an increase in the concentration of activated sludge, difficulties arise with the separation of sludge and clarification of purified water, which are due to the deterioration of the sedimentation properties of the silt mixture with an increase in their concentration. Traditional structuresfor separating silt mixture in the form of sedimentation tanks cannot provide effective clarification of purified water at a concentration of activated sludge above 4-6 g / l. This problem can be solved by using newstructures of aeration tanks-filter guns, flotation sludge separators, flotation combines, etc. These structures allow maintaining a high concentration of activated sludge in the aeration zone, but are difficult to operate. Consider the possibilities of using new developments for these purposes, for example, in the form of flotation combines.

First of all, we will consider the main stages of the processes occurring in the working space of the flotation combine, in the treatment of wastewater. The scheme of the flotation combine developed byus is presented in Fig. 4.28.

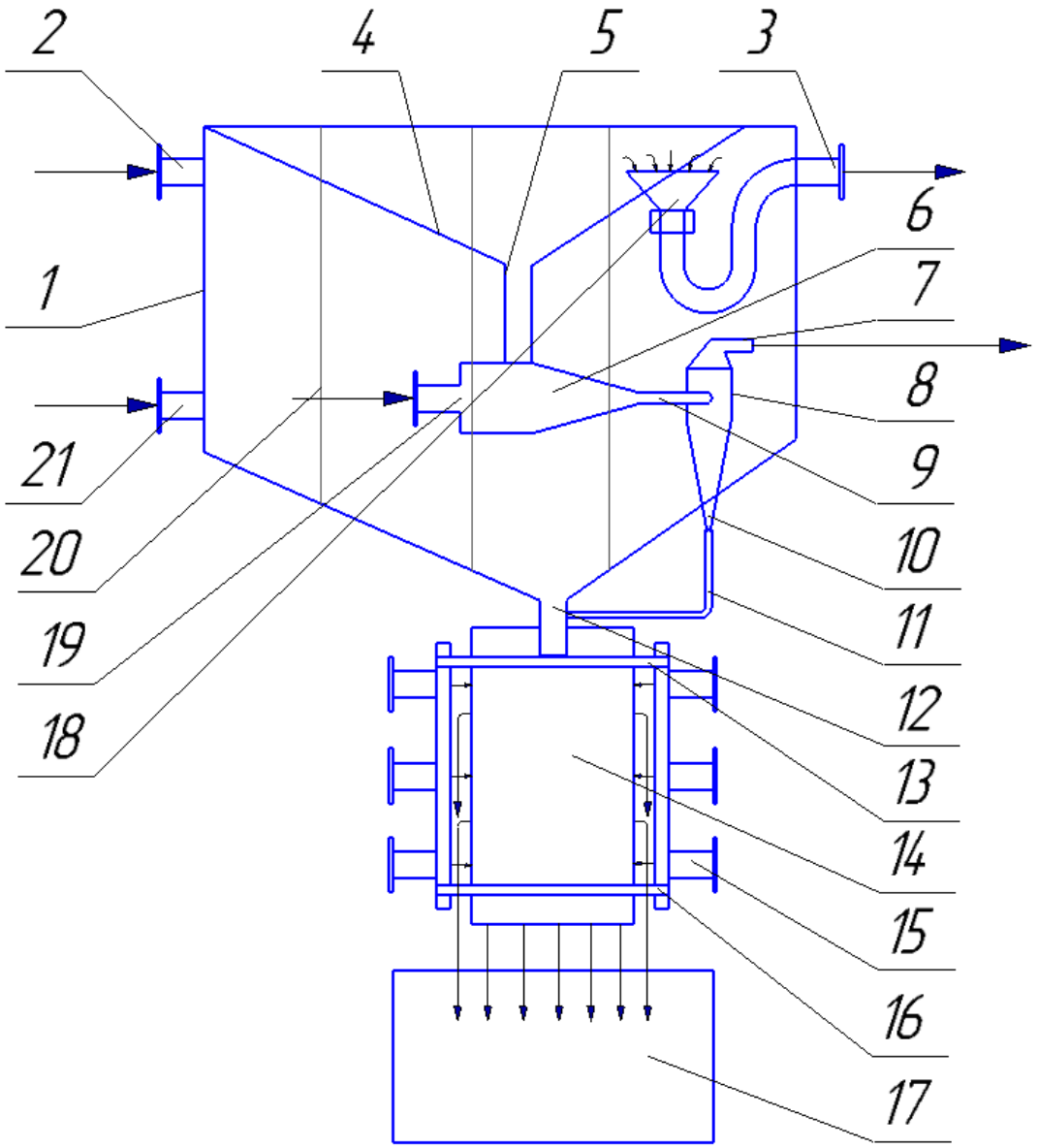


Fig. 4.28. Scheme of the flotation combine with a vibrating unit

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

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

The principle of operation of the flotation combineis as follows. The initial sludge mixture through the branch pipe 2 enters the body 1 of the flotation combine, where it is mixed with the working fluid entering through the branch pipe 21. As a result of mixing these flows, the formation of flocomplexes of active sludge flakes occurs - gas bubbles contained in the working fluid. The resulting flotation complexes with large bubbles of the order of 1 mm or more quickly enough float into the foam the layer and flotation complexes with smaller gas bubble sizes, called microflotocomplexes, are carried away by the flow of the purified liquid, which is further filtered through the perforated partitions 20. When passing through perforations, microflotocomplexes coalesce, combining into larger flotation complexes, and then float into a foam layer, which is collected in the foam trough 4 and then discharged through the branch pipe 5. The flotilla is then absorbed into the ejector 19, where, under the action of compressed air, the foam product is destroyed and converted into a liquid containing the original contaminants. After the ejector, the liquid is sent to the hydrocyclone 8, where it is separated into a condensed concentrate of activated sludge and a purified liquid. Further, the condensed concentrate enters the inner space 14 of block 13 through

pipeline 11, in which a bag of synthetic fabric is placed. Under the influence of external forces from the control devices 15, dewatering of the sludge in the bag occurs. In this case, the leachate is squeezed from the sediment, which is collected in the pallet 17, and the dehydrated sediment is removed along with the bag.

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

It should be noted that using a flocombine with a vibrating block, it is possible to obtain a sufficiently high degree of separation of activated sludge from water, exceeding in some cases by 20-25% the same indicator using known analogue devices. In addition, in this case, a precipitate is obtained, dehydrated to a residual moisture content of 85-90%.

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

After the silt mixture and the working fluid enter the working space of the flotation combine, a particle-bubble is formed. At the same time, as a rule, not all particles of activated sludge stick together with air bubbles and remain in a single state or in the form of aggregates precipitate.

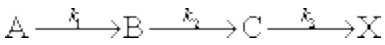
Particles stuck together with small bubbles form microflotocomplexes that slowly float and in this connection they are carried away by the flow of the purified liquid moving in a horizontal direction. Such microflotocomplexes, reaching the reticulate septum, come into contact with each other with the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

Let's denote the concentration of contaminants in water in the form of C, where part of the contaminants that have hydrophobic properties is C^1, and the other part in the form of C^2 is hydrophilic pollution.

Herewith

$$C = C^1 + C^2$$

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



For initial conditions: t = 0, $C^1_A = a_0$, $C^1_B = C^1_C = C^1_X = 0$.

Kinetic equations are:

$$\frac{dC^1_A}{dt} = -k_1 C^1_A$$

$$\frac{dC^1_B}{dt} = k_1 C^1_A - k_2 C^1_B$$

$$\frac{dC^1_C}{dt} = k_2 C^1_B - k_3 C^1_C$$

$$\frac{dC^1_X}{dt} = -k_3 C^1_C$$

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

Decision:

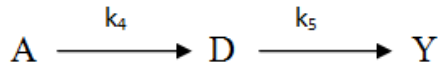
$$C_A^1 = a_0 e^{(-k_1 t)}$$

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

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

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

For the accompanying settling process we have:



with initial conditions: t = 0, C2A = b0, C2D = C2Y = 0.

the following kinetic equations can be written:

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

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

Here are the constants k4... k5 is characterized by the rates of transition of extracted hydrophilic particles from state A to D and Y to obtain a condensed precipitate.

Decision:

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

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

At

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

the concentration of the intermediate product reaches a maximum:

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

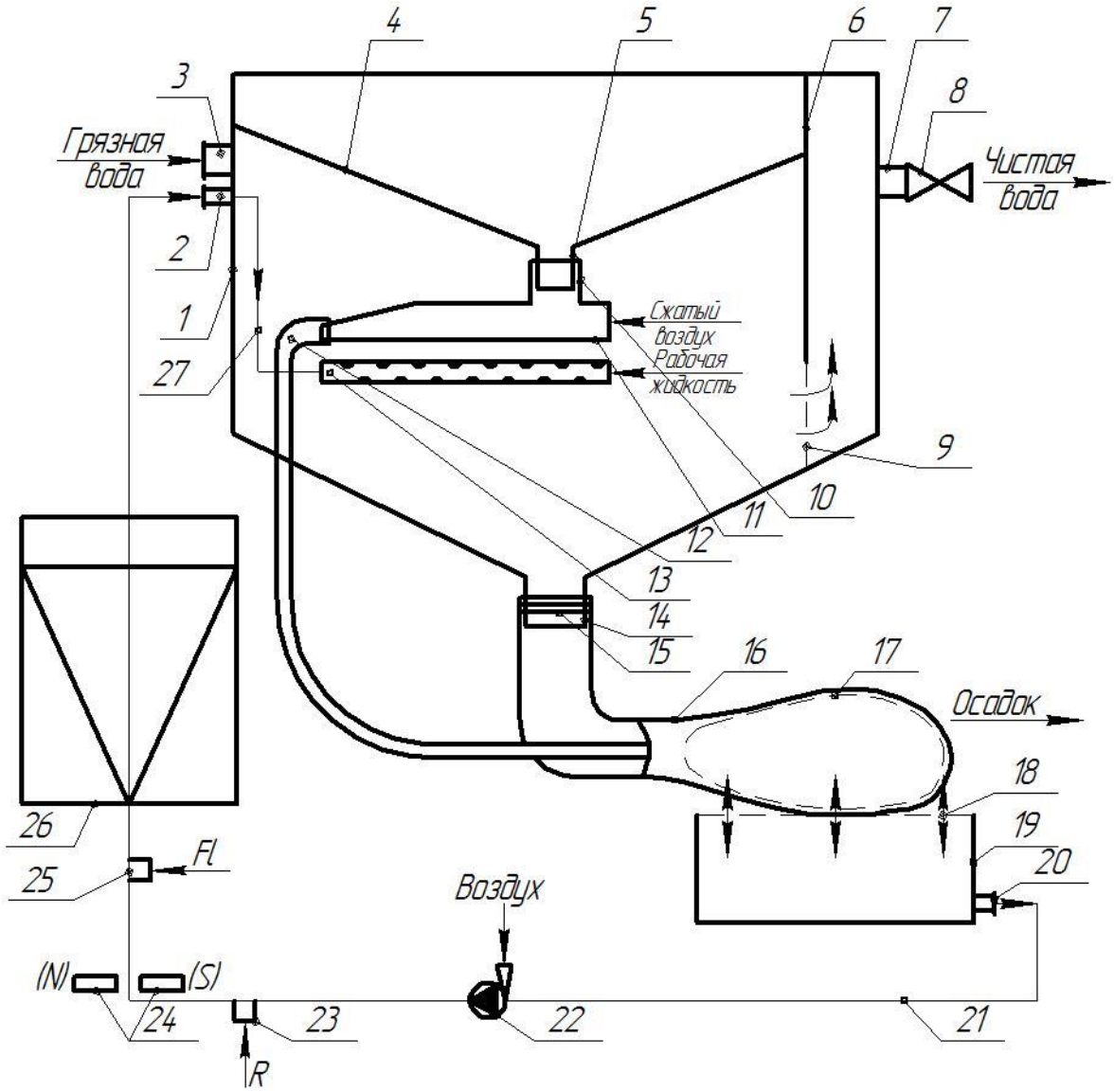
Concentration of the final product:

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

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

An improved version of the apparatus described above is the flotocombine, which includes body 1, (Fig. 1). 4.29), on the outside of which there are branch pipes 2 and 3 respectively for the supply of recirculating liquid and source (dirty) water, as well as a foam trough 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 sediment 14, on which the cover 15 of the bag 16, having pores 17, is worn. 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.



1 – Flotation combine body; 2 – branch pipe for supplying recirculating liquid; 3 – dirty water supply pipe; 4 – foam gutter; 5 – branch pipe for the output of the foam product; 6 – semi-submersible partition; 7 – clean water outlet pipe; 8 – adjustment valve; 9 – filter mesh; 10 – connecting element; 11 – ejector; 12 – connecting hose; 13 – perforated element; 14 – 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. 4.29 – Scheme of the flotation combain (Patent of the Russian Federation No. 2658411; author Ksenofontov B.S.)

The principle of operation of the flotation combine is as follows. The dirty water entering through the branch pipe 3 is mixed with the recirculating and working fluids, which leads to the formation of flotation complexes and aggregates of pollution particles without bubbles, which within about 15-30 minutes are separated respectively into a foam layer and sediment. The foam layer is removed into the foam chute 4 and then enters through the nozzle 5 by sucking into the ejector 11 and further through the hose 12 into the bag 16. Aggregates of contaminant particles without air bubbles precipitate, which through the branch pipe 14 and further through the cover enters the bag 16. The mixture of precipitate and foam product entering the bag 16 is dehydrated by gravity removal of moisture and the simultaneous intensifying action of the vibrating platform 18. The resulting filtrate is discharged through the branch pipe 19 and is further used as a recirculating liquid supplied to the workspace through the branch pipe 2. The dehydrated precipitate is removed along with the sac 16.

Pure water is discharged from the working space of the housing 1 sequentially through a lower window with a mesh 9 of the semi-submersible partition 6 and then through a branch pipe 7 with the possibility of regulating the discharge flow.

The use of the proposed version of the flotation combain makes it possible to obtain active sludge from concentrations up to 10%.

.

It should be noted that the beginning of the flotation process in such an apparatus occurs at the stage of conditioning with the formation of particle-bubble flotation complexes. 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.

Particles stuck together with small bubbles form microflotocomplexes that slowly float and in this connection they are carried away by the flow of the purified

liquid moving in a horizontal direction. Such microflotocomplexes, reaching the reticulate septum, come into contact with each other with the formation, as a rule, of larger vesicles, which quickly surface, forming a flotilla. Purified water, passing through the mesh partition, is removed using a special device and then removed from the flotation combine through the outlet pipe. The effect of water purification in this case significantly exceeds the results achieved on analog installations.

Another version of the flotation combain (application for invention 2017141314/05; author Ksenofontov B.S.) includes a housing 1 (Figure 4.30), on the outside of which there is an ejector 2 with pipes for supplying silt mixture with reagents 3, air 4, a foam gutter 5 with an outlet pipe 7, a connectinghose 11 with a branch pipe 16, and outlet pipes for clarifiedwater 10 and sediment 17, and inside the housing there are partitions 6 and a partition with a window, closed mesh 8 and a device for regulating the level of clarifiedwater 9. To supply the working fluid in the form of a water-air mixture, a branch pipe 22 is installed. At the bottom of the body 1, a screw thickener 13 with an auger 1 5 installed inside it, driven into rotation by an electric motor 12 , is additionally placed as a condensation unit for condensation of the sediment , and on the outside there is a branch pipe 14 for the output of the fugate and a condensed sludge collection chamber 21 with a false perforated bottom 18 installed inside it and on the outside a branch pipe 19 for the output of clarified water and a branch pipe 20 for the output of condensed sediment. In this case, the screw 15 is made with a length that is in relation to the diameter of the screw from 25: 1 to 35: 1 . Installed inside the body of the flotation combine, partition 8 with a window closed with a grid has a cell size of 0.01 to 0.7 mm. At the same time, the mesh is made of magnetic material, and the sediment collection chamber has aperforated false bottom with a live section of 20 to 60% of the total bottom area, and the perforations of the false bottom have the shape of squares with square side dimensions from 0.1 to 0.9 mm.

The principle of operation of the proposed flotation combine is as follows. The silt mixture is fed into the body 1 of the flotation combine through the branch pipe 3 of the ejector 2. At the same time, due to the suction, air enters through the nozzle 4. Further, the silt mixture enters the body 1, where simultaneously through the branch pipe 22 the working fluid enters in the form of purified water with air dissolved in it. When these flows are mixed, flotation complexes of active sludge flakes are formed - air bubbles and then they float into the foam layer formed in the foam trough 5.

The foam product then enters through the hose 11 and further through the branch pipe 16 into the screw thickener 13, which is also simultaneously supplied with sediment through the branch pipe 17. The mixture of the foam product and the precipitate is dehydrated by the electric motor rotating under the action of the electric motor 12, the screw 15, and then enters the chamber 21, condensing to the consistency of the dehydrated product by additional fluid removal by using a false bottom 18 with a live section of 20 to 60% and perforations in the form of squares with a side from 0.1 to 0.9 mm. In this case, the liquid separating from the sediment in the form of a fugate is removed from the screw thickener through the branch pipe 14. Dehydrated to about 80-90% residual moisture, the precipitate is removed from the chamber 21 through the branch pipe 20 and the liquid through the nozzle 19. Obtaining the lowest residual moisture is facilitated by the choice of the length of the screw, which in the optimal case is in relation to the diameter of the screw from 25: 1 to 35: 1. At the same time, as experiments have shown, the optimal value of the false bottom is within 20 - 60% of the total area of the bottom of the chamber 21, and the perforations of the false bottom, having the shape of squares, are optimal with the side of squares from 0.1 to 0.9 mm.

Clarified water passes through the windows of partitions 6 and partition 8 with a window closed with a grid that does not allow flotation complexes that do not have time to surface into the foam layer. This makes it possible to achieve high

efficiency of separating the flakes of activated sludge from water with the size of the mesh cells covering the window of partition 8 in the range from 0.01 to 0.7 mm. When using the grid outside the specified limits, the cleaning efficiency decreases, namely, with cell sizes less than 0.01, resistance to water movement increases sharply, and with dimensions of more than 0.7, there is a slippage of flotation complexes of particle-bubbles. At the same time, ferromagnetic particles can additionally linger on the grid, since the grid material can be magnetic.

Further, the clarified water through the liquid level control device 9 and the branch pipe 10 is removed from the body 1 of the flotation combine and can be used for its intended purpose.

The use of the proposed flotation combine can increase the efficiency of separating activated sludge flakes from water by about 15 -20% and increase the degree of condensation of the sludge by 1.5 - 2.2 times.

