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ENVIRONMENTAL ENGINEERING PROTECTION

Study guide
for students in the field of training
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Technosphere safety

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The textbook provides the classification and characteristics of the main types of environmental pollution, considers the basic laws of engineering protection of the atmosphere, hydrosphere, lithosphere from chemical and physical types of pollution. The description of the main chemical, physico-chemical and biochemical processes of wastewater treatment and protection of the lithosphere from waste is given, the mechanical processes of processing liquid and solid waste are considered.

The textbook is intended for university students studying in the field of training "Technosphere safety". It can be used by practitioners in postgraduate education and advanced training systems.

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INTRODUCTION

Man and nature are inseparable from each other and closely interrelated. Nature is the environment of life and the only source of necessary resources for life. Nature and its resources are the basis of life and development of human society.

However, each new decade increasingly exacerbates the contradictions in the interaction of society and nature. In the era of scientific and technological progress, the pressure on the nature of human economic activity has significantly increased. Excessive anthropogenic loads, imperfect production technologies, leading to depletion and pollution of the natural environment, have sharply worsened the quality of all natural systems.

Dangerous processes such as climate change, atmospheric gas composition, acid precipitation, depletion of the ozone layer are observed.

Agriculture exerts the greatest burden on the world's land, soil and water resources. The expansion and uncontrolled use of fertilizers, the mechanization of agriculture and the general impact of higher intensity monoculture farming, livestock grazing – all this significantly depletes land fertility, leads to land degradation and pollution of surface and groundwater. The productive capacity of land and water resource systems is approaching its limit. As agriculture intensifies, the degree and severity of land degradation increases.

Minerals are extracted from the depths in huge quantities, but only a small part of them is rationally used by humans, as a result of which the volume of polluting waste increases.

Environmental engineering (also known as environmental engineering, environmental engineering) is a set of scientific and engineering principles for improving the natural environment, providing clean water, air and land for human habitation and other organisms, as well as for cleaning contaminated sites.

The subject of environmental engineering is the impact of environmental factors and the influence of living organisms on production facilities.

§ 1 ENVIRONMENTAL ENGINEERING AND ITS PLACE IN THE SYSTEM OF KNOWLEDGE ABOUT MAN AND NATURE

Trying to understand the problems of human impact on the environment, ways to protect against negative manifestations of this impact, humanity has created many sciences and scientific directions, each of which operates with its own terminology and uses its own research methods.

The conceptual framework of environmental engineering includes many terms formed at the junction of various fields of knowledge. Let's look at some of them.

The biosphere is the shell of the earth in which the life of various organisms develops, covering the lower part of the atmosphere (up to 15 km), the entire hydrosphere (up to 12 km) and the upper part of the lithosphere (up to 5 km).

In the biosphere, living organisms and their habitat are organically linked to each other.

The biosphere originated 3.5...4.5 billion years ago. It is the result of the interaction of living and inanimate matter. (Development of the concept of the biosphere – V. I. Vernadsky).

The biosphere is developing. Human society is one of the stages of the development of life on Earth, i.e. one of the stages of biogenesis. A distinctive feature of biogenesis at the present stage of evolution is the influence of reason (intelligent human activity).

The noosphere is the sphere of the mind, the highest stage of the development of the biosphere, associated with the emergence and development of humanity in it, when intelligent human activity becomes the main factor of development.

One of the most important is the concept of an "ecological system" (ecosystem), which belongs to the class of complex systems, which is associated with the complexity of its definition and writing, the multi-link structural composition and the multi-connectivity of the constituent structural units.

Recently, a large number of phrases have appeared using the classic term "ecology". The term was first proposed by the German scientist Ernst Haeckel in 1886. Initially, ecology was considered as a science investigating the patterns of vital activity of organisms in their natural habitat, i.e. as bioecology. Currently, this term is used much more widely to denote a system of environmental knowledge consisting of a wide variety of areas.

Ecology is a science that studies the conditions of existence of living organisms, their relationship to each other and the environment in which they live.

An ecological system (ecosystem) is a collection of different species of organisms living together and their conditions of existence, which are interconnected with each other.

Ecological systems can be very different:
-microecosystems (a pot with a flower);
-mesoecosystems (a pond with its inhabitants);
- macroecosystems (a continent with people, animals, insects, etc.)
is another equally important concept – the ecological factor.

An environmental factor is an element of the environment that has a significant impact on a living organism.