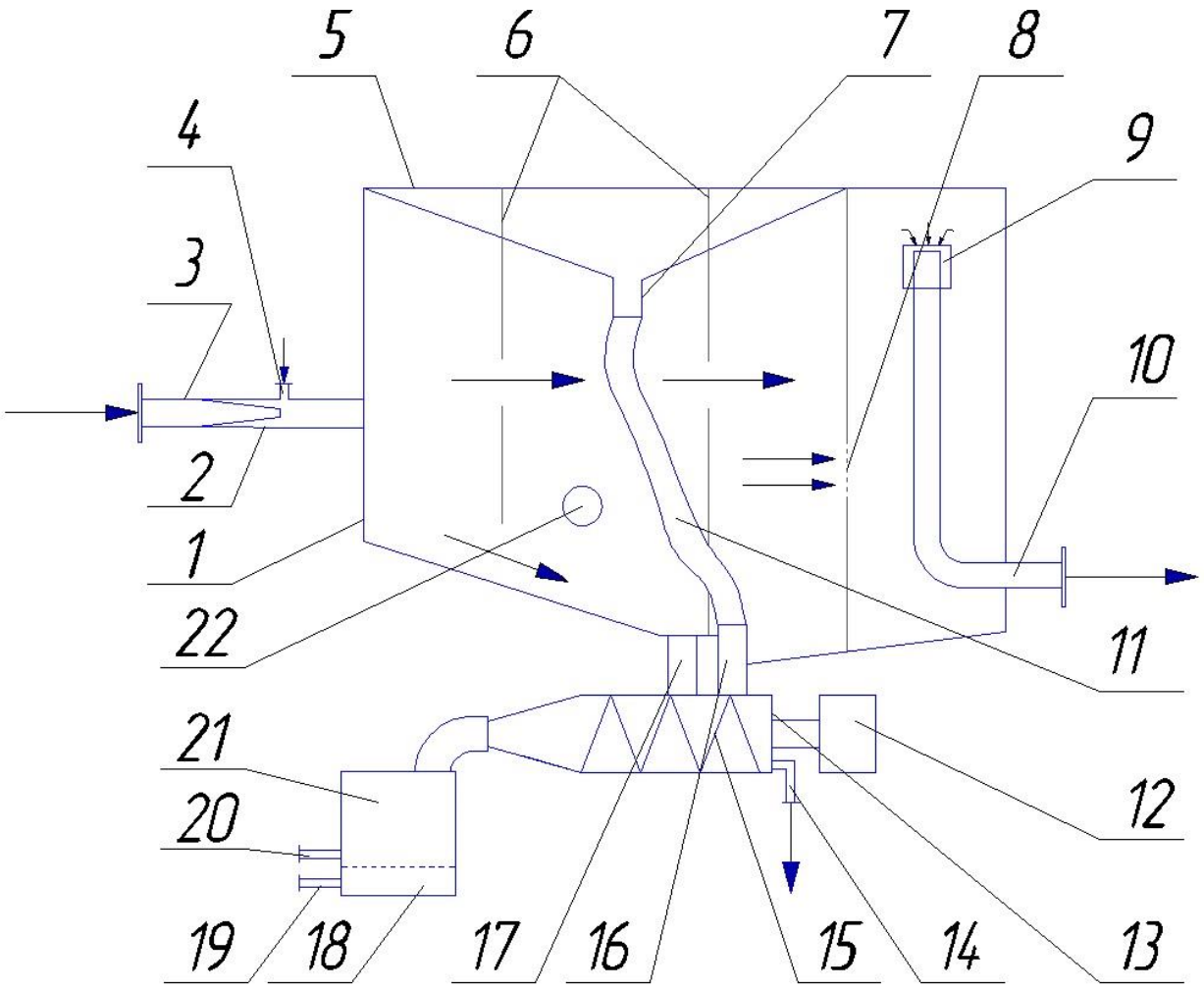


Fig. 4.30. Scheme of the flotation combine

(request for invention 2017141314/05; author Xenophontov B.S.)

The use of the proposed flotation combine can increase the efficiency of separating activated sludge flakes from water by about 15 -20% and increase the

degree of condensation of the sludge by 1.5 - 2.2 times.

The interaction of complexes with each other and their transition from one state to another forms the basis of models of processes occurring in the fleet combine.

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

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

Kinetic equation:

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

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

$C_A = a_0$,

and in other states:

$C_B = b_0$, $C_X = C_Y = 0$ decision:

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

$$C_A = a_0 - C_X;$$

$$C_B = b_0 - C_Y.$$

$A + B \xrightarrow{k_1} XA + C \xrightarrow{k_2} Y$(pollution A interacts with coagulant B and flocculant C)

Kinetic equation:

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

For initial conditions: t = 0, $C_A = a_0$, $C_B = b_0$, $C_C = c_0$ decision:

c_0 decision:

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

or

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

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

In successive processes, a product of one stage passes into the next herd.

Sequential processes can contain from two to several thousand stages.

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

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

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

Kinetic equations:

$$\frac{dC_A}{dt}=-k_1C_A;$$

$$\frac{dC_B}{dt}=k_1C_A-k_2C_B.$$

Decision: $CA = a_0 \exp(–k_1 t)$,

$$C_B=\frac{k_1C_A}{k_2-k_1}\left[\exp(-k_1t)-\exp(-k_2t)\right].$$

When the concentration of the intermediate product reaches a maximum:

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

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

Concentration of the final product:

$$C_C=a_0\left(1-\frac{k_2}{k_2-k_1}\exp(-k_1t)+\frac{k_1}{k_2-k_1}\exp(-k_2t)\right).$$

Consider the case of ion flotation.

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

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

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

Kinetic equations:

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

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

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

$$\frac{dC_X}{dt} = -k_3 C_C.$$

Decision:

$$C_A = a_0 \exp(-k_1 t);$$

$$C_B = a_0 k_1 (k_2 - k_1)^{-1} \left[\exp(-k_1 t) - \exp(-k_2 t) \right];$$

$$C_C = k_1 k_2 a_0 \left[\frac{\exp(-k_1 t)}{(k_3 - k_1)} + \frac{\exp(-k_2 t)}{(k_2 - k_1)(k_2 - k_3)} + \right.$$

$$\left. + \frac{\exp(-k_3 t)}{(k_3 - k_1)(k_3 - k_2)} \right];$$

$$C_X = a_0 \left[1 - \frac{k_2 k_3 \exp(-k_1 t)}{(k_2 - k_1)(k_3 - k_1)} - \right.$$

$$\left. - \frac{k_1 k_3 \exp(-k_2 t)}{(k_2 - k_1)(k_2 - k_3)} - \frac{k_1 k_2 \exp(-k_3 t)}{(k_3 - k_1)(k_3 - k_2)} \right]$$

For example, the case of the model of formation of megaaeroflocules

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

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

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

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

Where is m = j.

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

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

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

Kinetic equations:

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

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

Decision:

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

$$C_B = b_O - (a_O - C_A);$$

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

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

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

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

Where A is the initial pollution, P is the non-flotated microflot complex, 2P is the flotated microflot complex.

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

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

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

where , , i is the imaginary unit; $x = a_0\frac{k_2}{k_1}\beta = \frac{iJ_1\left(2i\sqrt{x}\right)}{H_1^{(1)}\left(2i\sqrt{x}\right)}$ J_0, J_1 – Bessel functions; - Hankel functions.$H_0^{(1)}H_1^{(1)}$

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

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

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

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

decision:

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

Where is;;; Ei is $\eta = \frac{k_2 a_0}{k_1}$ $\tau = 1+a_0k_1t$ $C_{p\max} = \frac{1}{2}\eta\tau_{\max}^2 a_0$an integral exponential function.

Consider the flotation of submicrofloral complexes according to the scheme

$$2A\xrightarrow{k_1}P2P\xrightarrow{k_2}C\ ,$$

where A is the initial contamination in the form of an unflated submicroflotocomplex, P is the non-flotated microflotocomplex, C is the state in the foam layer.

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

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

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

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

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

If the process includes a number of successive steps and the velocity constant of one of them is much less than the velocity constant of the other stages, then this step is limiting, and it is she who determines the speed of the entire percentageof the essa. For example, for purification processes using ion flotation, which occurs according to the scheme

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

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

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

$$A \xrightarrow{k_1} P_1$$

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

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

the second stage will be limited, provided that $k_2 < k1$ and $k_2 C_B < k_3 C_C$.

Series-parallel processes flotation and sedimentation:

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

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

Kinetic equations:

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

$$\frac{dC_{\text{P}}}{dt} = k_1 C_{\text{A}} - k_2 C_{\text{P}};$$

$$\frac{dC_{\text{C}}}{dt} = k_1^{'} C_{\text{A}} + k_2 C_{\text{P}}.$$

Solutions:

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

$$C_{\text{C}} = \frac{a_0 k_1^{'}}{k_1 + k_1^{'}}\left[1 - \exp\left(-(k_1 + k_1^{'})\, t\right)\right] + \frac{a_0 k_1}{k_2 - k_1 - k_1^{'}}\{1 -$$

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

$$\frac{dC_{\text{C}}}{d\Delta C_{\text{A}}} = \frac{k_1^{'}}{k_1 + k_1^{'}} + \frac{k_2}{k_1 + k_1^{'}}\frac{C_{\text{P}}}{C_{\text{A}}}.$$

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

$$\text{A} + \text{B} \xrightarrow{k_1} \text{P}_1 \; \text{P}_1 + \text{B} \xrightarrow{k_2} \text{P}_2 \; \text{P}_2 + \text{B} \xrightarrow{k_3} \text{C}$$

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

$$\frac{dC_{\text{P}_1}}{dt} = k_1 C_{\text{A}} C_{\text{B}}, ; C_{\text{P}_1} \cong k_1 a_0 b_0 t$$

$$\frac{dC_{\text{P}_2}}{dt} = k_2 C_{\text{B}} C_{\text{P}_1}, ; C_{\text{P}_1} \cong \frac{1}{2} k_1 k_2 a_0 b_0^2 t^2$$

$$\frac{dC_{\text{C}}}{dt} = k_3 C_{\text{B}} C_{\text{P}_2}, , C_{\text{C}_1} \cong \frac{1}{6} k_1 k_2 k_3 a_0 b_0^3 t^3$$

and the ratio between concentrations to equations:

$$-\frac{d\, C_{\text{P}_1}}{d\, C_{\text{A}}} = \frac{k_1 C_{\text{A}} C_{\text{B}} - k_2 C_{\text{B}} C_{\text{P}_1}}{k_1 C_{\text{A}} C_{\text{B}}} = \frac{\eta_1 C_{\text{A}} - C_{\text{P}_1}}{\eta_1 C_{\text{A}}};$$

$$-\frac{d\, C_{\text{P}_2}}{d\, C_{\text{A}}} = \frac{k_2 C_{\text{B}} C_{\text{P}_1} - k_3 C_{\text{B}} C_{\text{P}_2}}{k_1 C_{\text{A}} C_{\text{B}}} = \frac{\eta_2 C_{\text{P}_1} - C_{\text{P}_2}}{\eta_1 \eta_2 C_{\text{A}}}.$$

Solutions:

$$C_{\text{P}_1} = \frac{\eta_1}{1 - \eta_1} C_{\text{A}} + \frac{\eta_1}{\eta_1 - 1}\left(\frac{C_{\text{A}}}{a_0}\right)^{\frac{1}{\eta_1}} a_0;$$

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

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

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

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

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

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

Kinetic equations:

$$\frac{d C_A}{d t} = -(k_1 C_A + k_2 C_A C_P),$$

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

Solutions:

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

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

Stationary value of intermediate concentration

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

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

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

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

Kinetic equations:

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

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

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

Decision:

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

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

Maximum concentration of intermediate product

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

where for h $\varepsilon = \frac{\eta}{1-\eta}$< 1;

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

Consider the process of coalescence and flotation of microflotocomplexes:

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

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

Kinetic equations:

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

$$\frac{dC_P}{dt} = k_1 C_A - k_2 C_P^2 - k_2 C_P,$$

Solutions:

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

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

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

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

$$C_p = -\frac{k_1\sqrt{\eta_2}}{k_2}\,\sigma\times$$

$$\times\frac{J_{\eta_{11}}(2\sqrt{\eta_2})J_{-\eta_{11}}(2\sqrt{\eta_2}\sigma)-J_{-\eta_{11}}(2\sqrt{\eta_2})J_{\eta_{11}}(2\sqrt{\eta_2}\sigma)}{J_{\eta_{11}}(2\sqrt{\eta_2})J_{1-\eta_{11}}(2\sqrt{\eta_2}\sigma)-J_{-\eta_{11}}(2\sqrt{\eta_2})J_{1-\eta_{11}}(2\sqrt{\eta_2}\sigma)},$$

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

Considerthe investigative processes with equilibrium stages.

For example, reversible first stage flotation:

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

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

Kinetic equations:

$$\frac{dC_A}{dt} = -k_1C_A + k_2C_B;$$

$$\frac{dC_B}{dt} = k_1C_A - (k_2 + k_3)C_B;$$

$$\frac{dC_C}{dt} = k_3C_B.$$

Solutions:

$$C_A = a_0\left\{\frac{\lambda_2 - k_1^{-1}k_3}{\lambda_2(\lambda_2-\lambda_3)}\exp(-\lambda_2k_1t) + \frac{k_1^{-1}k_3 - \lambda_3}{\lambda_3(\lambda_2-\lambda_3)}\exp(-\lambda_3k_1t)\right\};$$

$$C_B = \frac{a_0}{\lambda_2-\lambda_3}\left[\exp(-k_1\lambda_3t) - \exp(k_1\lambda_2t)\right],$$

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

Reversible second stage flotation:

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

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

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

Kinetic equations:

$$\frac{dC_A}{dt} = -k_1C_A;$$

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

$$C_A = a_0 \exp(-k_1 t).$$

Solutions:

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

Flotation with collector and flocculant:

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

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

Kinetic equations:

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

If at t = 0 $C_C = c_0$, and the concentrations of the remaining foodare zero and the equilibrium concentration of , is $C_A = \frac{k_2 C_C}{k_1 C_B}$ quickly established, then

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

Flotation using various reagents:

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

In the case when a stationary concentration of C is quickly reached in the system, we get:

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

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

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

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

In the simplest version of the flotation combine in the form of a flotation settling tank, it is possible to carry out a more complete separation of activated sludge from water compared to the use of conventional equipment, in particular, to increase the degree of extraction (separation) of activated sludge by 10 - 15% and to increase the specific hydraulic load by 20 ... 25% compared to the corresponding indicators of known marine sedimentation tanks.

Testing and implementation of such a flotation settling tank were carried out in the practice of wastewater treatment (Fig. 4.31).

Fig. 4.31 - Photo of the sweepof the shell sample of the flotation tank

Testing and implementation of a flotation settling tank of a rolled structure showed the stability of its operation and the prospects for use in the practice of wastewater treatment.

A high concentration of activated sludge changes its properties - the specific rate of oxidation of organic compounds, the ability of the sludge mixture to separate and precipitate sludge decreases. However, with the exclusion of these shortcomings, the method of intensification of biological treatment with an increased concentration of activated sludge does not allow, in comparison with the

usual method, to increase the depth of treatment according to COD, to reduce the content of specific contaminants in the treated water, which are usually difficult to undergo biological treatment.

2. Use of technical oxygen for aeration

The disadvantages of aeration systems of aeration tanks (air consumption reaches several tens of m3 per 1m3 of wastewater; energy consumption per 1 kg of removed BOD is 1-2 kW / h; efficiency of aeration systems -1.5 -3%) led to the need to use technical oxygen for biological water treatment.

Studies on the use of oxygen for the intensification of biological wastewater treatment, including the development of special oxygen facilities that allow the efficient use of oxygen, as well as the application of this method of intensification on an industrial scale, have shown that the use of pure oxygen can increase the concentration of dissolved oxygen in the silt mixture from 1-2 to 4-8 mg / l. With an increase in the oxygen concentration from 0 to 6 mg / l, the oxidative power of the aeration tank increases to 3 -7 kg BOD/m3sut. A further increase in the concentration of dissolved oxygen slightly increases the oxidative capacity of the structure.

The use of technical oxygen in the biological treatment of wastewater not only increases the oxidative capacity of the aeration tank, but also significantly reduces the required aeration time.

Reducing the aeration time, and increasing the oxidative capacity allows to increase the productivity of treatment facilities.

In addition, it was found that an increase in the concentration of dissolved oxygen in aeration tanks (oxytenki) increases the specific rate of removal of organic contaminants, increases the degree of purification.

Recently, more and more attention of specialists is attracted by the possibility of intensifying biological wastewater treatment by supplying an ozone-air mixture to the aeration tank. This method of intensification of the biological treatment process can significantly increase the efficiency of cleaning for BOD, COD and suspended substances. Supplying an ozone-air mixture for aeration with an ozone concentration of 1 mg/L increases the degree of BOD purification from 70% to 95%. When supplying an ozone-air mixture in pulsed mode (10-15 minutes per hour), the residual COD is 1.3 times less than with the usual (air), with the same aeration time. Experimental studies show that ozone in small doses has a positive effect on various processes that take place during biological wastewater treatment. The supply of ozone to the sludge mixture during aeration allows to increase the speed and degree of biological treatment for BOD and COD while reducing the time Aeration. Ozonation affects the main characteristics of activated sludge: the sludge index decreases, the time of compaction of activated sludge, the specific resistance of the sediment. At the same time, the increase in activated sludge decreases, which leads to a decrease in the amount of excess sludge and the cost of its processing.

The use of an ozone-air mixture in the process of wastewater treatment does not require a complex re-equipment of existing aeration tanks. However, the widespread implementation of the advantages of this method is constrained by the lack of a deep well-developed justification for the use of ozone in the technology of treatment facilities, the lack of recommendations for its practical application, and the optimal norms of technological regimes.

3. Bioadsorption method of biological wastewater treatment

Biosorption is a method that combines the processes of adsorption and biochemical oxidation, which is widely used to intensify the process of biological purification. The effectiveness of this method is achieved by the high sorption

capacity of adsorbents to active sludge bacteria and to various classes of organic compounds. The most probable mechanism of action of adsorbents and activated sludge is to increase the physiological activity of attached bacterial cells, increase the concentration of the substrate due to its sorption on the surface of the adsorbent. enrichment of the medium with exoenzymes.

The type of sorbent used may be different. It is most often proposed to use powdered active carbon (PAHs) of the AG-3, KAD brand for the intensensification of the biological treatment process. Other materials can also be used as a sorbent, for example, crushed non-activated anthracite, sorbent KDT, etc.

The sorbent is injected directly into the aeration tank, together with circulating active sludge in an amount of 0.1 g / l to 10-20 g / l. Additives of adsorbents in the aeration tank increase the degree of wastewater treatment according to COD and BOD. For example, in the treatment of wastewater of petrochemical plants with COD = 14800 mg / l and BOD5 = 7470 mg / l after bioadsorption treatment, wastewater had COD and BOD20 - 55 and 11 mg / l, against 540 and 280 mg / l after conventional biochemical treatment.

Additives of adsorbents to the sludge mixture make it possible to increase the depth of treatment for specific pollutants contained in wastewater. So, when adding PAHs to the sludge mixture, the degree of water purification from petroleum products increased by 25-30%.

In many studies of the biosorption method, there is an improvement in the sedimentation properties of sludge: the silt index decreases, the color and smell of nadil water decreases.

The main restraining principle of the applicationof the biosorption method is the loss of the sorbent due to its removal with excess active sludge, loss due to abrasion during aeration and removal from secondary sedimentation tanks.

4. Use of mutagenesis

The use of the method of chemical mutagenesis made it possible to form populations of microorganisms that are well adapted to elevated substrate contents and are able to competitively suppress the development of pathogenic and filamentous bacteria. The change in the cenosis of activated sludge goes in the direction of adaptation to the physicochemical and biological specifics of a given effluent and is a microflora containing all the enzyme systems necessary for the degradation of pollutants characteristic of these objects.

Active sludge after special treatment improved its sedimentation properties. At the same time, a steady effect was achieved by increasing the speed and depth of removal of pollutants and improving the moisture-giving properties of sludge. In addition, the use of the method of chemical mutagenesis to improve the properties of activated sludge has significantly increased the hereditary diversity of microorganisms of activated sludge and significantly improved the quality of biological purification. Chemical mutagens contribute to the appearance of new, rare mutations, the beneficial properties of which are to increasephysiological activity, as well as its resistance to adverse factors. As a result of mutations, completely new enzymes can arise that can oxidize a substrate that is not degraded by ordinary active sludge.

New forms of microorganisms with an enriched set of enzymes arise as a result of their modification and mutation. Mutations can be natural with the sequential selection of those forms whose enzyme systems correspond to the substrates of the environment and are induced directly by the substrate, i.e. the chemical compound on which the enzyme system can act.Treatment of activated sludge with mutagens allows you to get active sludge capable of purifying wastewater with a higher concentrationof organic contaminants and at the same time achieving an increased degree of purification, It has been established that

mutagen treatment of activated sludge in the amount of 0.1 - 0.5 of the total volume allows to increase the degree of biological treatment of wastewater according to COD from 55-72% to 80 -95%. Mutagenic treatment of activated sludge allows to achieve a deep degree of treatment of wastewater containing certain types of organic contaminants. For example, the use of mutagenesis allows to increase the degree of wastewater treatment, the use of mutagenesis is complicated by the fact that with a non-stationary mode of discharge of wastewater to treatment facilities, with sharp changes in the concentration of pollutants, some of the mutants are not preserved and the initial state of the activated sludge is restored. Also, the use of chemical mutagenesis is associated with the complexity of processing activated sludge with mutagen. With significant fluctuations in the flow rate of wastewater and the concentration of pollution, this requires enhanced control:

- For the operation of structures;

- the concentration of the injected mutagen;

- the frequency of administration and the duration of treatment of activated sludge. All thiscomplicates the work of treatment facilities The use of this method is justified in local installations with a relatively constant composition of contaminants, for wastewater treatment of a specific workshop or a separate production plant.

5. Use of special strains and adapted microorganisms

Oneof the possible ways to intensify the process of biological wastewater treatment can also be the use of special strains of bacteria and adapted microorganisms. The use of strains of microorganisms is effective in the treatment of wastewater of a certain composition with specific contaminants. Adapting them to a certain type of pollution allows you to accept more highly concentrated

wastewater for treatment and purify it with a high degree. For example, specific complexes of bacteria were bred to release wastewater from pyridine, methanol and acetic acid. These microorganisms are able to oxidize 98.9 -99.2% of methyl alcohol at its initial concentration of 400-500 mg / l within three days, completely oxidize acetic acid at its concentration of 400 -500 mg / l, reduce the pyridine content by 90 -100% at an initial concentration of 260 -370 mg / l.

The use of specialized microorganisms and biocenoses in conventional aeration tanks is complicated by the fact that microorganisms of many species most often do not form zooglean clusters, do not give sediment and are carried out of the aeration zone. To improve settling, coagulation, flotation, centrifugation are used, which requires additional costs. With a high concentration of contaminants in wastewater entering for treatment in aeration tanks with specialized microflora, the residual concentration of contaminants is quite large and it is necessary to finish wastewater treatment at the second stage with ordinary active sludge.

Therefore, the use of microbiological methods is advisable at local installations with a low wastewater flow rate and a constant composition of contaminants, or at stage 1 facilities, followed by biological treatment facilities of the usual type.

Abstract topics

1. Modern technologies of biological wastewater treatment.

2. Technologies of biological wastewater treatment at wastewater treatment plants in Moscow.

3. Technologies of biological wastewater treatment at sewage treatment plants in St. Petersburg.

4. Modern technologies for the removal of biogenic elements in foreign practice.

5. Theoretical basis of the Modified Bardenpho process.

6. Theoretical foundations of the UCT process.

7. Theoretical foundations of the JHB process.

8. Application of membrane technologies in foreign practice of biological wastewater treatment.

9. Methods of intensification of biological wastewater treatment.

10. Differences in approaches and technologies to the tasks of biological wastewater treatment abroad and domestic practice.

4.5. Introduction of new technologies on the example of JSC Mosvodokanal

(According to the official website of JSC Mosvodokanal, reports and publications of employees of JSC Mosvodokanal, authors Kozlov M.N. and others.)

The main directions of development of the capital's sewage treatment plants are their reconstruction with the transition to modern technologies for the removal of nitrogen and phosphorus and the introduction of ultraviolet disinfection systems. The combination of these two technologies makes it possible today to return water to nature, which fully complies with domestic sanitary and hygienic requirements and European standards.

It is known that many new technologies for wastewater treatment were tested and tested at the treatment facilities of Moscow, consider the treatment facilities of "old" Moscow, which include the combined Lyuberetsky and Kuryanovsk treatment facilities, as well as small facilities in Zelenograd and Yuzhnoye Butovo.

Lyuberets treatment facilities (VOC) with a capacity of 3 million m3 / 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. The processes occurring here are akin 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.

The technological scheme of wastewater treatment of Lyuberets treatment facilities is presented in Fig. 4.32.

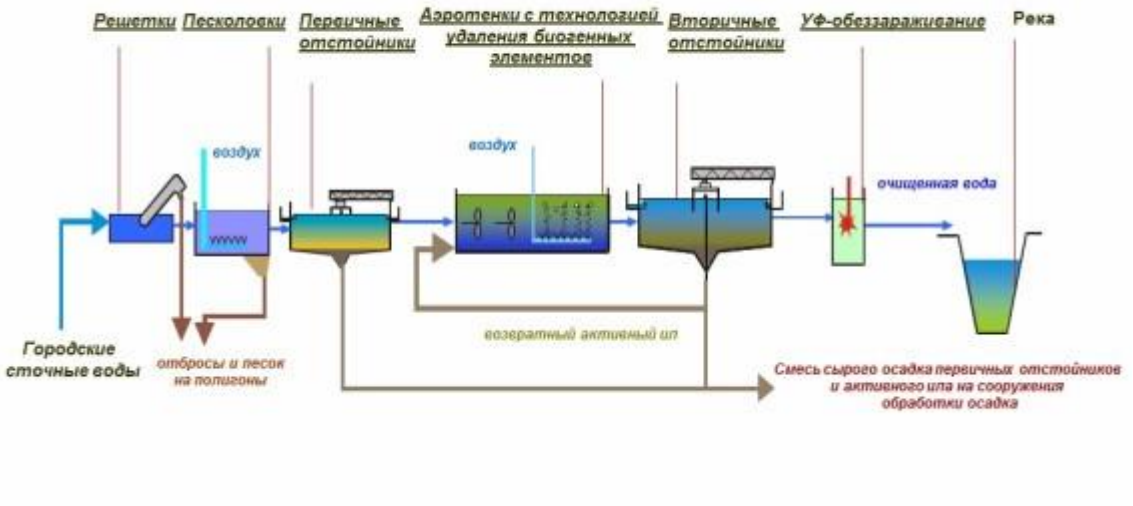


Fig. 4.32. Schematic andechnological scheme of wastewater treatment of Lyuberetsky wastewater treatment plants (Official site of JSC Mosvodokanal)

The LOS complex includes three independently functioning wastewater treatment units: the Staraya Station (LOSSt.) with a design capacity of 1.50 million m3 per day, the I unit of the Novolyuberetsky wastewater treatment facilities (NLOS-1) - 1 million m3 per day and the II block of the Novolyuberetsk wastewater treatment facilities (NLOS-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 VOC: household items of citizens, garbage of food production, plastic containers and plastic bags, as well as construction and other garbage. To remove them on VOCs, 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 VOC 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 treatment of wastewater 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.

Kuryanovsk sewage treatment plants

Kuryanovsk wastewater treatment facilities (KOS) with a design capacity of 2.2 million m3 / day, which are the largest in Europe, provide reception and treatment of household and industrial wastewater of the north-western, western, southern, south-eastern districts of Moscow (60% of the city's territory) and, in addition, a number of cities and towns of the Moscow region. with a capacity of 1.0 million m3 per day, the I unit of the Novokuryanovsk wastewater treatment facilities (NKOS-1) - 600 thousand m3 per day and the II block of the Novokuryanovsk treatment facilities (NKOS-2) - 600 thousand m3 per day.

KOS work according to the technological scheme of complete biological treatment, including at the reconstructed structures of NKOS-I and NKOS-II with the removal of biogenic elements: the first stage is mechanical purification, including filtering water on the 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. Part of the biologically treated wastewater is subjected to post-treatment on fast filters and is used for the needs of industrial enterprises instead of tap water.

With wastewater, a large number of different types of garbage enter the KOS: household items of citizens, garbage of food production, plastic containers

and plastic bags, as well as construction and other garbage. To remove them, mechanized grates with gaps of 10 mm are used on the KOS.

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. Various types of sand traps are operated at the KOS - vertical, horizontal and aerated.

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 at the KOS are of open type and have a radial shape, with different diameters - 33, 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, 4-corridor type. The working depth of the aeration tanks of the old unit is 4 m, the NKOS aeration tanks - 6 m. Biological treatment of wastewater 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.

The entire volume of wastewater treated at the KOS enters the after-treatment facilities. The capacity of the straining department is 3 million m3 / day, which allows the entire volume of biologically purified water to pass through flat slotted sieves. Part of the water after filtering is filtered on fast filters and is used for technical needs as a circulating water supply.

Since 2012, all wastewater that has undergone a full cycle of treatment at the Kuryanovsk wastewater treatment plants has been subjected to ultraviolet disinfection before discharge into the Moscow River (capacity 3 million m3 / day). Due to this, the indicators of bacterial contamination of biologically purified KOS water reached normative values, which had a beneficial effect on the quality of the water of the Moscow River and the sanitary and epidemiological state of the water area as a whole.

Sediments formed at various stages of wastewater treatment are supplied to a single sludge treatment complex, which includes sludge compactors and belt thickeners, methane tanks, decanter centrifuges for sludge dewatering using flocculants.

Experience of JSC "Mosvodokanal" on the removal of biogenic elements

(according to MOSVODOKANAL JSC, presented in the form of reports on Ekvatek 18 and publications in journals of recent years. authors: Kozlov M.N. et al.)

The experience of practical implementation of technologies for the removal of biogenic elements, in our opinion, is probably the largest at the treatment facilities of MOSVODOKANAL JSC. And in this regard, the data that are presented by the relevant servicesof Mosvodokanal JSChave not only great practical, but also significant cognitive interest. This is especially true for the introduction of such technologies at large and ultra-large facilities of Mosvodokanal JSC.

Recall that from 01.01.2019, the requirements of the Federal Law "On Amendments to the Federal Law "On Environmental Protection" and Certain Legislative Acts of the Russian Federation" dated 21.07.2014 No. 219-FZ on the transition of sewage treatment plants with a capacity above 20 thousand m3 / day (I category of nature users) to rationing for integrated environmental permits, that

is, according to technological standards of the best available technologies in accordance with the Information and Technical Handbook on BAT (ITS 10-2015).

It is known that the Kuryanovsk and Lyuberets treatment facilities of MOSVODOKANAL JSC in accordance with ITS 10-2015 belong to ultra-large treatment facilities (design capacity of each up to 3 million m3 / day), consisting of the largest blocks (500-600 thousand m3 / day). In accordance with ITS 10-2015, the best available technologies for such facilities are:

- Purification with biological removal of nitrogen and phosphorus with acidification (BAT 7e)

- Purification with biological removal of nitrogen and biological-chemical removal of phosphorus (BAT 7g)

- Purification with biological removal of nitrogen and biological-chemical removal of phosphorus with acidification (BAT 7z).

For these technologies, the indicators and standards are given in Table 4.8 in accordance with ITS 10 – 2015.

Table 4.8. Technological and standards for BAT 7d – 7z.

(Kozlov M.N. et al. Ekvatek 18)

Technological indicator	Unit	Value for BAT 7d-7z, not more than (values are given as annual averages)
Suspended solids	mg/l	10
BOD_5	mg/l	8
Cod	mg/l	80
Nitrogen of ammonium salts	mg/l	1
Nitrate nitrogen	mg/l	9 (11 with a ratio of $N\text{-}NH_4$ and BOD_5 greater than 0.25)
Nitrite nitrogen	mg/l	0,1
Phosphorus phosphates	mg/l	0,7

It is known that Moscow wastewater is lowly concentrated in organic pollution. In this regard, acidification is extremely relevant for Moscow treatment plants to increase the content of biodegradable organic matter in wastewater for the effectiveness of denitrification and dephosphatization. This is reflected in an increase in the ratio of BOD5/N and BOD5/P.

Removal of nutrients at the Lyuberetsky wastewater treatment plantx

The VOC Nutrient Removal Unit (BUBE) with a flow rate of 0.5 million m3/day was immediately inspected with nutrient removal technology. Bat 7e technology was introduced at the unit - purification with biological removal of nitrogen and phosphorus with acidification. Since 2006, the unit has been operating using UCT technology (a scheme of the University of Cape Town) - the biological removal of nitrogen and phosphorus. In 2012, the UCT-K process, an alternative to the acidification process, was introduced at the unit (Mosvodokanal JSC signed a license agreement for the right to use a patent for invention No. 2424199 "Method for biological treatment of wastewater with activated sludge", in which a method for fermentation of sediment in the anaerobic zone of an aerotank operating according to the UCT scheme) was patented. The achieved quality of water purification meets the standards.

Removal of biogenic elements at the Kuryanovsk sewage treatment plant x

The new Kuryanovsk Wastewater Treatment Plant (NKOS) consists of two units NKOS1 and NKOS-2, which were built and launched in 1971 and 1977 according to the technological scheme of oxidation of organic pollution, respectively. The total capacity of the units was 2 million m3 / day. In the period 2012-2018, a phased reconstruction of these blocks is taking place with the introduction of technology for the removal of nutrient elements with acidification

(BAT 7e). The project includes the reconstruction of aeration tanks with the introduction of anaerobic, anocyclic and aerobic zones according to the UCT scheme, parts of the primary settling tanks into secondary sedimentation tanks, activated sludge seals into acidifiers, replacement of blowing equipment, reconstruction of sand traps and grates, introduction of a process automation system. As is known from the literatureand practical experience, when switching to modern technologies in the volumes of existing aerotanks, it is necessary to reduce the productivity of structures, since the implementation of four processes (oxidation of organic compounds, nitrification, denitrification, biological removal of phosphorus) requires more purification time than provided for by old projects. The productivity of NKOS after reconstruction will be 1.2 million m3 / day (60% of the productivity block before reconstruction). In November 2014, work on the reconstruction of NKOS-1 aeration tanks was completed. In January 2015, the load was completely redistributed from NKOS-2 to NKOS-1, the NKOS-2 facilities were put out for reconstruction. During the reconstruction of NKOS-2, the hydraulic load on NKOS-1 was 800-1000 thousand m3 / day. In this regard, the implementation of the technology for the joint removal of nitrogen and phosphorus in NKOS-1 aeration tanks was not possible (it was previously assumed that an oxidative treatment scheme would be used for the period of reconstruction of NKOS-2). Nevertheless, technological calculations have shown that under these conditions the technology of nitrification / denitrification can be implemented with the allocation of two zones - anoxid and aerobic. In March 2015, work was carried out on the transfer of NKOS-1 aeration tanks to the technological scheme of nitrification / denitrification with a hydraulic load of 800 thousand m3 / day. The commissioning of facilities using nitrification /denitrification technology is described in detail in Article [7], where it is concluded that it is advisable to work during the reconstruction of the technological scheme of nitrification / denitrification. Compared to the traditional oxidative scheme, denitrification

provides greater nitrogen removal efficiency (by the sum of the three inorganic forms). After the completion of the reconstruction of the NKOS-2 facilities, both units of the facilities (NKOS-1 and NKOS-2) will be fully transferred to the technology of biological removal of biogenic elements (NPR-technology), developed by specialists of JSC Mosvodokanal and tested in 2002-2004 at the aerotank No. 14 of the Lyuberets treatment facilities At the end of 2017, the reconstruction of the NKOS-2 aerotanks was completed. However, the reconstruction of the unit remains incomplete: part of the primary settling tanks has not been converted to secondary sedimentation tanks, activated sludge compactors into acidoficators, the reconstruction of sand traps and grates has not been carried out, the implementation of the process automation system has not been completed. Under these conditions, the implementation of the technology of joint removal of nitrogen and phosphorus in NKOS-2 aeration tanks is not possible. Therefore, the NKOS2 aeration tanks were put into operation using nitrification/denitrification technology, as well as the aerotanks of the NKOS-1 unit. The cleaning quality at the NKOS-1 and NKOS-2 units is close to the currently existing standards (PDKrybkhoz) and meets the technological standards of the best available technologies (Table 4.9).

Table 4.9. Concentrations of pollutants in incoming and purified water of NKOS (Kozlov M.N. et al. Ecwatek 18).