Environmental factors are usually divided into:

-factors of the inanimate environment (for example, climatic – temperature, humidity, pressure, etc.);

-biotic – factors of the living environment associated with the influence of living beings;

-anthropogenic – factors influencing the process of human activity.

Human ecology is a science dealing with the study of the ecosystem "man – environment".

The main subject of the study of anthropogenic ecology is the human impact on the environment, as well as the reverse effect of the environment on human life.

Anthropogenic ecology is an interdisciplinary science based on a complex of "ecologized" fundamental sciences and applied disciplines that solve the problems of rational interaction between human society and nature. Engineering ecology occupies a special place among the applied disciplines included in anthropogenic ecology.

Engineering ecology is an applied discipline that represents a system of scientifically based engineering and technical measures aimed at preserving the quality of the environment in conditions of growing industrial production.

Engineering ecology arose at the junction of technical, natural and social sciences.

Along with the term "engineering ecology", terms similar in meaning are often used, for example: "applied ecology", "industrial ecology", "life safety", "environmental protection", "environmental protection", "labor protection", etc.

Environmental protection is a system of legal, technical and sanitary measures ensuring the rational use, conservation and reproduction of natural resources.

Environmental protection should be attributed to areas that use environmental knowledge, rather in the context of prohibitions or restrictions (technical, legal, organizational, etc.) rather than optimizing environmental management.

Nevertheless, environmental protection is a system that practically implements targeted actions formed within the framework of the scientific discipline "Engineering Environmental Protection or "Engineering Ecology".

Engineering environmental protection is a system of scientifically based engineering and technical measures aimed at developing engineering methods for studying the human–environment ecosystem, engineering and technical methods and means of protecting humans and their environment from especially dangerous, dangerous and harmful anthropogenic factors.

Any industrial enterprise that includes material, energy and human resources employed in the production process can be considered as an ecological system "man – production facility – environment".

The problem of environmental safety within the framework of a manufacturing enterprise should be analyzed in a broad aspect as a complex task of ensuring internal safety and harmlessness, as well as environmental protection.

Solving the problem of environmental safety of industrial enterprises requires a knowledge system that combines achievements in the field of occupational safety, environmental protection and industrial safety.

Occupational safety and health is a system of legislative acts and corresponding socio-economic, technical, hygienic and organizational measures that ensure the safety, preservation of human health and efficiency in the process of work.

Safety engineering is a system of organizational and technical measures and means to prevent the impact of dangerous and harmful production factors on workers.

Environmental protection is a system of legal, technical and sanitary measures ensuring the rational use, conservation and reproduction of natural resources.

When systematizing information about the ecosystem "human – production facility – environment", developing technical methods and means of protecting humans and their environment, the generalized concept of "anthropogenic production factors" (ACE) is used.

Anthropogenic factors are factors that arise in the course of human activity.

It should be noted that human activity can be domestic, industrial and also related to military operations, be accidental or intentional. And anthropogenic factors can cause negative changes in the health of a person directly involved in the production process, and anthropogenic changes in the environment affected by this production process.

By their nature, anthropogenic factors can be:
-physical,
-chemical,
-biological,
-psychophysiological.

According to their action, ACE can be divided into:
-harmful, the effects of which on workers in certain conditions
lead to illness or decreased performance (for example, noise, vibration, electromagnetic fields),
-dangerous, the effects of which in certain conditions lead to injury or other sharp deterioration of health (electric current, chemicals in certain concentrations, etc.), depending on the level and the duration of exposure, a harmful production factor can become dangerous.
-especially dangerous – which, under certain conditions, lead to an industrial accident, when they create damaging factors for the population, personnel, and the environment, leading to catastrophic consequences (fire, explosion, radiation, etc.).
A quantitative assessment is given by the probability of occurrence of these factors and the concept of "risks".

Risk is the probability of human and material losses or damage.

Thus, the subject of environmental engineering or environmental engineering research is the interaction of technological and natural processes in human–production–environment systems at various levels.
The identification and analysis of anthropogenic production factors, the development of a set of ways and means to reduce their negative impacts are engineering and environmental support for the production process or engineering environmental protection.

§ 2 CHARACTERISTICS OF ENVIRONMENTAL POLLUTION AND THE MAIN METHODS OF ITS PROTECTION

2.1 Environmental quality indicators

Environmental pollution can be called a change in the quality of the environment, which can cause negative consequences. Pollution can be classified as follows (Table 1).

Table 1 - Classification of types of environmental pollution

Pollution	Definition
1	2
1 Mechanical	Contamination of the environment with agents that have only a mechanical effect without chemical and physical consequences (for example, garbage).
2 Chemical	Changes in the chemical properties of the environment that have a negative impact on ecosystems and technological devices.
3 Physical	Changes in the physical parameters of the medium: temperature-energy, wave, radiation (radiation or radioactive), etc.
3.1 Thermal (thermal)	An increase in ambient temperature, mainly due to industrial emissions of heated air, exhaust gases and water; may also occur as a secondary result of changes in the chemical composition of the medium.
3.2 Light	Violation of the natural illumination of the area as a result of the action of artificial light sources; may lead to anomalies in the life of plants and animals.
3.3 Noise	An increase in the intensity of noise above the natural level; in humans, it leads to increased fatigue, decreased mental activity and, when reaching 90-100 dB, to gradual hearing loss.
3.4 Electromagnetic	Changes in the electromagnetic properties of the environment lead to global and local geographical anomalies.

4 Radiation	Exceeding the natural level of radioactive substances in the environment.
5 Biological	The emergence of animal and plant species in ecosystems and technological devices that are alien to these communities and devices.
5.1 Biotic	The spread of certain nutrients, which are usually undesirable from the point of view of people, in areas where they have not previously been observed (for example, excrement and other waste products of animals).
5.2 Microbiological analysis	The appearance of a large number of microorganisms associated with their mass reproduction on anthropogenic substrates or in environments modified during human economic activity; Acquisition of pathogenic properties or the ability to suppress other organisms in communities by a previously harmless form of micro-organisms.

All these types of pollution are interrelated, and each of them can become an impetus, a catalyst for the emergence of other types of pollution. In particular, chemical pollution of the atmosphere can contribute to an increase in viral activity, and, consequently, biological pollution.

As a rule, there are upper and lower critical boundaries of environmental parameters, after crossing which irreversible changes occur in ecosystems. For example, some substances are necessary in small quantities, and in significant quantities they are strong poisons. This can be said about electromagnetic fields, and radioactive background, etc.

In the scientific and technical literature, the term "environmental quality index" is used for environmental quality indicators (a higher index corresponds to better quality) and the term "environmental pollution index" (a higher index corresponds to greater pollution).

The pollution index is a qualitative and quantitative characteristic of the contaminating principle (substances, radiation, etc.).

A very ambiguous term that includes the concepts of the volume (quantity) of a pollutant in the environment and the degree of its impact on objects, including humans, correlated with time or intensity of processes.

Let's return to it a little later, having considered the concept of maximum permissible concentrations (MPC).

The maximum permissible concentration (MPC) is a legally approved sanitary and hygienic or fisheries standard.

MPC refers to such a maximum concentration of chemical elements and their compounds in the environment, which, when daily influenced for a long time on

the human body, does not cause pathological changes or diseases established by modern research methods, at any time in the life of the present and subsequent generations.

The following standards are used to assess environmental pollution:

-standards of maximum permissible concentrations (MPC) of chemicals, including radioactive, other substances and microorganisms - non-compliance with which can lead to environmental pollution, degradation of natural ecological systems;

-standards of permissible physical impacts - standards that are established in accordance with the levels of permissible impact of physical factors on the environment and, subject to which, environmental quality standards are ensured.

The criteria for environmental quality are currently the maximum permissible concentrations (MPC), which are hygienic standards.

For most pollutants, two MPC values are set: the maximum single and the average daily. Let's look at these concepts in more detail.

MPC is the maximum permissible concentration of a chemical substance in the air of the working area, mg/m^3.

MPC should not cause diseases or abnormalities in the state of health during work or in the long-term life of the present and subsequent generations with daily (except weekends) work within 8 hours or other duration, but not more than 41 hours per week, during the entire work experience.

MPC_{CC} is the maximum permissible average daily concentration of a chemical in the air of populated areas, mg/m^3.

MPC_{CC} is the maximum permissible average daily concentration of a chemical in the air of populated areas, mg/m^3.

MPC_{mr} is the maximum permissible maximum single concentration of a chemical in the air of populated areas, mg/m^3.

MPC_{mp} should not cause reflex reactions in the human body when inhaled for 30 minutes. This indicator is set for substances with a specific effect (for example, a pungent odor) and can be considered a standard if its value is lower than the MPC_{CC}.