Index	suspended solids, mg/l	COD, mg/l	$N\text{-}NH_4$, мг/л	$N\text{-}NO_2$, мг/л	$N\text{-}NO_3$, мг/л
Coming	90-115	300-340	28-35	0	0

Purified	6-9	40-50	0,3-0,4	0,02-0,05	9-12
$MPC_{fish\ farm}$	11		0,4	0,02	9,1
Technological standard of BAT	10	80	1	0,1	9-11

The data obtained are confirmed by extensive experience in the operation of treatment facilities.

Treatment facilities "Yuzhnoye Butovo"

Treatment facilities "Yuzhnoye Butovo" with a capacity of 80 thousand m3 per day were built according to the concession model "VOOT" ("build - own - operate - put into operation to the city").

Currently, in connection with the expiration of the Investment Agreement (between MOSVODOKANAL and TSV Helter, concluded in 2000), from 01.11.2012, the treatment facilities were transferred to the economic management of Mosvodokanal as a workshop for integrated water purification of the Kuryanovsk treatment facilities.

Technological processes at treatment facilities include (Fig.4.16): mechanical wastewater treatment (receiving chamber, grates, aerated sand traps), biological treatment with deep removal of nitrogen-containing and phosphorus compounds (phosphorus pools, aeration tanks, secondary sedimentation tanks), post-

treatment on sand filters, ultraviolet disinfection of water at UV channel type installations. Processes are fully automated.

At the treatment facilities, the treatment of sludge - excess activated sludge is provided, including sealing and mechanical dewatering on filter presses using reagents (ferric chloride and lime). The dehydrated sludge is disposed of together with the dehydrated sediments of the Lyuberets treatment facilities of Mosvodokanal JSC.

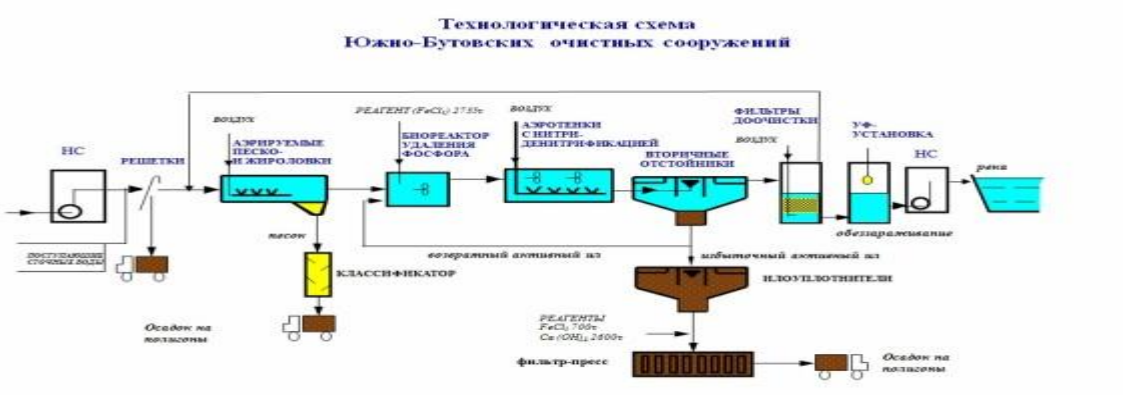


Fig.4.33. Scheme of treatment facilities "Yuzhnoye Butovo" (according to JSC Mosvodokanal)

Treatment facilities in Zelenograda

In connection with the tightening of requirements for the quality of treated wastewater, on the territory of the Zelenograd aeration station in 2000, treatment facilities designed to remove nitrogen and phosphorus compounds with a capacity of 140 thousand m3 per day were put into operation.

The facilities were built according to the concession model "VOOT" ("build - own - operate - transfer to the city") with the attraction of foreign investment. Currently, in connection with the expiration of the Investment Agreement (between Mosvodokanal and TSWHelter, concluded in 1998), from 01.07.2013, the treatment facilities were transferred to the economic management of Mosvodokanal JSC.

The technological scheme of water purification includes (Fig.4.34)::

biological treatment (three-line grate, sand trap, phosphorus pools, aeredemas designed for the removal of biogenic elements, secondary sedimentation tanks);

additional cleaning using rapid filters and with water disinfection with ultraviolet light.

Sludge treatment is absent at these treatment plants. Excess activated sludge is discharged into the centralized wastewater disposal system of Moscow at the Kuryanovsk treatment facilities.

Fig.4.34. Scheme of Zelenograd treatment facilities (according to JSC Mosvodokanal)

The prospects for the introduction of membrane technology at Moscow wastewater treatment plants are becoming a reality.

Theadvantages ofthe technology withthe use of membrane bioreactors include a significant reduction in the volume of structures and the area occupied by them due to the high concentration of activated sludge; the possibility of a higher load per unit of volume, as well as a significant reduction in the amount of excess activated sludge. In this regard, membrane technologies represent one of the prospects for the development of treatment facilities in conditions of limited territories.

The introduction of technologies for removing nitrogen and phosphorus from municipal wastewater leads to the need to increase the volume of bioreactors (by 20–30%) and secondary sedimentation tanks (by 15–20%) compared to traditional water treatment technologies in aeration tanks. In conditions of high cost of urban land areas, it is necessary to search for highly efficient technologies that allow for deep wastewater treatment without increasing the volume of structures, as well as the reliability of their operation. Membrane biological reactors (MBR reactors) have gained recognition in the world, as they provide a consistently high quality of purification, including from biogenic elements, while reducing the volume of existing biological treatment facilities. The world experience of operating MBR reactors on an industrial scale for a long time (at a number of treatment facilities - more than 10 years without replacing membranes) shows high reliability of both the equipment and the technology itself.

Large-scale use of MBR reactors has become available only in the last 10-15 years. The technology based on membrane filtration is now successfully used, primarily in relatively small structures. High capital and operating costs, as well as insufficient experience in the operation of MBR reactors in wastewater treatment,

limit the spread of this technology. At the same time, with the advent of less expensive and more efficient MBR modules and the introduction of more stringent requirements for the quality of treated water in developed countries, interest in MBR technology has increased significantly.

Since the mid-1990s, thanks to improvements in the design of cheaper membranes, MBR reactors have become a viable alternative to traditional technology in full-scale, high-capacity wastewater treatment plants. In Europe, such municipal wastewater treatment plants were put into operation in great Britain, in Porlock (3800 conditional inhabitants) in 1998, in 1999 at treatment plants in Germany, in the cities of Bchel and Rdingen (1000 and 3000 conditional inhabitants, respectively) and in France, in the city of Bchel and Rdingen (1000 and 3000 conditional inhabitants, respectively) and in France, in the city of Porlock. Perthes-en-Gtinais (4500 conditional inhabitants). After 5 years, facilities were put into operation in Karst (Germany), designed for 80 thousand conditional residents. No less active development of MBR-reactors took place in the USA, Japan and other countries. Currently under construction are the Brightwater treatment plant, located in the state of Washington, USA. In 2011, the capacity of facilities at maximum loads will be 495 thousand m3 / day, and by 2040 - up to 645 thousand m3 / day.

MBR reactors are manufactured and supplied by many large companies: Zenon Environmental (now GE Water & Process Technologies, USA), Kubota (Japan), Mitsubishi Rayon Engineering, Norit X-Flow (Netherlands), Huber Technology (Germany), Koch Membrane System (USA), Memcor (part of the Siemens Group), Orelis Mitsui (Japan), Wehrle Werk, HofBerg (Germany), etc.

To assess the effectiveness of the use of membrane technology for the removal of biogenic elements at the Moscow treatment facilities, semi-industrial

tests were carried out at a pilot plant located at the Kuryanovsky treatment plants. 4.34.

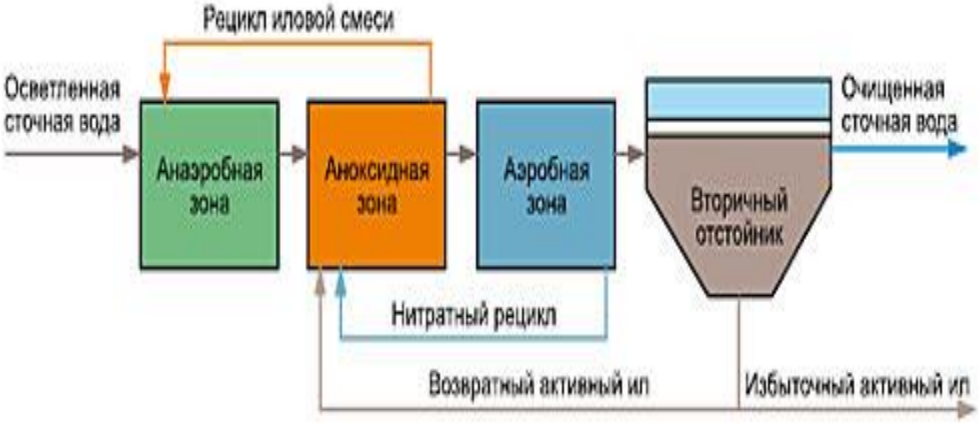


Fig. 4.34. Technological scheme of the pilot plant with gravity sludge separation

The average indicators of treated wastewater were, mg / l: suspended substances - 8.5; N–NH4 – 0,38; N–NO2 – 0,035; N–NO3 – 8,7; P–PO4 – 0.3 (Table 1). As can be seen from Fig. 6 (left part), in some periods of operation there was an excess of purified water indicators for ammonium nitrogen and nitrite nitrogen. The instability of the nitrification process was associated with volley inflows of industrial wastewater at the KOS, which was recorded by a sharp increase in COD in clarified water. An additional confirmation of this phenomenon was that in the aeration tanks of the old KOS unit, which purify the same water as the pilot plant, at the same time there was a decrease in the quality of purified water for nitrogen. Removal of phosphates in the control mode proceeded stably, the content of P-PO4 in the purified water did not exceed 0.4 mg / l (Table 4.10).

Table 4.10. Test results of the pilot unit with a membrane module (according to MOSVODOKANAL JSC)

Показатель, мг/л	Пилотная установка без мембранного модуля (контрольный этап)		Пилотная установка с мембранным модулем (100% объема установки)		Пилотная установка с мембранным модулем (70% объема установки)	
	осветленная вода	очищенная вода	осветленная вода	очищенная вода	осветленная вода	очищенная вода
Взвешенные вещества	70	8,5	85	< 1	80	< 1
ХПК	200	48	220	31	225	35
$БПК_5$	75	4,5	87	3,1	85	3,3
$N–NH_4$	23	0,38	25	0,21	24	0,25
$N–NO_2$	–	0,035	–	0,018	–	0,02
$N–NO_3$	–	8,7	–	9,1	–	8,9
$P–PO_4$	1,9	0,3	2	0,2	1,8	0,2

In the second stage of research (more than 140 days), the hydraulic mode of the installation was initially optimized, since the operation of the membrane module is largely dependent on the hydraulic load. In total, four different hydraulic modes were worked out. In Fig. Figure 8 shows the dynamics of the transmembrane pressure from the beginning of operation of the membrane module of the installation. At the time of launch, the lowest pressure was recorded - 0.1 bar. Then the pressure gradually increased to 0.15-0.17 bar. On average, at a flow rate of 170 l/h, which corresponds to a specific flow rate of 12.3 l/(m2·h), the transmembrane pressure was kept at 0.14 bar. For a short-term intensive filtration regime with a flow rate of 270 l/h (specific flow rate of 19.6 l/(m2·h), the transmembrane pressure also did not exceed 0.2 bar.

When switching to the second hydraulic mode with a lower permeate pumping flow rate (110 l / h, or 8 l / (m2 · h), the transmembrane pressure decreased to 0.07 bar and then gradually increased to a constant value of 0.15 bar. this is explained by the high resistance of the membrane module to clogging at a flow rate of 110–170 l/h (8–12.3 l/(m2·h).

Forthis type of membrane, the minimum transmembrane pressure is provided at a load of less than 110 l / h (8 l / (m2 · h), the optimal hydraulic load for

the pilot plant is 140-170 l / h (10.1-12.3 l / (m2 · h). This flow rate was established during the control stage of the study, when the silt separation was carried out in the membrane module. The use of the membrane module made it possible to increase the dose of activated sludge from 1.8-2.3 to 6.5-7.6 g / l. Water quality indicators, cleaned in a pilot plant with a membrane sludge separator, presented in Fig. 6 and 7 (middle and right parts) and in Table. 1.

The average concentrations of ammonium nitrogen and nitrite nitrogen were 0.21 and 0.018 mg/l, respectively (Fig. 6, Table 1), which is lower than the PDCrybhosis of the corresponding indicators. Concentrations of phosphorus phosphates fluctuated in the range of 0.1–0.4 mg / l. At the same time, as can be seen from Fig. 7, salvo discharges of industrial wastewater do not affect the stability of the nitrification process, unlike the operation of the installation without a membrane module. The observed increase in the concentration of N–NH4 in purified water (synchronously with the peak values of COD in clarified water) practically did not exceed the standards of PDCrybhoz. The use of a membrane module stabilized the ammonium removal process.

In the course of the studies, the concentrations of all forms of nitrogen and phosphorus phosphates in each reactor were measured, and a profile of pollutant concentrations during water purification was obtained. Based on experimental data, it was concluded that two out of four aerobic reactors are sufficient for complete nitrification. The number of unified bioreactors in the anaerobic and oxid zones was also excessive. According to the test results, the volume of the aerobic zone was halved (two reactors were excluded from operation). One oxid reactor and both selectors were decommissioned, which led to a reduction in the volume of the installation by 30%, a reduction in the aeration period of the silt mixture to 1.3 hours, the time spent in the anoxid zone to 1.3 hours, in the anaerobic zone to 1.9 h. 6, even with a 30% reduction in installation volume, salvo discharges had

little effect on nitrification processes. Indicators of the quality of purified water practically did not exceed the normative values (Table 4.11)..

Table 4.11. Comparative indicators of the quality of purified water (according to JSC Mosvodokanal)

Показатель	После мембранной установки «Huber»	После ультрафиолетового обеззараживания на ЛОС	СанПиН 2.1.5.980-00
Общие колиформные бактерии (ОКБ), КОЕ/100 мл	30–700*	130–450	500
Термотолерантные колиформные бактерии (ТКБ), КОЕ/100 мл	35–130*	50–100	100
Колифаги, БОЕ/100 мл	3–5	0–32	10
* Превышение нормативов СанПиН в 20% проб.			

The results of bacteriological and virological studies of wastewater purified at the pilot plant are presented in Table. 2. For comparison, microbiological indicators of biologically purified wastewater of Lyuberets treatment plants, which has undergone UV disinfection, are given. The number of total coliform bacteria (CBS) in the purified water of the plant reflects the spread of values during the study. In 80% of water samples, the OKB content was lower than 500 CFU/ml, i.e. within the standard limits. The data presented indicate that ultrafiltration membrane sludge separation makes it possible to reduce the contamination of purified water according to microbiological indicators to values corresponding to the standards for fishery reservoirs in 80% of samples. This ensures a quality comparable to that of water that has undergone UV treatment.

Since there is no removal of suspended solids due to the use of a membrane, the use of MBR technology makes it possible to maintain the age of active sludge, optimizing it to ensure a sufficiently high activity of heterotrophic bacteria and nitrifications. In this regard, technologies based on MBR reactors provide a

guaranteed quality of purification from suspended and organic substances and ammonium nitrogen.

The advantages of MBR technologies include: a significant reduction in the volume of structures and the area occupied by them due to high concentrations of activated sludge; the possibility of a higher load per unit volume; a significant reduction in the amount of excess activated sludge. The use of MBR technology is promising for the development of treatment facilities in conditions of limited territories.

Studies have shown that the use of membrane technology can effectively implement the process of biological removal of nitrogen and phosphorus for low-concentrated municipal wastewater with a reduction in the volume of structures by 30%. At the same time, high stability of nitrification processes in the conditions of salvo discharges of highly concentrated industrial wastewater is ensured, which is an advantage compared to sludge separation in secondary sedimentation tanks. The quality of purified water for suspended substances meets the requirements for technical water supply without additional tertiary treatment systems. Membrane technologies are considered as one of the most promising areas for the developmentof biological treatment of municipal wastewater.

The water purified at the Moscow treatment facilities has not been disinfected until recently. This was due to the lack of an economical and at the same time environmentally friendly method of disinfecting large masses of water. The use of traditional chlorination was impossible due to a number of fundamental problems:

storage of large reserves of chlorine gas on the territory of treatment facilities within the city and its transportation is dangerous both for the population and for the environment;

residual concentrations of active chlorine in treated wastewater are toxic to hydrobionts;

in disinfected wastewater, carcinogenic and mutagenic organochlorine compounds are formed, which can persist for a long time in the natural environment and enter the human body through the trophic chain.

Taking into account the importance of wastewater disinfection, MOSVODOKANAL JSC was constantly engaged in the search for an acceptable technical solution to this problem.

In 1995, based on the results of the generalization of domestic and foreign experience, an assessment of the main known methods of decontamination was carried out. According to the totality of indicators, the method of disinfection with ultraviolet light was recognized as the most acceptable, as highly effective in epidemiological terms and not accompanied by the formation of by-products that adversely affect the environment and human health.

The method of ultraviolet (UV) disinfection is based on irreversible damage to DNA and RNA molecules of microorganisms due to photochemical effects of light energy.

The source of UV rays in industrial installations are special lamps filled with a mixture of mercury vapor and inert gases, emitting in the UV spectrum under the influence of an electric current of ultra-high frequency.

UV lamps placed in protective covers and assembled in modules are located in the flow of disinfected liquid flowing around them from all sides. Protective covers are usually made of quartz glass, transparent to UV rays, and are designed to stabilize the temperature regime of lamps and prevent their direct contact with water.

Resolutions of the Government of Moscow No. 289-PP of May 11, 2004 and 176-PP of March 14, 2006 set the task to fully equip the Lyuberetsky and Kuryanovsk treatment facilities with UV disinfection units, which was gradually implemented.

4.6. Basics of calculation of treatment facilities

General information about calculation methods

It is well known that there are two methods for calculating aeration tanks.

1 method. Calculation of oxidation time - T using the difference in concentrations of C1 and C2, the rate of oxidation and the dose of sludge ai is a kinetic method that hastraditionally been used in SNiP and otherdomestic literature. All these methods are applied to the aeration tank-mixer and in general the oxidation time T is calculated by the formula:

T =(C1-C2)/R*ai, (4.3)

where T is the residence time, C1 is the concentration in the source water, C2 is the concentration in the purified water, R is the specific reaction rate, ai is the sludge dose.

It is assumed that in the biocenosis of the sludge there are the necessary microorganisms that provide the calculated reaction rate. At the same time, it is guaranteed that at the reaction rate calculated for these conditions and the dose of sludge taken, the required concentration in the purified C2 water will be achieved.

2 method.Determination of the volume of aeration tanks through the age of sludge. In the domestic literature, the details of this method are described in detail and are based on the retention of the necessary type of microorganisms in the biocenosis, the condition of which is written with the expression:

$1/\theta cp=\mu - kd,$ (4.4)

where θp - the age of the sludge (day), μ - the growth rate of microorganisms (1 / day), kd - the rate of death of microorganisms (1 / day).

If this condition is met, the required type of microorganisms is retained in the biocenosis. In this case, the value of the μ can be taken as constant - according to the maximum growth rate μmax or calculated in accordance with the conditions, for example, a given concentration of C2 in purified water, then when applying the Mono equation for μx = μmax× (C2 / (C2 + C)) the expression (4.4) will take the form:

$1/\theta = \mu max \times C2/ (KC+C2) - kd,$ (4.5)

where KC is the substrate semi-saturation coefficient.

In this case, the retention of the species in the biocenosis is guaranteed at a given concentration of C2 in the purified water.

In this case, the expression for the age of yl θ is calculated by the formula:

$\theta= 1/m\times(KC+C2)/C2 - (1/kd)$ (4.6)

When taking into account only biological processes in stationary conditions, both methods of calculation coincide. The age of sludge can be determined by dependence:

$$\theta = \frac{(W \times a_i)}{\Pi_p},$$

где объем аэротенка $W = Qt$, прирост ила $\Pi_p = QY(C_1 - C_2)$, Y — коэффициент прироста;

Тогда $\theta = \frac{ta_i}{Y(C_1 - C_2)}$,

где из (1) — общее время пребывания в аэротенке: $t = \frac{(C_1 - C_2)}{R \times a_i}$

Следовательно: $\theta = \frac{\frac{(C_1 - C_2)}{R \times a_i} \times a_i}{Y(C_1 - C_2)} = \frac{1}{RY} = \frac{1}{\mu}$, или $\theta = \frac{1}{\mu}$

As a result, half tea is a well-known expression from the literature :

$1/m=1/mmax\times(Kc+C2)/C2 – 1/kd$ or $\mu=\mu max\times C2/(Kc+C2) – kd$

But for existing wastewater, the increase is determined not only by biological factors.

According to modern concepts, in mathematical modeling, growth is determined by the following components:

1) the amount of the inert part of the weighted COD, which directly turns into an increase;

2) the amount of non-hydrolyzed bio-oxidizable suspended solid;

3) the increase in heterotrophs, phosphate of batteries, nitrifications without taking into account the biomass formed during death;

4) dead biomass - the number of dead microorganisms without taking into account the hydrolysis of dead biomass;

5) inert part of biomass - a part of dead biomass that is not amenable to hydrolysis;

6) added as a result of chemical deposition of the ash part of the sludge.

Obviously, the components listed in paragraphs 1, 2, 5 and 6 are added to the growth, taking into account only the factors of growth of microorganisms and their death. For fast-growing species, primarily heterotrophs, the difference arising in the calculation systems is not so significant and the efficiency of bod (COD) purification can be calculated both using the kinetic approach and through the age of the sludge. At the same time, for microorganisms of nitrifiers with low growth rates and a small proportion in the biocenosis, the calculation of the volume through the age of the sludge is preferable, since an additional increase that is not

taken into account in the calculation of the kinetic approach can lead to a decrease in the number or absence of these microorganisms in the biocenosis.

When using mathematical modeling, the retention (concentrations of individual conditional species) of microorganisms are calculated through the age of the sludge, and the result of purification is calculated through the residence time and reaction rate, taking into account the calculated concentrations of conditional species. Thus, in mathematical modeling, both approaches to the calculation of aeration tanks are implemented jointly.

Another, alternative method of calculating structures is the use of a load on silt. It is known that theload on silt is associated both with the return of sludge and with the efficiency of cleaning and is a good empirical parameter for calculating aeration tanks. At the same time, the load parameter is considered insufficiently accurate for the calculation of aeration tanks with biological removalof nitrogen and phosphorus. Therefore, this parameter is recommended for calculating the volume of aeration tanks only if there is sufficient empirical data or as a verification parameter. Let us consider in more detail the removal of nitrogen and phosphorus from wastewater in order to quantify the proposed methods.

Biological methods of wastewater treatment from nitrogen compounds

Analysis of numerous literature data andstudies indicate that simultaneously in one structure in a single-yl system it is impossible to fully carry out the processes of nitrogen and phosphorus removal, since for the biological removal of phosphorus it is necessary to observe the alternation of the aerobic and anaerobic zone, and the time spent in anaerobic conditions should be at least 3-4 hours, which leads to inhibition of obligate aerobes. In addition, under anaerobic conditions in the presence of nitrates, the metabolism of microorganisms is suppressed, with the help of which the process of biological dephosphotization is carried out. All

biological processes require nitrogen in one form or another for the synthesis of cellular proteins and nucleic acids.

The first process in the transformation of nitrogen compounds is the formation of ammonium nitrogen from organic compounds. This process is called ammonification and is carried out by enzymes produced by microorganisms. Nitrogen is used for the growth of microorganisms, and thus part of the inorganic nitrogen passes into the newly formed bacterial cells. Microbiological studies have established that the nitrogen content in the bacterial cell is 11 - 13% of the dry matter. At a high age of silt and a sufficiently high temperature, a steady accumulation of nitrifying bacteria occurs, and ammonium nitrogen is oxidized first to nitrite, and then to nitrate. The process is called nitrification and occurs only in the presence of oxygen. The resulting nitrate nitrogen can be used to oxidize organic compounds, reducing to free nitrogen, which is blown away during aeration into the atmosphere. This process is multi-stage. Nitrate nitrogen is first reduced to nitrite, and then to nitrous oxide (N_2O), and finally to molecular nitrogen, this process is called denitrification and proceeds in the absence of oxygen, but in the presence of easily oxidedorganic compounds. Nitrification is carried out mainly by microorganisms of the genera Nitrosomonas and Nitrobacter. First of all, the optimal nitrification regime depends on the concentration of dissolved oxygen, the pH value, the temperature of the purified water, the concentration of the substrate - ammonium ions. These microorganisms use inorganic carbon as the only source of carbon.

The minimum concentration of oxygen for the nitrification process is 1.5 mg / dm^3, however, an increase in the oxygen concentration of more than 2 mg / dm^3 does not give a technological effect, but increases operating costs. The specific growth rate of nitrifiers, like other biological processes, is extremely sensitive to

the temperature regime. Optimal temperatures for the nitrification process are the temperatures of the treated wastewater 20 - 25 ° C.

Denitrification

Removal of nitrate nitrogen is carried out in the process of dissimilation reduction - denitrification. Many bacteria - facultative anaerobes in the acts of respiration use the bound oxygen of nitrates and reduce nitrate with the release of molecular nitrogen or nitrous oxide N_2O. Gaseous forms of nitrogen in the process of aeration pass from the purified water into the atmosphere. Denitirifiers are chemoorganoheterotrophs and for the metabolic process they need organic carbon. When used as organic feed for the original wastewater, the concentration of organic substances in the denitrifier according to BOD_5 must be at least 20% higher than the concentration of chemically bound oxygen, or otherwise, the condition must be met: $BOD_5 = 4C_{N\text{-}NO\ 3}$.

Denitrifiers are chemoorganoheterotrophs by the type of metabolism, they use organic substances both for obtaining energy (as a result of a redox reaction accompanied by the transfer of protons and electrons) and for the synthesis of cellular matter.

The most used scheme of structures with activated sludge, which produces simultaneous purification of carbon and nitrogen compounds, is the 4-sectionionic Bardenfo scheme. To effectively carry out denitrification, carbon of incoming wastewater is used, as well as carbon formed as a result of endogenous decay of biomass. Ammonium passes through the first oxygen-free zone, and then turns into nitrites and nitrates in the first aerobic zone. The latter partially return back to the first b The acid-free zone, as well as entering the second oxygen-free zone for additional denitrification using endogenous carbon. In the second aerobic zone, molecular nitrogen is released into the atmosphere.

Dephosphotization

The traditional method of removing phosphorus from wastewater is chemical, in which phosphates are precipitated by adding salts of calcium, magnesium and iron. The essence of the biological method of phosphorus removal is that the microorganisms of activated sludge consume phosphorus for biological needs, and phosphates are included in the inanimate part of the activated sludge. At the same time, the inclusion of the anaerobic stage in the traditional scheme leads to the fact that the amount of phosphorus absorbed by the active sludge increases several times. Under alternating anaerobic and aerobic conditions, bacteria of the genus *Acinetobacter,* which have an increased ability to accumulate phosphates (Matsuo, Mino, 1984), are fixed in the community of microorganisms of active sludge.

Among the most well-known schemes of structures with activated sludge, which simultaneously remove carbon, nitrogen and phosphorus compounds, we can distinguish the A^2 / O process, the 5-section Bardenpo process, UCT.

Characteristic parameters of schemes for the combined removal of carbon, nitrogen and phosphorus compounds from wastewater are given in Tables 4.12 – 4.13 according to Metcalf & Eddy, 1994).

Table 4.12. Characteristic parameters of schemes for the combined removal of carbon, nitrogen and phosphorus compounds from wastewater according to Metcalf & Eddy, 1994

Characteristic	Units	A^2O	Process	UCT

			Bardenpo	
Ratio of contaminants to the mass of activated sludge, (F/M)	kg BOD/kg day	0,15-0,25	0,1-0,2	0,1-0,2
Time of stay of active sludge, θ_{with}	Day	4-27	10-40	10-30
Activated sludge	g/dm^3	3-5	2-4	2-4
Residence time of wastewater, θ	h			
Anaerobic zone		0,5-1,5	1-2	1-2
Anoxic zone 1		0,5-1,0	2-4	2-4
Aerobic zone 1		3,5-6,0	4-12	4-12
Anoxic Zone 2			2-4	2-4
Aerobic zone 1			0,5-1,0	
Return of activated sludge	% of incoming liquid	20-50	50-100	50-100

Internal recycle	% of incoming liquid	100-300	400	100-600

Table 4.13 Resource requirements

Advantages and disadvantages of biological treatment plants with simultaneous removal of carbon, nitrogen and phosphorus compounds (Metcalf & Eddy, 1994)

Process	Advantages	Disadvantages
A^2/O	Excess sludge has a high phosphorus content (3-5%) and can be used as a fertilizer	With low temperature tours, cleaning is bad
Bardenpo	The amount of excess sludge is minimal. Silt has a high phosphorus content and can be used as a fertilizer. Total nitrogen is reduced to a minimum level.	It requires larger volumes of construction and energy consumption than A^2/O. The primary sump reduces the removal of nitrogen and

		phosphorus. Goes at high BOD/P.
UCT	It has slightly smaller volumes of structures than Bardenpo.	Goes with high BOD/P. It requires large expenditures of electricity for internal recycles.

These schemes and comparative characteristics were obtained abroad and as shown by studies conducted by Mosvodokanal on the pilot industrial line of the aeration tank of the Kuryanovskaya aeration station (Moscow), they cannot be used without adaptation at the treatment facilities of Russian cities.

The main reason is the insufficient amount of biodegradable substances to implement both the process of denitrification and dephosphotization. Specialists of mosvodokanal managed to show that the supply of unclarified wastewater to the anaerobic zone of the aeration tank allows to obtain a higher quality of treatment for phosphorus, but the instability of the process was noted. In the course of research, it was found that it is possible to combine the processes of denitrification and dephosphotization in different zones of the same structure at low concentrations of organic substances. In this case, in order to implement a stable dephosphotization process, it is advisable to supply active sludge from the

anoxid zone to the anaerobic zone of the aeration tank, after the denitrification process, while eliminating competition between denitrifiers and phosphoraccumulating bacteria for the substrate. Thus, the implementation of biological denitrification and dephosphotization can be implemented at the treatment facilities of Russian cities that have specifically low concentrations of organic compounds in wastewater at high values of the ratios of N / BOD and R / BOD. However, the choice of a rational scheme should be made empirically, by specialists who have the skill of setting up structures of this type.

At the treatment facilities of small settlements, it is advisable to use the physicochemical method of phosphorus removal.

Calculation of the main technological parameters of the operation of biological wastewater treatment plants

(according to Kharkina O.V., Kharkina S.V., Handbook of the Ecologist, 2016, No6)

Ensuring the quality requirements for treated water requires daily monitoring by the operational services in relation not only to the technical condition of the structures, but also to the technological parameters of their operation. Below are the main technological parameters of the operation of biological wastewater treatment plants that implement nitrogen and phosphorus removal technologies, and examples of their calculation.

During the technological control of the considered treatment facilities, we recommend determining the following design parameters:

1) load on incoming contaminants:

load on organic compounds (BOD5, BODpoln, COD);

load on ammonium nitrogen and/or total nitrogen;

phosphorus load of phosphates and/or total phosphorus;

load on suspended substances;

load on specific contaminants;

2) the hydraulic residence time of wastewater in the structure;

3) the ratio of the amount of nutrients coming from wastewater to the mass of microorganisms of activated sludge (load on active sludge);

4) the general age of activated sludge, the aerobic age of activated sludge;

(5) the efficiency of contaminant removal;

6) correlation BODfull:N:P.

The load of the contaminations in question M(Si) (kg/day) is determined by the formula:

$$M(S_i) = \frac{S_i \times Q_d}{1000}$$

where Si is the concentration of the contamination in question, mg/L or g/m3;

Qd is the consumption of wastewater entering the biological treatment, m3 / day.

EXAMPLE 1 Calculate the load insuspended substances at Sc = 140 mg/L; Qd = 16 000 m3/day:

$$M(S_c) = \frac{S_c \times Q_d}{1000} \times \frac{140 \times 16000}{1000} = 2240 \frac{kg}{day}.$$

The hydraulic residence time of wastewater in a structure is the ratio of the volume of the structure to the flow rate of wastewater entering it.

For aerotanks, the hydraulic residence time of wastewater tat (h) is determined by the formula:

$$t_{at} = \frac{V_{aer} \times N_{aer}}{Q_d} \times 24,$$

where Vaer is the volume of one aerotank, m3;

Naer — number of working aerotanks;

Qd is the consumption of wastewater entering the biological treatment, m3 / day.

EXAMPLE 2

Let's calculate the hydraulic residence timeof wastewater in the aeration tank at Vaer = 19 000 m3; Naer = 4; Qd = 100 000 m3/day:

$$t_{at} = \frac{V_{aer} \times N_{aer}}{Q_d} \times 24 = \frac{19000 \times 5}{100000} \times 24 = 22{,}8 \text{ ч.}$$

The ratio of the amount of nutrients coming from wastewater to the mass of microorganisms of activated sludge F/ M is the ratio of the daily amount of organic substrate coming from wastewater for biological treatment to the mass of the ash-free substance of activated sludge (AAS) in aeration tanks, and is determined by the formula:

$$\frac{F}{M} = \frac{S_i \times Q_d}{x_{aer} \times (1 - z) \times V_{aer} \times N_{aer} \times 1000},$$

where Si is the concentration of the substrate in question (BOD5, BPCPol or COD), mg/L or g/m3;

Qd — consumption of wastewater entering biological treatment, m3/ day;

xaer - the dose of activated sludge in aeration tanks (average for all aeration tanks), g / l or kg / m3;

z is the ash content of silt, fractions of one;

Vaer — volume of one aerotank, m3;

Naer — the number of working aeration tanks.

EXAMPLE 3

Let's calculate the ratio of the amount of nutrients coming from wastewater to the mass of microorganisms of activated sludge at Si (BOD5) = 130 mg / l; Qd = 13,000 m3/day; xaer = 3.5 g/l; z = 0.35; Vaer = 2300 m3; Naer = 3,2:

$$\frac{F}{M} = \frac{S_i \times Q_d}{x_{aer} \times (1 - z) \times V_{aer} \times N_{aer} \times 1000} =$$

$$= \frac{130 \times 13000}{3{,}5 \times (1 - 0{,}35) \times 2200 \times 3{,}2 \times 1000} =$$

$$= 0{,}106 \ \frac{kgBOD_5}{kgAAS \times day}.$$

The aerobic age of activated sludge is the basic criterion for both the calculation and operation of aeration tanks that implement nitrification processes. To ensure the design value of the aerobic age of activated sludge is the task of engineers operating treatment facilities.

During the operation of facilities, the real values of the total and aerobic ages of the activated sludge should be constantly recorded during technological control and kept within the range of values specified in the project.

The total age of the active sludge Θtot (day) is determined by the formula:

$$\theta_{tot} = \frac{N_{aer} \times V_{aer} \times x_{aer}}{x_{WAS} \times Q_{WAS}},$$

where Naer is the number of running aeration tanks;

Vaer — volume of one aerotank, m3;

xaer - the dose of activated sludge in aeration tanks (average for all aeration tanks), g / l or kg / m3;

xWAS - dose of excess activated sludge, g / l or kg / m3;

QWAS — excess activated sludge consumption, m3/day.

The aerobic age of the active sludge ΘA (day) is determined by the formula:

$$\theta_A = \frac{N_{aerobi} \times V_{aerobi} \times x_{aerobi}}{x_{WAS} \times Q_{WAS}},$$

where Naerobi is the number of aerobic zones of all aerotanks;

Vaerobi — the volume of the aerobic zone of one aerotank, m3;

x_{aerobi} - a dose of activated sludge in the aerobic zone, g / l or kg / m^3;

x_{WAS} - dose of excess activated sludge, g / l or kg / m^3;

Q_{WAS} — excess activated sludge flow rate, m^3/day.

The calculation is carried out according to the average daily indicators for the previous day. Data on the age of sludge are updated 1 time per day and are one of the most important technological parameters. Ensuring the required age of active sludge is regulated by the consumption of excess sludge.

EXAMPLE 4

Let's calculate the total age of active sludge at Naer = 3; Vaer = 7200 m3; xaer = 3.5 g/l; xWAS = 6 g/l; QWAS = 700 m3/day:

$$\theta_{tot} = \frac{N_{aer} \times V_{aer} \times x_{aer}}{x_{WAS} \times Q_{WAS}} = \frac{3 \times 7200 \times 3{,}5}{6 \times 700} = 18\ day.$$

The effectiveness of removal of pollutants both in general at sewage treatment plants and at individual facilities is determined by the formula:

$$Э_{S_i} = \frac{S_{i,\,inf} - S_{i,\,ef}}{S_{i,\,inf}} \times 100\ \%,$$

where ESi is the removal efficiency of the si contaminant in question, %;

Si, inf is the concentration of the si contaminant in question at the inlet to the structure, mg/L;

Si, ef is the concentration of the si contaminant in question at the outlet of the structure, mg/L.