The quality of natural waters depends on the composition and quantity of dissolved and suspended substances, microorganisms, hydrobionts, as well as on temperature, acidity and other physico-chemical parameters. Water quality can be assessed by physical, chemical, bacteriological and hydrobiological parameters.

Water quality standards and standards are different for sanitary and fishery water bodies.

One of the factors determining the quality of the natural environment is the maximum permissible emission into the atmosphere (MPI).

MPD is a standard established under the condition that the content of pollutants in the surface layer of air from a source or combination of sources does not exceed the pollution determined by air quality standards for the population, wildlife and flora.

Let's return to the concept of the pollution index. Thus, the pollution index (IZ) is an indicator that qualitatively and quantitatively reflects the presence of a pollutant in the environment and the degree of its impact on living organisms.

The ATMOSPHERIC POLLUTION INDEX (ISA) is a complex indicator of the degree of atmospheric pollution calculated in accordance with the methodology (RD 52.04 186-89) as the sum of average concentrations in MPC units, taking into account the hazard class of the corresponding pollutant.

For example, the atmospheric pollution index is calculated for the five main pollutants (the sum of the average concentrations normalized to the average daily MPC, taking into account the hazard class). A five-point rating scale is used: satisfactory situation (ISA < 5), relatively tense (ISA from 6 to 15), significantly tense (ISA from 16 to 50), critical (ISA from 51 to 100), catastrophic (ISA over 100).

To objectively compare the water quality of various water bodies with each other, an indicator is often used - the water pollution index (ISI), which is calculated based on the 6 ingredients that are of the greatest importance. Depending on the value of the ISV, the water quality class is set.

The conversion of the absolute values of pollution into the ISA makes it possible to more realistically take into account the environmental harm caused by pollutants of varying degrees of harmfulness.

2.2 Sources of atmospheric pollution

150 million tons of various aerosols enter the Earth's atmosphere annually; 220 million tons of sulfur dioxide; 450 million tons of carbon monoxide; 75 million tons of nitrogen oxides. An average of 300 kg of emissions into the atmosphere per year per inhabitant of the Earth.

The main sources of pollution of the external air environment are:

-industrial enterprises, primarily chemical, petrochemical and metallurgical plants;

-heat generating plants (thermal power plants, heating and industrial boilers);

- transport, first of all, by car.

Emissions from energy facilities account for about 60%, transport 20-25%, industry 15-20%.

The causes of significant emissions into the atmosphere are: the absence or ineffective localization of sources of gases and dust; insufficient tightness, design flaws of production equipment, its technical malfunction; improper management of technological processes, etc.

Dust and gas pollutants of the air. Aerosols

Air quality, its effects on the body, as well as equipment and technological processes are largely due to the content of suspended particles in it, mainly dust.

Dust of technological origin is characterized by a wide variety in chemical composition, particle size, shape, density, character of particle edges, etc.

Dust causes harm to the body as a result of mechanical action (damage to the respiratory organs by sharp edges of dust), chemical (poisoning with toxic dust), bacteriological (pathogens enter the body together with dust).

According to hygienists, dust particles with a size of 5 microns or less are able to penetrate deeply into the lungs up to the alveoli. Dust particles of 5-10 microns in size are mainly retained in the upper respiratory tract, almost without penetrating into the lungs. Dust has a harmful effect on the respiratory system, eyesight, and skin.

The most severe consequences are caused by the systematic inhalation of dust containing free silicon dioxide SiO_2. As a result, silicosis occurs. This is one of the forms of lung disease associated with inhaling dusty air - pneumoconiosis. The effect of dust on the organ of vision causes conjunctivitis, dermatitis on the skin.

Organic dusts, such as flour, can be a breeding ground for the development of microorganisms. Dust particles can be a condensation core for liquid vapors. Together with dust, substances that cause intense corrosion of metals, etc., can enter the room. Many dusts form explosive mixtures with air.

Carbon monoxide (carbon monoxide CO) is a colorless, odorless gas. Highly toxic substance. CO emissions occur in foundries, thermal, blacksmith shops, in boiler houses, especially those running on coal fuel, CO is contained in the exhaust gases of cars, tractors, etc.

CO penetrates into the blood through the lungs. When combined with hemoglobin, it forms carboxyhemoglobin. At the same time, the supply of oxygen to the body is disrupted. In severe cases, suffocation occurs.