The determination of the ratio of BPCP:N:P in wastewater entering for biological treatment during the operational control of treatment facilities is carried out on the day of receipt of the results of the relevant analyzes from the laboratory. To create working conditions for the growth of microorganisms in wastewater, there must be a sufficient amount of biogenic elements, and the values of BPCP: N: P should be no more than 100: 5: 1.

The sufficiency of nitrogen in incoming wastewater for biological treatment is determined by comparing the values of the minimum required concentrations of N and P with their concentrations in incoming wastewater.

The minimum required nitrogen concentration in Nreq wastewater supplied for biological treatment (mg/L) is determined by the formula:

$$N_{req} = \frac{БПК_{полн,\ inf}}{(БПК_{полн} / N)_{req}},$$

where BODfull, inf is the value of BODfull in incoming wastewater for biological treatment, mg/l;

(BODfull/N)req is the required ratio of BOD:N, which should be no more than 20.

The minimum required concentration of phosphorus in Preq wastewater entering biological treatment (mg/l) is determined by the formula:

$$P_{req} = \frac{БПК_{полн,\ inf}}{(БПК_{полн} / P)_{req}},$$

where BODfull, inf is the value of BODfull in incoming wastewater for biological treatment, mg/l;

(BODfull/P)req is the required ratio of BPCp:P, which should be no more than 100.

Deviations of the above parameters from the design values require their immediate adjustment.

4.7. Comparison of calculation methods of biological treatment plants

The updated SNiP allowed the calculation of structures with biological removal of nitrogen and phosphorus to use any, including foreign calculation methodology. Since 2012, the SNiP has approved the use of modern mathematical models for calculation. The choice of one or another calculation method is determined by the designer under his responsibility.

In this regard, in the domestic periodical literature, a discussion has unfolded between different grpps of developers using different calculation methods. First of all, this is a discussion between doctor of technical sciences, professor Shvetsov V.N. on the one hand and on the other - Epov A.N. and candidates of technical sciences Danilovich D.A. and Kanunnikova M.A.

Basics of biological wastewater treatment facilities with removal of biogenic elements according to Shvetsov V.N. and Morozova K.M. (Water supply and sanitation equipment. 2013. No 11, p.42- 47)

Using the method of Shvetsov V.N. and Morozova K.M. r, biological treatment facilities should be calculated on the basis of experimentally obtained kinetic constants, coefficients of nitrification and denitrification processes and for each limiting indicator, depending on the requirements for the quality of purification. The calculation algorithm includes the following stages: substantiation of initial data on the costs and qualitative composition of wastewater in accordance with the required degree of reliability (availability of at least 85–90%); selection of the technological scheme of operation of structures – the number of stages and (or) stages, the order and scheme of their operation; determination of kinetic constants of the equations of enzymatic kinetics of transformation of each andz of the main components of pollution based on experimental data or on the basis of an existing database; preliminary calculation of the amount of excess activated sludge and clarification of the material balance for nitrogen and phosphorus; identification of the limiting component of pollution, the oxidation of which will take the longest time; calculation of the volume of facilities for the limiting component with the determination of the degree of purification for other components of pollution.

The calculation of the volume of nitrification and denitrification zones in the aeration tank must necessarily be made taking into account organic nitrogen, which in the process of ammoniation passes into ammonium nitrogen. One of the main conditions for the formation of a technological scheme for the biological treatment of wastewater with nitri-denitrification is the value of the ratio of BPCP to total nitrogen (N) of at least 4: 1. The calculation of biological treatment facilities is carried out according to the BOD indicatorfull, not BOD5. BoD_5 indicator, according

to Shvetsov V.N. and Morozova K.M., is not a measure of the content of biologically oxidizable organic contaminants in wastewater, but corresponds only to a certain proportion of organic substances that can be oxidized under certain conditions and depends on many factors (temperature, degree of adaptation, dilution, concentration of microorganisms, etc.). Only for purified water, bod_5 can be close to BOD. Technological calculation of nitri-denitrification processes requires determining the volume of nitrification and denitrification zones while maintaining a balance between transformable forms of nitrogen compounds and oxidation of organic matter at each stage of treatment. This ensures a given degree of wastewater treatment for all dictating components (BOD, ammonium nitrogen, nitrate nitrogen). In this regard, a given degree of wastewater purification is ensured. the time of stay in the dephosphatization zone should be (when treating weakly concentrated wastewater) 20-30 minutes, with a longer residence time, the depth of decay of organic contaminants increases and the balance of BOD / N is disturbed, which is necessary for the denitrification stage. The residence time of wastewater in the aerobic zone (nitrification zone) of the aeration tank is calculated both for the removal of BOD and for nitrification. The volume of the aerobic zone is selected at a higher value, and then the degree of purification for the second component is specified. The calculation of the time of stay (hour) in the nitrification zone (and the denitrification zone) is carried outtaking into account organic nitrogen and nitrogen loss with excess activated sludge and suspended substances.

Onthe opinion of Shvetsov V.N. and Morozova K.M. , theresults of long-term experimental studies of nitri-denitrification processes with various types of municipal and industrial wastewater make it possible to supplement the calculation method laid down in SNiP 2.04.03-85 with formulas and data for the calculation and optimization of the operation of aeration tanks with the removal of nitrogen and phosphorus compounds. The developed program allows, on the basis of kinetic equations and material balance equations, to make a technological calculation of

all stages of the process, to optimize nitri-denitrification scheme, calculate the optimal parameters of circulation flows, ensure high reliability of facilities and a high degree of biological wastewater treatment from organic contaminants and nitrogen compounds while complying with modern requirements for discharge both into the sewerage system and into the reservoir. According to the authors, thismodel has been tested on a large number of objects and is used in the calculation and design of circulating cyclic schemes for the removalof nitrogen and phosphorus compounds.

In contrast to the above provisions, candidate of technical sciences D. A. Danilovich and engineer A. N. Epov in his article "Comparative analysis of methods for calculating biological treatment facilitiesfor wastewater with nitrogen removal" (Water Treatment. Water treatment. Water supply. 2017. № 4. pp. 28–40) state that the methodology of the Research Institute of VODGEO is "manual" and simplified, does not apply to mathematical models; the parameter specific speed of nitrification is not applicable for calculations; the influence of temperature and other factors is not taken into account; "simplified" equations of enzymatic kinetics are not applicable to nitri-denitrification processes due to unacceptable distortions caused by factors that these equations do not take into account; the age of sludge determines the quality of the treated water, regardless of the content of contaminants in the incoming wastewater; when calculating the growth of sludge, it is necessary to use the age of sludge; the residual concentration of the substance (in purified water) does not depend on its initial concentration; the calculation of aeration tanks should be carried out on the basis of the age of the sludge.

To argue their statements, the authors provide an analysis of the methods used in world practice. In this regard, in order not to deviate from the presentation of the main line of the course, we present an analysis of these methods according to the data of A.N. Epov and D.A. Danilovich in the form of a separate section. At

the same time, the author of the manual would like, on the basis of his extensive experience in studying biotechnological processes, to note that the methods used approximately describe the biotechnological process with the changing composition of the incoming substrate and other parameters of the uncontrolled process and, as a result, the non-constant composition of the biocenosis of activated sludge, cannot claim the truth in the aftermath of the instance, but can only describe the process of biological purification with a certain degree of accuracy. Wastewater. This feature is very clearly manifested in biotechnological enterprises with biological wastewater treatment, in the main production of which a strictly controlled process is used, and at the stage of biological treatment an uncontrolled process.

In this regard, of course, discussions will continue and the author of the manual hopes that in the future this will lead to a refinement of the calculations of biological wastewater treatment facilities.

4.8. Normative values of technological parameters of treatment facilities and actions of personnel in case of their violation

According to Kharkina O.V. and Kharkin S.V. (Ecologist's Handbook, 2016, No. 6), effective control of quantitative and qualitative characteristics of incoming and treated wastewater is one of the most important elements of reliable operation of treatment facilities operating on the technology of removing nutrient elements.

Management of the technological process of biological wastewater treatment should be carried out on the basis of an analysis of the results of technological control, which will achieve the highest technical and economic performance indicators of facilities and improve technological processes.

Systematic analysis of the results of production and technological control is aimed at timely detection of violations in the technology of wastewater treatment and prevention of diversion from treatment facilities of water that does not meet the requirements of sanitary rules and standards for the protection of surface water from pollution.

The main indicators requiring control and monitoring are given in Table 4.14 (Ecologist's Handbook, 2016, No. 6), and the approximate frequency of monitoring the quality characteristics of wastewater is in Table 4.15. (Ecologist's Handbook, 2016, No6)

Table 4.14. Controlled parameters of operation of aeration tanks operating on the technology of nitrogen and phosphorus removal

Name of the indicator	Normative value of the indicator	Current operational parameters
Wastewater consumption (m^3/h)	Not more than the design value and not less than 80% of the design value	Current value for the previous day
Flow rate of return activated sludge (m^3/h)	plus – minus 10% of the design value	is determined by the current values
Nitrate recycling consumption (m^3/h)	plus – minus 10% of the design value	is determined by the current values
Ratio of return activated sludge to wastewater flow	plus – minus 10% of the design value	is determined by the current values
Ratio of nitrate recycle to wastewater consumption	plus – minus 10% of the design value	is determined by the current values
Dose of activated sludge at the exit from the aerobic zone of the aeration tank (g / l)	plus – minus 10% of the design value	According to nalithic control data
Dose of recurrent activated sludge (g/L)	plus – minus 10% of the design value	According to nalithic control data
Dose of excess activated sludge (g/L)	plus – minus 10% of the design value	According to nalithic control data
Ash content of activated sludge (%)	The received value is fixed	According to nalithic control data

Silt index (cm^3/g)	130-160	According to nalithic control data
Concentration of dissolved oxygen in the aerobic zone (mg/L)	1,8 – 2,2	According to nalithic control data
Concentration of dissolved oxygen in the anoxid zone (mg/l)	0 – 0,15	According to nalithic control data
Amount of excess activated sludge (m^3/day)	Estimated value that provides the design value of the age of activated sludge	Determined for the previous day
Total age of active sludge (day)	plus – minus 10% of the design value	According to nalithic control data
Aerobic age of active sludge (day)	plus – minus 10% of the design value	According to nalithic control data

Table 4.15. Approximate control of the quality characteristics of wastewater entering the biotreatment and purified water

Qualitative indicators of the operation of aeration tanks	Timing of indicator determination
Determination in incoming water of COD, BOD_5, suspended substances, nitrogen oxides, phosphates	2-3* times a week
Determination in purified water of COD, BOD_5, suspended solids, nitrogen oxides, phosphates	2-3* times a week
Nitrogen oxides and phosphates in reactive activated sludge	1 time per week
Ilov index**	1 time per week
Alkalinity (mg/L)	3 times a week
$BoD_{ratio\ of\ 5}$ to nitrogen and phosphorus	3 times a week

BOD_5 purified water	daily
Possible inhibitory factors	daily
ORP, pH, temperature, dissolved oxygen	daily

*- desirable option;

** - if necessary

Analysis of the above parameters will allow you to quickly assess the problem, understand the cause of its occurrence and make appropriate technological decisions.

Table 4.16 (Ecologist's Handbook, 2016, No. 6) presents possible violations of the technological parameters of biological wastewater treatment facilities that implement nitri-denitrification technologies, and gives recommendations for restoring the normal mode of their operation.

Table 4.16. Possible violations of the technological parameters of biological wastewater treatment facilities from nitrogen using nitri-denitrification technology

Violation of the regime	Elimination of violations
Low dissolved oxygen concentration (less than 2 mg/L)	conduct additional qualitative analysis of the flowing runoff;

	increase air consumption by about 25-50%
	if possible, automate the air supply
	if the oxygen concentration continues to decrease, clean and repair the aeration system
Increase in oxygen concentration in the anoxid zones, for example, more than 0.15 mg / l	adjust the oxygen regime; if possible, install an automatic air supply.
Increasing the dose of activated sludge by more than 10% of the design	Increase the consumption of excess activated sludge; reduce the level of sediment in the primary sedimentation plants.
Reducing the dose of activated sludge	Increase the level of sediment in the primary sedimentation tanks; Reduce the consumption of excess activated sludge.
Reducing the age of activated sludge is less than the design value	Reduce to the minimum possible level of sedimentation in primary sedimentation tanks; reduce the hydraulic load on the aeration tanks.

Increasing the age of activated sludge above the design value	Increase the consumption of excess activated sludge
Increase in silt index more than 160 cm^3/g	Increase air consumption by about 50%
Foaming	Increase air consumption by about 50%; increase the consumption of excess activated sludge by approximately 30%; increase the consumption of returning activated sludge, etc.

Thus, theoperation of biological wastewater treatment facilities operating on nitrogen and phosphorus removal technology requires operational services to know the biochemical processes carried out in aeration tanks.

With a stable discrepancy between the qualitative characteristics of the treated water and the design values, it is necessary to conduct a detailed technological audit of treatment facilities with the involvement of independent specialists.

4.9. Start-up, adjustment and operation of treatment facilities

Start-up and commissioning largely determine the effectiveness of the subsequent operation of treatment facilities, since it is at these two stages that the formation of activated sludge occurs, the optimal technological modes of cleaning are determined, and professional skills in conducting the technological process are developed among the maintenance personnel.

The implementation of commissioning works requires comprehensive preparation. By the time the treatment facilities are put into operation and for the test start, which is carried out on clean water, it is necessary to preliminarily prepare the maintenance personnel, who must undergo an internship at existing treatment facilities, preferably of a related type. It is also necessary to provide preliminary special training for the personnel of chemical and microbiological laboratories, their mastery of the entire complex of analytical methods for monitoring the operation of structures. All personnel must be trained in safety and industrial sanitation.

The most time-consuming and responsible stage during the start-up of the facility is the accumulation of activated sludge, and, most importantly, its adaptation to specific pollutants characteristic of the industrial wastewater of this enterprise.

The accumulation of activated sludge can occur under the following conditions:

(a) In the vicinity, there are treatment plants that treat industrial wastewater of similar composition;

b) wastewater contains specific microflora;

c) there are no operating treatment facilities in the vicinity that treat identical industrial wastewater that does not contain specific microflora.

In the first case, excess activated sludge from secondary settling tanks, existing treatment plants are fed into sewage treatment plants (STP). Activated sludge is delivered by appropriate vehicles, such as tanker trucks. Initially, almost all the imported active sludge goes to the formation of immobilized microflora in biofilters and only then flakes of silt appear in aeration tanks. The primary concentration of activated sludge is set in the range of 0.2 - 0.3 g / dm3. Then the

STP is allowed on the channel with a load of 10 - 15% of the calculated one. Upon reaching the concentration of activated sludge of 2.5 - 3.0 g / dm3, the STP is loaded to the design load and ensures the stability of all parameters at the level provided for by the technological regulations for these facilities.

If industrial wastewater contains a specific microflora, then the mixed runoff is prepared in accordance with the parameters provided for by the technological regulations for the operation of the STP with the design load.

Household effluents can also be used for the formation of activated sludge. In this case, the wastewater is circulated in the COP and gives a load of not more than 50% of the calculated one. Then, having stopped supplying the last wastewater, they continue to circulate, continuously observing the disappearance of ammonium nitrogen and the appearance of nitrates (if the Aerotank COP must work with nitrification), as well as the content of dissolved oxygen. At the same time, observations should be made of the appearance of rapidly depositing activated sludge during the settling of typical flakes. After that, wastewater is let into the duct, gradually increasing the load on them to the calculated one.

If the STP must provide partial purification, then the activated sludge is obtained by the method described above, but the load is increased based not on the amount of nitrates, which do not happen during partial purification in the purified water, but from the value of BOD5 of water released from the settling zone of this STP.

During the launch period, it is also possible to turn on the STP immediately on a small load. After achieving sustainable results of purification of the effluent entering the STP, the load on it is gradually increased, bringing it to the calculated one.

It is also possible to use thermally dried activated sludge to accelerate its accumulation or silt from the nearest reservoir.

An important stage in the start-up period of operation of treatment facilities is the adaptation of the microflora of activated sludge to specific pollutants of all categories of wastewater that are supposed to be treated at these treatment

facilities. Adaptation of microflora should be carried out in advance, before the launch of industrial wastewater to treatment facilities. Preliminary adaptation of activated sludge to specific components of wastewater can significantly reduce the development period and create conditions for trouble-free operation of the STP at full load from the initial moment of receiving industrial wastewater.

Under these conditions, the facilities quickly reach their design capacity and the stable quality of treated wastewater are ensured. The adaptation process can be carried out in several ways, mainly by feeding model runoff to the STP. For this purpose, specific pollutants are added to household wastewater entering treatment facilities after mechanical treatment (substandard products of chemical industries or concentrated wastewater of similar existing industries delivered in tanker trucks, railway tanks, etc.) can be used. The dosage of specific pollutants is carried out from special containers and adjusted depending on the load taken. The load is established in accordance with the biochemical properties of pollutants and their digestibility by saprophytic microflora, but not less than 50% of the permissible load.

According to the same principle, industrial wastewater is also dosed if it is used to adapt activated sludge. Observations have shown that the use of smaller loads is not rational, since in conditions of minimal intake of specific pollutants in the composition of the treated effluent (i.e., together with household wastewater), the microflora of activated sludge absorbs them in small quantities. At the same time, the competing role of organic polluting components of household wastewater is increasing, they serve as the main nutrient substrate, and, consequently, there is no directed restructuring of the biochemical properties of bacteria.

Under such conditions, a specific microflora of activated sludge cannot be formed, since it is grown by the method of directed variability with the final result

of the formation of given biochemical properties and, most importantly, in artificial conditions of existence, a bacterial population is formed that can significantly increase the specific rates of biochemical oxidation of a specific substrate. According to the laws of enzymatic catalysis, the rate of reaction of oxidation of the substrate initially depends on its initial concentration. Based on this principle, it is necessary to carry out the process of primary adaptation of activated sludge to specific components of industrial wastewater. Its adaptation can occur sequentially or comprehensively, and depends on the needs of chemical production. Most often, production necessity dictates the use of consistent adaptation to each category of wastewater, which is due to the launch schedule of the main technological production facilities of the chemical enterprise.