Cyanides. Cyanides include: cyanide (prussic acid) (HCN), its salts (KCN, NaCN, CH_3CN), and others. HCN is a colorless liquid with the smell of bitter almonds. Prussic acid is used in the production of nitrile rubber, synthetic fiber and organic glass, in the extraction of precious metals from ores, etc.

Prussic acid can enter the body through the mucous membranes of the respiratory tract and digestive tract, in small amounts through the skin. Salts of hydrocyanic acid enter the body in the form of dust through the oral cavity. Prussic acid and its compounds are highly toxic. Cyanides entering the body disrupt blood circulation and oxygen supply to the body.

Hydrogen sulfide (H_2S) is a colorless gas with the smell of rotten eggs. It is found in the processing, production or application of barium sulphide, sodium sulphide, antimony, in the leather industry, in sugar beet production, in artificial silk factories, in oil extraction and processing and other industries. It enters the body through the lungs, in small quantities through the skin. It has a high toxicity. It affects the central nervous system, disrupts the blood supply to the body.

Lead (Pb). Heavy metal. At a temperature of 400-500 °C begins to intensively emit vapors. Lead and its compounds enter the air at enterprises for the smelting of lead, for the production of batteries, lead paints, for the production of shot, etc. Lead compounds are used in industrial production: lead sulfide, lead oxide, lead meerkat, lead sulfate, etc.

Lead enters the body mostly through the respiratory tract, as well as through the digestive tract. Lead disrupts the work of the circulatory organs and the central nervous system, the digestive system, and metabolic processes in the body. It can accumulate in various organs (bones, brain, liver, muscles).

Mercury (Hg). Liquid metal. Evaporates at room temperature. In production, mercury is used in its pure form and in the form of compounds (chlorine, cyanide, sulfur dioxide, nitric acid, etc.). Almost all of them are poisonous. Mercury is used in the manufacture of measuring instruments (thermometers, barometers), mercury mercury, mercury rectifiers, obtaining gold from ores, etc.

Mercury vapor enters the body under production conditions through the respiratory system. When mercury enters the body, the nervous system and gastrointestinal tract, kidneys are mainly affected.

Carcinogenic substances. A number of substances used in industry can cause malignant tumors in various parts of the body. Such substances are chromium, arsenic, nickel, asbestos, beryllium, soot, resin, pitch, mineral oils and a number of others. These neoplasms can also occur after a significant period (several years) after stopping working with the relevant substances.

An aerosol is a dispersed system in which the medium is gas, air, and the dispersed phase is solid or liquid particles.

For large particles, the size is determined by the ability to remain suspended for a long time. Usually we are talking about particles up to 100...200 microns in size.

There are dispersion and condensation aerosols. Dispersion aerosols are formed during the crushing (dispersion) of solid and liquid substances.

Condensation aerosols - during condensation of saturated vapors, as well as as a result of gas reactions.

Aerosols include dusts, mists and fumes.

Dusts are dispersive aerosols with solid particles, regardless of the dispersion. Dust is also called a collection of settled particles.

Fog is a gaseous medium with liquid particles, regardless of their dispersion.

Smoke is condensation aerosols with a solid dispersed phase or including both

solid and liquid particles.

Dust of natural origin includes dust formed as a result of soil erosion, as well as dust arising from the weathering of rocks, etc. Organic dust-like particles - pollen, plant spores - also have a natural origin.

Many technological processes are aimed at producing various materials consisting of small particles called pulverized materials.

Most types of dust arise as a result of processes related to the processing of materials.

Depending on the material from which the dust is formed, it can be organic or inorganic.

A significant part of industrial dust is of mixed origin. Let's consider their basic properties.

Dispersion is the degree of grinding of a substance.

The dispersed composition is understood as the size distribution of aerosol particles.

The dispersed composition of dust is of paramount importance for the development and improvement of dust collection devices and systems, as well as for the implementation of measures to prevent the release of dust and its spread.

Density is the mass of a unit volume, kg/m^3.

There are true, apparent and bulk densities of dust particles.

The true density is the mass of a unit volume of the substance from which the dust is formed.

Apparent density is the mass of a unit volume of particles, including the volume of closed pores. The apparent density of a monolithic particle is equal to the true density of a given particle.

Bulk density is the mass of a unit volume of trapped dust freely poured into a container. The volume occupied by dust includes the internal pores of the particles and the intermediate space between them.

The specific surface area of an aerosol is the ratio of the surface of all particles to their mass or volume.

The adhesion of dust. The tendency of particles to adhere to each other is determined by their autohesional (cohesive) properties and in the dust cleaning technique is called "stickiness".

The interaction of particles with each other is called autogenesis.
The interaction of particles with surfaces is called adhesion.

Hygroscopicity of dust is its ability to absorb moisture from the air. Moisture absorption affects dust properties such as electrical conductivity, stickiness, flowability, etc.

The moisture content of the dust expresses moisture content or humidity.

Moisture content is the ratio of the amount of moisture in a substance to the amount of absolutely dry matter.

Humidity is the ratio of the amount of moisture in a substance to the total amount of a substance.

The hygroscopic moisture of the dust, i.e. the moisture that is retained on its surface, in pores and capillaries, can be determined by drying the dust sample to a constant mass in a drying cabinet.

Wettability of dust. Wet dust collection is based on wetting the dust with sprayed water. The wettability of dust determines the possibility of its hydraulic removal, the use of wet dust removal of industrial premises.

Combustibility and explosiveness of dust. The ability to form an explosive mixture with air and the ability to ignite are the most important negative properties of many types of dust. Many types of dust form explosive mixtures with air that can explode.

Substances such as grain and sugar in a pulverized state become not only flammable, but also explosive.

Dust suspended in the indoor air is explosive. The settled dust (gel) is flammable. However, under certain conditions, the settled dust is capable of passing into a suspended state, forming explosive mixtures. Both an explosion and gorenje dust in suspended state can occur.

Harmful gases and vapors

Many technological processes at enterprises of the metallurgical, chemical, petrochemical industries, in the workshops of machine-building plants are accompanied by the entry of harmful gases and vapors into the atmospheric air. Transport is also a pollutant of atmospheric air.

Purification methods are adopted depending on the physico-chemical properties of the contaminant, the aggregate state, the concentration in the medium being cleaned, etc.

An innovative solution for the protection of atmospheric air is the creation and implementation of waste-free technological processes in which all production waste is not released into the environment, but is used for useful purposes.

The most important measure to reduce emissions into the atmosphere is to improve the technological process in the direction of reducing waste and using it.

Another important measure is the sealing of the equipment.

Waters and water dispersion systems

It is known that the total amount of natural water on Earth is 1,386 million cubic meters. km, of which there is 35 million cubic meters of fresh water. km, i.e. about 2.5%. The volume of freshwater consumption in the world reaches 3,900 billion cubic meters per year. Moreover, about half of this amount is irretrievably consumed, and the other half turns into wastewater.

Water used in industry is divided into:

-cooling,

-technological,

- and energy.

In industry, 65...80% of the water consumption is consumed for cooling liquid and gaseous products in heat exchangers. In these cases, the water does not come into contact with material flows and is not polluted, but only heats up.

Process water is divided into:

- environment - forming,
- washing,
- reactionary.

Medium–forming water is used for dissolution and formation of pulps, in the enrichment and processing of ores, hydrotransportation of products and waste products; washing - for washing gaseous (absorption), liquid (extraction) and solid products and articles; reaction - as part of reagents, as well as during distillation and other processes. Process water is in direct contact with the environment. Energy water is consumed to produce steam and heat equipment, premises, and products.

To reduce the consumption of fresh water, circulating and closed water supply systems are being created. In the case of recycled water supply, the necessary wastewater treatment, cooling of recycled water, treatment and reuse of wastewater are provided. The use of recycled water supply makes it possible to reduce the consumption of natural water by 10...15 times.

To prevent biological fouling of devices and structures, the content of organic substances and compounds of biogenic elements (nitrogen, phosphorus), which are a nutrient medium for microorganisms, is limited in recycled water.

Wastewater is water that has been in domestic, industrial or agricultural use, as well as passed through a contaminated area.

Depending on the conditions of formation, wastewater is divided into:

- household or household-fecal (BSV),
- atmospheric (DIA),
- industrial (PSV).

Household water is the drains of showers, laundries, canteens, toilets, from washing floors, etc. They contain impurities, of which ~ 58% are organic and 42% are mineral. Atmospheric waters are formed as a result of precipitation and flowing from the territories of enterprises. They are polluted by organic and mineral substances.

Industrial wastewater is liquid waste that occurs during the extraction and processing of organic and inorganic raw materials.