The main indicators of the creation of a specific microflora of activated sludge during the starting period are the criterion of optimal loads and the criterion of complete stability of all technological and analytical parameters of the biochemical oxidation process.

Carrying out the start-up mode of operation of the STP at minimum loads, i.e. less than 50% of those provided for by the regulations, leads to ineffective cleaning results, since under these conditions an ecosystem of activated sludge is formed with random microbial communities that preserve the main type of metabolism inherent in them when living in natural conditions. The resulting stage of such adjustment of the operation of treatment facilities is unstable hydrochemical indicators of treated wastewater, inexplicable, at first glance, "slippage" of increased concentrations of pollutants in the purified liquid.

The well-established process of adaptation of activated sludge, discussed above, is the basis for the formation of specific microflora, which causes high rates of biochemical oxidation of specific substrates.

An important final stage of the start-up period of the treatment facilities is the organization of continuous reception of industrial wastewater at the time of start-up of chemical production. During this period, it is of great importance to maintain the loads on the active sludge at the achieved level. Periods of forced "starvation" of activated sludge, which are possible in the pre-start period, should be completely excluded.

The assumption of such situations will negate all efforts to adapt the active sludge and the formation of its specific microflora. Observations have shown that the phase of forced starvation of activated sludge causes not only a sharp decrease in the oxidative capacity of bacteria, but also a change in its physical properties. There is a loss of large masses of activated sludge with purified wastewater, as starving active sludge floats in the settling zone.

It is also important to prevent sharp fluctuations in the concentrations of pollutants in the treated wastewater and volley emissions of wastewater with increased concentrations of pollution, since with the regular occurrence of such situations, the degeneration of activated sludge with the mass development of filamentous forms of bacteria can occur.

During the adjustment and start-up of the main chemical industries, the composition and amount of wastewater generated may be subject to sharp fluctuations. The task of the technological staff is to properly organize the reception, mixing and averaging of wastewater and, if necessary, to adjust the flows before entering the STP. At the same time, it is required to carry out regular analytical monitoring of industrial wastewater with the determination of bichromate oxidizability, pH, nitrogen compounds and specific ingredients.

Thus, carrying out the whole complex of technological measures aimed at organizing the launch of treatment facilities and adapting activated sludge to the components of industrial wastewater will form a specific microflora of activated

sludge, which has a high oxidative capacity relative to the ingredients inherent in wastewater of this chemical production. This will serve as the basis for the effective operation of treatment facilities and their achievement of design capacity.

Technological control during the start-up, adjustment and operation of treatment facilities

Technological control during the start-up, adjustment and operation of treatment facilities allows providing personnel with timely and reliable information sufficient to develop the necessary decisions for the management of treatment facilities.

Control of the operation of facilities is based on determining the values of such parameters of the biological treatment process as the flow rate and temperature of wastewater of all types, the concentration of pollutants, pH, the physicochemical and sanitary parameters of wastewater after treatment facilities, the aeration period, the concentration of activated sludge and the amount of oxygen in aeration zones.

The values of the process parameters (flow, temperature, pH, concentration, etc.) can be determined by the relevant devices and appliances, as well as as by calculations (determination of the aeration period, load on the active sludge, oxidative capacity of structures, etc.).

During technological control, it is necessary to take into account the time of passage of the purified liquid through the treatment facilities.

To ensure control of the wastewater treatment process at certain points, samples of the liquid to be treated, silt mixture, treated wastewater are periodically taken. The location of sampling points depends on the scheme of treatment facilities and their design. However, in any case, the sampling points are chosen so

that the technological personnel can obtain information about what wastewater enters the treatment facilities, what is its quantitative and qualitative composition, the qualitative composition of the treated wastewater and what are the conditions for the biochemical process of oxidation of pollution in the STP and bioreactors.

When analyzing the selected samples, physical, chemical and bacteriological indicators are determined that allow the technologist to make the necessary decisions to control the technological process of biological treatment. The list of types of indicators is determined, first of all, by the characteristics of the sample, the conditions of operation of treatment facilities.

5. Filtration facilities for post-treatment

Filters are often used for post-treatment of biologically treated wastewater.

Various filters for water purification are known, in which the processes of water purification from various contaminants, including suspended substances, are carried out.

Known filters for water purification include a housing with inlet and outlet pipes located on the outside and a filter load located inside the filter load with the output of purified water through the drainage system (Frog B.N., Levchenko A.P. Water treatment. M.:MGU, 1996. - pp. 229-304.) A significant drawback of the

proposed device is the low degree of water purification from suspended substances.

A technical solution is known in the form of a combifilter for water purification from suspended substances (RF patent No. 2060788, Combined filter for water purification, reg. 1993.05.27, publ. 1996.05.Authors: Mirkis I.M., Mirkis V.I., Arkhipov A.I.). A significant drawback of the proposed device is a low degree of water purification from suspended substances.

A significant drawback of the well-known combifilter is a low degree of water purification from suspended substances and a large consumption of reagents.

To eliminate these shortcomings, the author proposed a combifilter for purifying water from suspended substances, the scheme of which is shown in Fig. 5.1.

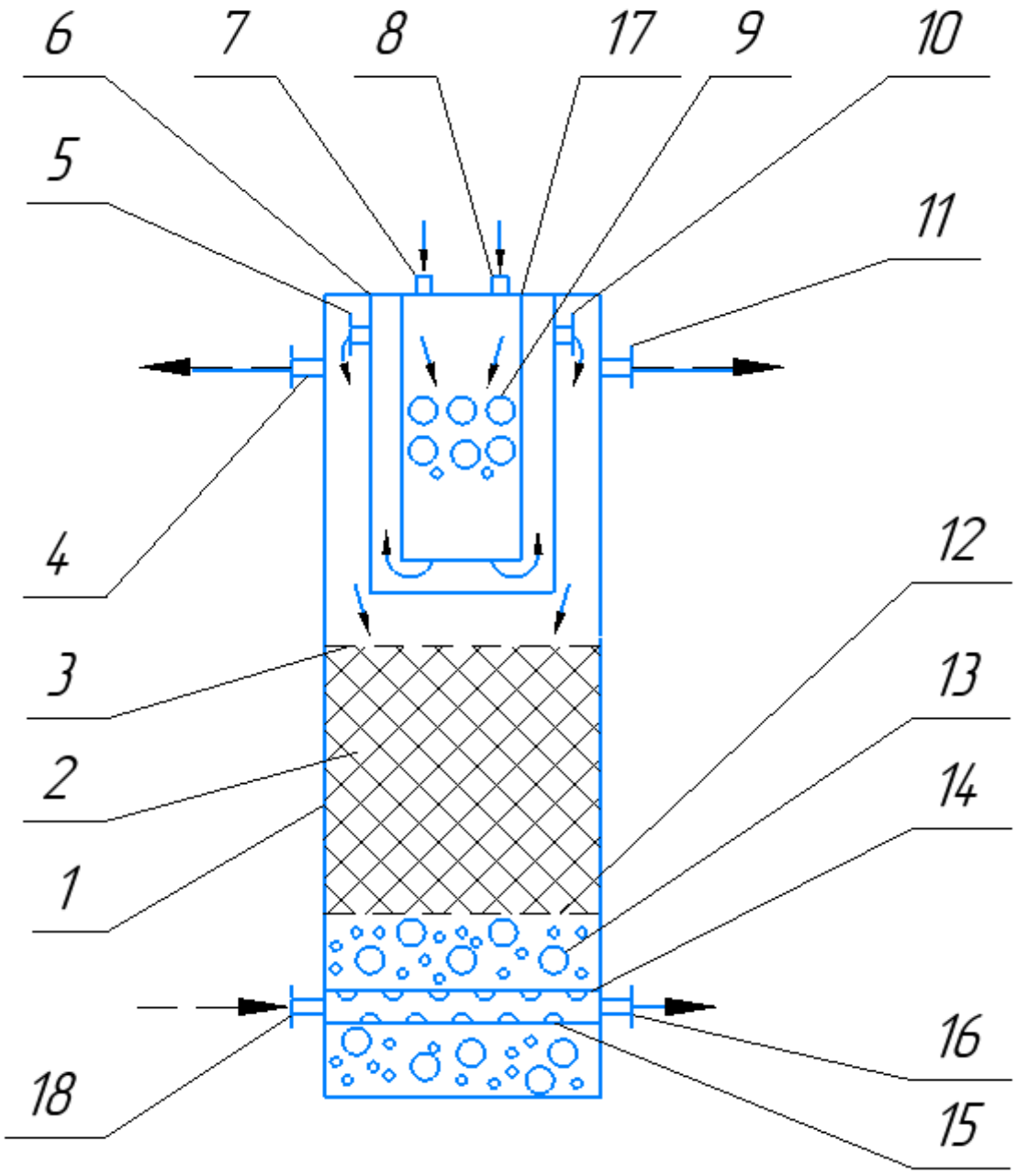


Fig. 5.1. Scheme of combifilter-1 for water purification

(patent of the Russian Federation for a utility model No. 209470, pr.11.11.2021, decision on issuance dated 02.02.2022.)

The proposed combifilter -1 for water purification includes a housing 1, on the outside of which there are branch pipes 4 and 11 for the output of washing

water, a branch pipe 7 for the supply of dirty water, a branch pipe 8 for supplying a reagent solution, a branch pipe 16 for the output of purified water and a branch pipe 18 for purifying water supply, and inside the housing there is a filter load 2 located between the grates 3 and 12, above which is a mixing chamber 6 with nozzles 5 and 10, inside of which is placed a cylindrical glass 17 with a floating nozzle 9 with particle sizes from 1 to 50 mm, and below the filter load there is a drainage load layer 13, and the ratio of particle sizes of the filter and drainage loads is respectively from 1: 2 to 1: 10, which has been proved experimentally. In this case, inside the drainage load there is a drainage system in the form of a perforated pipe 14 with holes 15.

The principle of operation of the proposed combifilter is as follows. The original (dirty) water through the inlet pipe 7, as well as the solution of the reagent, enter the housing 1 of the combifilter through the nozzle 8, directly into the cylindrical cup 17 with a floating nozzle 9 with particle sizes from 1.0 mm to 50.0 mm. Due to the intensive movement of particles 9, there is an effective mixing of the reagent solution with water, which increases the effect of water purification. The particle size of the floating nozzle was substantiated experimentally. Further, the water treated with the reactant is supplied through the grate 3 to the filter loading layer 2 and then discharged through the drainage layer 13 and the drainage system 14 and further through the outlet pipe 16. At the same time, the ratio of particle sizes of the filter and drainage loads is respectively from 1: 2 to 1: 10, which has been proven experimentally.

Flushing the filter consists in supplying flushing water through the branch pipe 18 and with the output of waste flushing water through the branch pipes 4 and 11.

When using the proposed combifilter for water purification, the quality of purified water for suspended substances is guaranteed to meet the standards of

drinking water and does not exceed 0.5 mg / l. In the case of using known devices, the concentration of suspended substances is about 1.5 mg / l, which in some cases does not guarantee the quality of drinking water.

The proposed combifilter for water purification can be autonomously used for the treatment of both natural waters, as well as wastewater of various industries as a local treatment plant with an area smaller than in the case of use withweapons - analogues up to 1.5 times.

Another variant of the utility model is the development of a new design of the combifilter, which provides a high degree of water purification from suspended substances and a decrease in the consumption of reagents. The technical result is to increase the efficiency of water purification from suspended substances and reduce the consumption of reagents. The task and the specified technical result are achieved by the fact that the proposed combifilter for water purification from suspended substances, including a housing on the outside of which there are inlet and output pipes, and inside in series there are a reagent mixing chamber with water with a floating nozzle, layers with filter and drainage loads, and in front of the mixing chamber coaxially to the combifilter there is an ejector with an inlet pipe for water supply and coagulant and flocculant supply pipes located obliquely to the surface of the ejector, and after the drainage loading, an aeration chamber with a compressed air supply pipe is placed and at the same time the coagulant and flocculant supply pipes are located obliquely to the surface of the ejector at an angle of 15 -150^0 and 10 - 135^0, respectively.

The author has developed a more advanced model of the combifilter.

In Fig. Figure 5.2 shows a diagram of a combifilter - 2 for the purification of water from suspended substances.

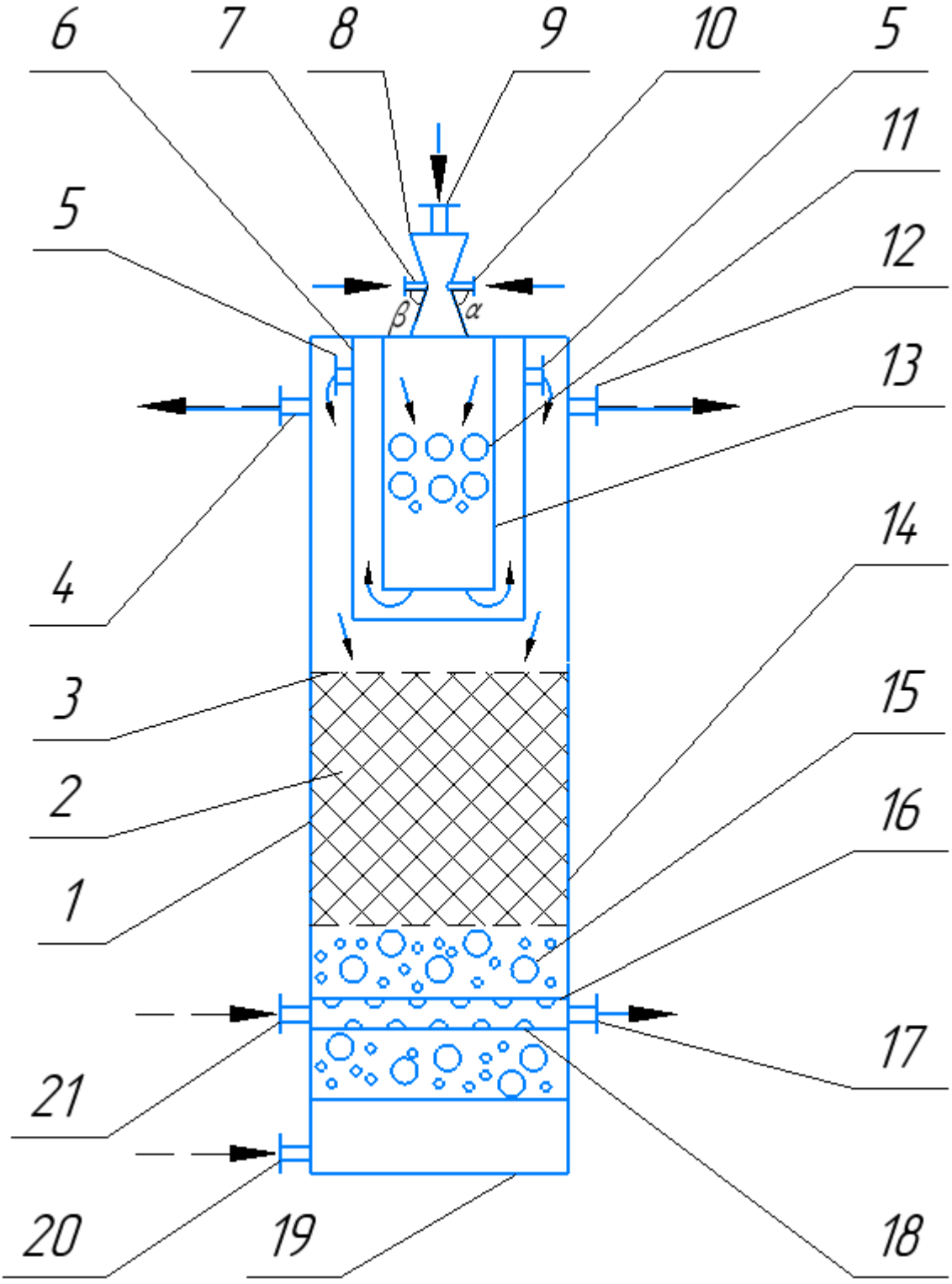


Fig. 5.2. Scheme of combifilter-2 for water purification from suspended substances (Utility Model Application No. 2022108408/05(017417. Applicant and author Ksenofontov B.S.)

The proposed combifilter - 2 for the purification of water from suspended substances includes a body 1, on the outside of which there are branch pipes 4 and 12 for the output of washing water, a branch pipe 9 for the supply of dirty water, which is the inlet part of the ejector 8, a branch pipe 7 with an angle of β for supplying a coagulant solution, a branch pipe 10 with an angle of α for supplying a flocculant solution, as well as a branch pipe 17 for the output of purified water, compressed air supply branch pipe 20 and flushing water supply pipes 21, and inside the housing there is a filter load 2 (quartz sand, crushed and undressed claydite, AC-sorbent, etc.) located between the grates 3 and 14, above which a mixing chamber 6 with branch pipes 5 is installed, inside of which is placed a cylindrical glass 13 with a floating nozzle 11 with particle sizes from 1 to 50 mm, and below the filter load is a layer of drainage loading 15 (gravel, crushed stone, etc.). Inside the drainage load is a drainage system in the form of a perforated pipe 16 with holes 18. To loosen the filter and drainage loads, compressed air is supplied through the nozzle 20 to the aeration chamber 19.

The principle of operation of the proposed combifilter - 2 is as follows. The original (dirty) water through the inlet pipe 9 enters the ejector 8, creating a vacuum in the zone of the branch pipes 7 and 10, through which the coagulant solution is sucked respectively through the branch pipe 7 and through the branch pipe 10 of the flocculant solution. Further water purification occurs due to filtration through the filtering (pos. 2) and drainage (pos. 15) loading At the same

time, the effectiveness of cleaning depends on the suction and mixing of coagulant and flocculant solutions, the supply of which is carried out through branch pipes 7 and 10, installed respectively at the angles of β and α to the surface of the ejector. As established during the experiments at the value of the α angle in the range of 10 - 1350 and the angle of β in the range of 15 - 1500, the best

efficiency of wastewater treatment and the lowest consumption of reagents are observed.

The purified water is discharged through the nozzle 17. Maintenance of the filtering (pos. 2) and draining (posp. 15) loads in working condition is carried out by periodic water-air washing. In this case, the washing water is supplied through the branch pipe 21, and the compressed air through the branch pipe 20 to the aeration chamber 19. The withdrawal of the washable water-air mixture occurs through branch pipes 4 and 12.

When using the proposed combifilter - 2 for water purification, the quality of purified water for suspendedsubstances when usedas filter loads, for example, in the form of quartz sand or AC-sorbent, and as drainage loads, for example, in the form of gravel or crushed stone, does not exceed 0.3-0.4 mg / l with coagulant consumption of 30-40 mg / l and flocculant 5-15 mg / l. In the case of using known devices, the concentration of suspended substances is about 0.5-1.0 mg / l with coagulant consumption of 50-100 mg / l and flocculant 25 -50 mg / l.

The proposed filter can be used in the treatment of almost any natural and wastewater.

The effectiveness of wastewater treatment from suspended substances using the specified combifilters is presented in Fig. 5.3.

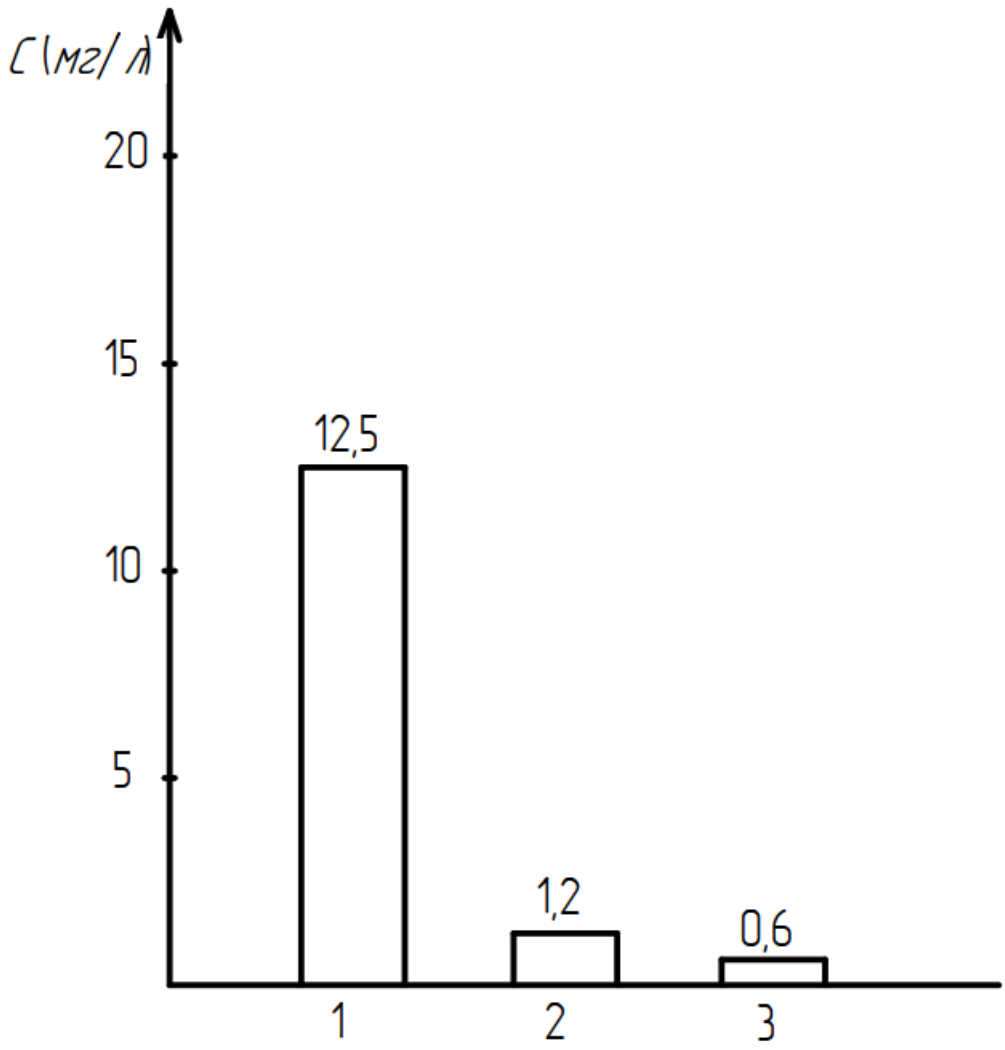


Fig. 5.3. Efficiency of water purification from suspended substances using combifilters: 1 – source (dirty) water; 2 – purified water on a combifilter 1; 3 - purified water on a combifilter 2; C (mg / l) - the concentration of suspended substances.

Analysis of the data presented in Fig. Figure 5.3 shows that the best results are achieved using a combifilter - 2. This indicates, in our opinion, the effectiveness of using the built-in chamber in combination with an ejector for mixing reagents with the water to be purified.

Test questions

1. The essence of the method of extracting biogenic elements from wastewater using the Bordenfo method.
2. The essence of the method of extracting biogenic elements from wastewater using the method of the University of Cape Town.
3. The essence of the method of extracting biogenic elements from wastewater using the method of the University of Johannesburg.
4. Basics of calculation of aeration tanks with the achievement of normative indicators for nitrogen and phosphorus.
5. Analysis of methods for calculating aeration tanks with the achievement of normative indicators for nitrogen and phosphorus.

Bibliography

Main literature

1. Ksenofontov B.S. Biological wastewater treatment. M.: Infra – M. 2020. – 255 p.

2. Yakovlev S.V., Voronov Yu.V. Vodootvodenie i wastewater treatment/Uchebnik dlya vuzov: - M.: ASP, 2004. – 704 p.

3. Hentse M. Wastewater Treatment: Per. c eng./ Henze M., Armoes P., La-Cours-Jansen Y., Arvan E.- M.: Mir, 2006. – 480 p.
4. Kuznetsov A.E., Gradova N.B. Scientific foundations of ecobiotechnologies (for this course are of interest the sections "Ecosystems of natural environments and biological treatment facilities", "Anthropogenic factors of pollution", "Biotransformation of nitrogen and sulfur compounds"). Uchebs sob. – M.: Mir, 2006. – 504 p.
5. Getmantsev S.V., Nechaev I.A., Gandurina L.V. Treatment of industrial wastewater by coagulants and flocculants. Scientific publication. DIA Publishing House. – M.: 2008. – 272 p.
6. Alekseev E.V. Physico-chemical wastewater treatment: Uchebnoe posobie. – M. : Izdatelstvo Obshchestvo stroitel'nykh vuzov, 2007. – 248 p.
7. Ksenofontov B.S. Water preparation and water disposal: ucheb. posobie / B.S.Ksenofontov. – M.: ID «Forum»: Infra – M, 2018. – 298 p.
8. Pakhnenko E.P. Sewage sludge and other non-traditional organic fertilizers. – M.: BINOM. Laboratory of Knowledge, 2007. – 311 p.
9. Voronov Yu.V., Yakovlev S.V. Vodootvodenie i chistochnye vody: ucheb. for universities (direction "Construction"). 4-e ed., dop. i pererab. M.: ASV: Izd-vo MGSU, 2006. – 704 p.
10. Laskov Yu.M., Voronov Yu.V., Kalitsun V.I. Examples of calculations of sewage structures. Ucheb. sob. for universities. 3-e ed., pererab. i dop. – M.: Alliance, 2008. – 256 p.
11. Pugachev E.A. Processes and devices for processing sewage sludge. – 2010. – 208 p.
12. Samygin V.D., Ignatkina V.A. Processes and devices for wastewater treatment. Tutorial. – 2009. – 223 p.
13. Standard technical regulations for the use of sewage sludge as an organic fertilizer of 19.06.2000
14. Agricultural use of wastewater: Handbook / L.P. Ovtsov, V.V. Ignatova, E.E. Elik et al.; Sost. E.E. Elik. – M.: Rosagropromizdat, 1989. – 223 p.

15. Serpokrylov N.S. et al. Ecology of wastewater treatment by physicochemical methods. – M.: ASV, 2009. – 262 p.
16. Kichigin V.I. Vodootvodnye sistemy promyshlennykh enterprises: ucheb. sob. for universities. – M.: ASV, 2011. – 656 p.
17. Lapitskaya M.P. Wastewater treatment (examples of calculations): ucheb. for universities and secondary specialists. Images. (special. "Water Supply and Sewerage") / Lapitskaya M.P., Zueva L.I., Balaeskul N.M., Kuleshova L.V. – Minsk, Vysshaya Shkola, 2007. – 256 p.
18. Gogina E.S. Removal of biogenic elements from wastewater. Monograph. — M.: MGSU, 2010. — 120 p.
19. Zhmur N.S., "Technological and biochemical processes of wastewater treatment at facilities with aeration tanks.", M.:AQUAROS, 2003. – 512 p.
20.ITS 10-2015 Wastewater treatment using centralized wastewater disposal systems of urban district settlements.

Further reading

21. Ryazanov V.L., Sevastyanova G.S. Development and improvement of the method of biochemical wastewater treatment., M., 1982., (Review. Inform./VNIIIS.Ser.9 Eng.provision of facilities of construction; issue 2).

22. Skirdov I.V., Dmitrieva A.A., Shvetsov V.N. Influence of the concentration of activated sludge on the rate of biochemical oxidation / Purification of industrial wastewater: Sb. Nauchno.tr. VNII VODGEO. M., 1974.

23.Karelin Ya.A., Zhukov D.D. Et al.. Treatment of industrial wastewater in aeration tanks,,M., Stroyizdat,1973.

24. Yakovlev S.V., Skirdov I.V., Shvetsov V.N., Application of technical oxygen for biological wastewater treatment.,// Water supply and sanitary technics.1972, No4.

25. Rotmistrov M.N.. Gvozdyak P,.I.,Stavskaya S.S. Microbiology of water purification.,Kiev.,Nauk. Dumka, 1978.

26. Rappoport I.A., Vasilyeva S.V.. Application of chemical mutagenesis in the biological destruction of industrial chemical waste.// Self-purification and bioindication of polluted waters.M.. 1980.

27. Silantyeva N.S., ZamelinV.I., Fedosova N.F. Intensification of the process of biological wastewater treatment with the help of chemical mutagens // Application of chemical mutagens in the protection of the environment from pollution and in agricultural practice.M., 1981.

28. ChelnokovA.A., TrukhachevT.V.. Astakhov V.A. Intensification of the process of biotreatment of wastewater with microprimes of ozone // Microbiology of water purification.: Theses of reports 1 All-Union.conf.,,Kiev,1982.

29. Khabarov O.S.Bezreagent intensification of wastewater treatment., M., Metallurgy, 1982.

30. Iost H. Physiology Cells.M., Peace, 1975.

31. BrayJ., WhiteK. Kinetics and Thermodynamics of Biochemical Processes., Moscow, 1959.

32. Henze M. wastewater treatment. M., Mir, 2004.

33. Voronov Yu.V. etc. Reconstruction and intensification of sewage treatment plants, M., Stroyizdat.1990.

34. Nechaev A.P., Slavinskaya A.S. et al., Intensification of post-treatment of biologically treated wastewater // Water supply and sanitary technics, 1991, No12.

35. StepanovA.S.et al. Intensification of biological treatment processes at sewage treatment plants. Samara.//Water supply isanitarnaya tekhnika.M.,.2006, No9.

36. Kolesnikov V.P., Ksenofontov B.S.Khudokormov A.A., Kochetov A.N. /Ed. Ksenofontova B.S. Technological processes of wastewater treatment, production of feed proteins, chemical synthesis. Novocherkassk, Lik, 2016. – 198 p.

37. Collection of reports of the
conference "Water supply and sanitation of populated areas and industrial enterprises: effective solutions and technologies".. Moscow, Crocus Expo, 25-26 September 2018.

38. Bazyakina N.A. Purification of concentrated wastewater. M.: Gosstroyizdat, 1958.

39. Gvozdyak P.I., Dmitrienko T.M., Kulikov N.I. Purification of industrial wastewater attached by microorganisms // Chemistry and water technology. 1985. T. 7. № 1. S. 64-68.

40. Zhmur N.S. HDPE F SB 14.1.77-96. Methodical guide to hydrobiological and bacteriological control of the biological treatment process at facilities with aeration tanks. M., 1996.

41. Rogovskaya Ts.I. Biochemical method of cleaning production wastewater. M.: Stroyizdat, 1967.

42. Epov A.N. , V.I. Bazhenov. Calculation of aeration tanks with the removal of biogenic elements / Collection of reports of the Congress "Water: Ecology and Technology". M., Ekvatek, - 2008.

43. Meshengiser Yu.M., Esin M.A., Smirnov A.V. Energy-saving approach to the implementation of technology for the removal of biogenic elements at water purification facilities / Collection of materials of the X international scientific production conference // Solving problems of environmental safety in the water management industry. Novosibirsk 1-2 October. - 2014.

44. K.M. Morozova K.M. Principles of calculation of systems of biological wastewater treatment / Journal of VST. - 2009. - 1. - S. 26-31.

45. Vavilin V.A., Vasiliev V.B. Mathematical modeling of processes of biological wastewater treatment by active sludge / Nauka. – 1979.

46. Epov A.N., Nikolaev V.N. Intensification of deep wastewater treatment in aeration tanks by optimizing the age of sludge / Overview information. IEZHKH. - 1989.

47. Epov A.N. Kanunnikova M.A. Development of standard solutions for the automation of biological wastewater treatment processes with joint removal of nitrogen and phosphorus / BAT Journal. - 2014. - №3.

48. Technical Specifications for Anaerobic-Anoxic-Oxic Activated Sludge Process HJ 576—2010/ Chinese National Environmental Standards. - 2010.

49. A.N. Epov, V.A. Zagorsky, D.A. Danilovich, F.A. Dayneko, N.A. Belov, S.E. Berezin, V.I. Bazhenov. Reconstruction of aerotenkov Lyuberets station / Housing and Communal Services. - 2000. - 4. - P. 1-3.

50. M.A. Kanunnikova, A.N. Epov. Respirometric determination of kinetic coefficients of the nitrification rate equation / Journal Water Supply and Sewerage. - 2009. – 4

51. Code of rules, SP 32.13330.2012. Kanalizacija. Naruzhnye seti i sooruzhenija [Sewerage. Public utilities], Revised edition of SNiP 2.04.03-85, M, 2012. pp. 1–92 (in Russian).

52. Standard ATV-DVWK-A 131E, Dimensions of Single-Stage Activated Sludge Plants. — 2000. — 57 p. (in English).

53. GPS-X 5.0 Technical Reference. Copyright 1992-2006 Hydromantis, Inc (in English).

54. A. N. Jepov, V .I. Bazhenov. Raschet ajerotenkov s udaleniem biogennyh jelementov [Calculation of aeration tanks with biogenic elements removal], collection of reports of the congress «Water: ecology and technology», M., ECWATECH, 2008 (in Russian).

55. Meshengiser Ju. M., Esin M. A., Smirnov A. V. Jenergosberegajushhij podhod k realizacii tehnologii udalenija biogennyh jelementov na sooruzhenijah ochistki vody [Energy saving approach to the implementation of the technology of biogenic elements removal on water treatment facilities], The collection of materials of the X

international scientific-production conference, The problems of ecological security in the water sector, Novosibirsk 1–2 of Ocotber, 2014 (in Russian).

56. Stroitel'nye normy i pravila SNiP 2.04.03-85. Kanalizacija. Naruzhnye seti i sooruzhenija [Building Code (SNiP) 2.04.03-85. Sewerage. Public utilities], M., 1986 (in Russian).

57. Stroitel'nye normy i pravila SNiP II-32–74. Kanalizacija. Naruzhnye seti i sooruzhenija [Building Code(SNiP) II-32-74. Sewerage. Public utilities], M., 1975 (in Russian).

58. K. M. Morozova. Principy rascheta sistem biologicheskoj ochistki stochnyh vod [The principles of calculation of biological wastewater treatment systems], Water Supply and Sanitary Technique, 2009, 1, pp. 26–31 (in Russian).

59. Vavilin V. A., Vasil'ev V. B. Matematicheskoe modelirovanie processov biologicheskoj ochistki stochnyh vod aktivnym ilom [Mathematical modeling of biological wastewater treatment by activated sludge], Nauka, publ., 1979 (in Russian).

60. Jepov A. N., Nikolaev V. N. Intensifikacija glubokoj ochistki stochnyh vod v ajerotenkah putem optimizacii vozrasta ila [Intensification of deep cleaning of wastewater in aeration tanks by optimization of sludge age.], Survey information, Academy of municipal economy named. K. D. Pamfilova, 1989 (in Russian).

61. M. Khentce. Ochistka stochnykh vod. Biologicheskie i khimicheskie protcessy [Wastewater treatment. Biological and chemical processes], M., Mir, 2004 (in Russian).

62. Epov A. N. Kanunnikova M. A. Razrabotka tipovykh reshenii po avtomatizatcii protcessov biologicheskoi ochistki stochnykh vod s sovmestnym udaleniem azota i fosfora [Development of standard solutions for automation of processes of biological wastewater treatment with joint removal of nitrogen and phosphorus.], Best available techniques,journ., 2014, №3 (in Russian).

63. Technical Specifications for Anaerobic-Anoxic-Oxic Activated Sludge Process HJ 576－2010/ Chinese National Environmental standards, 2010 (in English).

64. A. N. Epov, V. A. Zagorskii, D. A. Danilovich, F. A. Daineko, N. A. Belov, C. E. Berezin, V. I. Bazhenov. Rekonstruktciia aerotenkov Liuberetckoi stantcii [Reconstruction of the Lyubertsy aeration station], ZhKKh,journ., 2000, 4, pp. 1–3 (in English)

65. M. A. Kanunnikova, A. N. Epov. Respirometricheskoe opredelenie kineticheskikh koeffitcientov uravneniia skorosti nitrifikatcii [Respirometry determination of kinetic coefficients of the nitrification rate law], Water supply and sanitary techniques, journ., 2009, 4 (in Russian).

66. MON F SB 14.1.92-96. Methods of sanitary and biological control. Methodical guide to hydrobiological control of filamentous microorganisms of activated sludge.

67. Zhmur N.S. PHD F SB 14.1.77-96. Methodical guide to hydrobiological and bacteriological control of the biological treatment process at facilities with aeration tanks. M., 1996.

68. Shvetsov V.N., Morozova K.M. Calculation of biological wastewater treatment facilities with the removal of biogenic elements. Water supply and sanitary engineering. 2013, No.11, p.42 -46.

69. Danilovich D.A., Epov A.N. Comparative analysis of the methodology for calculating biological wastewater treatment facilities from nitrogen. Water purification. Water treatment. Water supply.2017, No4, p.28-40.

70. Kharkina O.V., Khar'kin S.V. Wastewater treatment from nitrogen and phosphorus : effective operation and calculation of treatment facilities / O. V. Kharkina, S. V. Kharkin // Ecologist's Handbook. - 2016. - No 6. - P. 82-96 :