Wastewater is contaminated with various substances:

- biologically unstable organic compounds;
- low-toxic inorganic salts;
- petroleum products;
- biogenic compounds;
- substances with specific toxic properties, including heavy metals, biologically rigid non-degradable organic synthetic compounds.

Wastewater from many industries, in addition to soluble inorganic and organic substances, contains colloidal impurities, as well as suspended coarse and fine impurities.

Classification of impurities by their phase-dispersed state:

a) heterogeneous systems:

I - suspensions, particle size 10^{-1} microns (suspensions, emulsions, microorganisms and plankton);

II - colloidal solutions, particle size 10^{-1}...10^{-2} microns (sols and solutions of high molecular weight compounds).

b) homogeneous systems:

III - molecular solutions, particle size 10^{-2}...10^{-3} microns (gases soluble in water, organic substances);

IV - ionic solutions, particle size 10^{-3} microns (salts, bases, acids).

Depending on the physical state of the phases, the following liquid heterogeneous systems are distinguished:

-suspensions,

-emulsions,

- foam.

The suspension consists of a liquid and solid particles suspended in it.

Depending on the particle size, coarse suspensions with particles of 100 microns in size, thin (0.5...100 microns) and turbid (0.1...0.5 microns) are distinguished. Colloidal solutions with particle sizes less than 0.1 microns occupy an intermediate position between suspensions and true solutions.

The emulsion consists of two immiscible or partially miscible liquids, one of which is distributed into the other in the form of liquid droplets.

The size of the dispersed phase particles in emulsions varies quite widely.

Foam is a system consisting of a liquid and gas bubbles distributed in it.

Wastewater is a polydisperse heterogeneous system. During the deposition process, the size, density, shape of the particles, as well as the physical properties of the particles of the system change.

Industrial waste

Industrial waste is classified according to the industry, the possibility of processing, aggregate state, toxicity, etc. One of the most important indicators is the degree of danger to human health. According to GOST 12.1.007-76, the system of occupational safety standards. Harmful substances. Classification and general safety requirements, all industrial waste is divided into hazard classes (Table 2):

Table 2 - Classification of industrial waste by its hazard

Hazard class	Characteristics of the substance (waste)
The first	extremely dangerous
Second	highly dangerous
Third	moderately dangerous
Fourth	low-risk

For example, the first hazard class includes wastes of mercury, sulema, potassium chromate, arsenic oxide and other highly toxic substances.

The second hazard class includes the presence of copper chloride, nickel chloride, lead nitrate and others in waste.

The third class includes the presence of copper sulfate, lead oxide, and carbon tetrachloride in waste.

The fourth is the presence of manganese sulfate, phosphates, zinc chloride, etc.

Energy pollution of the environment

Energy pollution is provoked by an actively developing industry, numerous energy facilities, transport enterprises, and communication facilities.

The types of energy pollution include: vibration action; electromagnetic radiation fields; ionizing radiation; ultrasound.

Vibrations are the vibrational movements of particles that occur during the operation of shock–acting technical installations.

In an urban environment in a residential area, noise is caused by the movement of heavy vehicles, elevators, pumps, and industrial installations.

Vibration pollution includes infrasound. Its sources are rocket engines, aircraft engines, and gas testing devices.

The degree of infrasound pressure often exceeds the norm even at a significant distance from the direct source.

Vibrations and noises have a negative effect on a person, causing serious consequences: physical illness, decreased mental activity and stress. On urban highways and in adjacent areas, sound levels can reach 70...80 dBA.

A source of electromagnetic radiation is any device that generates or absorbs electricity. Industrial sources are television towers and high—voltage power lines. Household sources include microwaves, televisions, and telephones. Zones with elevated levels of electromagnetic fields of radio frequencies have a radius of up to 100..150 m.

The negative effect of electromagnetic radiation is manifested in the incorrect operation of human physiological functions. The brain and endocrine system are most susceptible to negative effects.

Sources of ionizing energy pollution include: nuclear reactors; X-ray machines; any devices using isotopes; radioactive waste.

Ionizing radiation provokes a disorder of biochemical processes in humans: tissues mutate, new compounds are formed that are not peculiar to the body.

Exposure to ionizing radiation on humans can occur as a result of external and internal radiation.

External radiation is caused by sources of X-ray and gamma radiation, proton and neutron fluxes. Internal radiation is caused by alpha and beta particles, which enter the human body through the respiratory organs and digestive tract.

Another type of energy pollution is vibrations of high–frequency sound waves - ultrasound. Sources of this type are certain types of production equipment and ultrasound medical devices. The waves are divided into air and contact waves.

Ultrasound is the only type of energy pollution that, at low intensity, has a beneficial effect on humans: it improves metabolic processes and promotes accelerated transportation of blood to body tissues. But with intense waves and prolonged contact, cell destruction is observed.

The preservation of the ecological situation and the protection of the environment from energy pollution includes the transition to waste-free production and the use of additional protective equipment.

In general, the areas of biosphere protection include: modernization of the technological process; elimination of toxic waste, reduction of radiation intensity; development of new equipment and protective screens, etc.

2.3 The main methods of environmental protection

Methods for cleaning dust-air emissions

Neutralization of emissions involves either the removal of harmful substances from an inert carrier gas, or their transformation into harmless substances. Both principles can be implemented through various physical and chemical processes.

Dry, wet and electrical methods are used to neutralize aerosols (dusts and mists). The dry methods are based on gravitational, inertial, centrifugal deposition mechanisms or filtration mechanisms. When using wet methods, the purification of gas emissions is carried out by the interaction between liquid and dusty gas. The electric purification of gases is based on the ionization of gas molecules by electric discharge and the electrification of particles suspended in the gas.

Two-stage cleaning can be applied to the treatment of emissions. Louvered grilles and cyclone apparatuses can be used for pre-cleaning, and porous filters, electrofilters or wet dust collectors can be used for final cleaning.

Liquid aerosols can be coagulated by changing the state parameters (cooling and pressure increase) in order to precipitate and subsequently wet capture methods in wet scrubbers, porous and electric filters, and absorbers.

Wet methods for cleaning solid and liquid aerosols have a significant drawback – the need to separate the trapped pollutant from the trapping liquid. For this reason, wet methods should be used only in the absence of other cleaning methods, giving preference to methods with minimal liquid consumption.

Emissions whose pollutants represent a multiphase system are the most difficult to clean. In this case, the emissions must go through several processing stages sequentially.

If solid or liquid aerosols do not contain elements other than carbon, hydrogen and oxygen (vegetable dust, wool fibers, mineral oil mists, etc.), then they can be neutralized in one stage – by direct combustion in the furnaces of boilers and furnaces.

Methods for cleaning gas emissions

Dispersed and gaseous pollutants are often the result of the same production processes, move together in communications, interact in purification plants and the atmosphere. It is necessary to take into account the entire complex of pollutants present in the technological release.

Chemical processes are successfully used to neutralize emissions based on the principle of removing toxic impurities along with physical ones. By means of the latter, the physical properties of impurities can be changed within a wide range in order to facilitate their further capture.

Only substances whose molecules consist of carbon, hydrogen and oxygen atoms can be subjected to heat treatment for the purpose of neutralization. Otherwise, thermal decontamination plants become sources of atmospheric pollution.

Absorption, adsorption, catalytic, thermal and condensation methods are used to neutralize waste gases from gaseous and vaporous toxic substances. Absorption methods are based on the absorption of gases or vapors by liquid absorbers. Adsorption methods are based on the absorption of impurities by solid porous bodies. Catalytic purification methods are based on chemical transformations of toxic impurities into non-toxic ones on the surface of solid catalysts. Thermal methods are based on the combustion of combustible harmful impurities.

In order to capture gaseous impurities, condensation and sorption processes are used, and pollutants are converted into harmless compounds through thermochemical and chemical processes. The corresponding devices are called condensers, absorbers, adsorbers, thermal degradation plants, thermal oxidation, thermocatalytic plants, chemical reactors.

For some gas pollutants, chemical absorption (chemisorption) can be successfully applied – a process in which the pollutant to be removed reacts chemically with the absorber and forms a neutral or easily removable compound from the process. Such processes are specific and are developed specifically for each type of emissions and set of pollutants.

The most versatile means of cleaning emissions from gaseous pollutants currently remains adsorption, and the most versatile adsorbent is activated carbon. Through adsorption, it is fundamentally possible to extract any pollutant from emissions in a wide range of concentrations.

Wastewater treatment

To create closed water supply systems, industrial wastewater is treated to the required quality:

-mechanical,

-chemical,

-physico-chemical,

- biological,

-thermal methods.

Cleaning methods are divided into:

-regenerative,
-destructive.

Recovery methods involve the extraction of all valuable substances from wastewater and further processing. In destructive methods, pollutants are destroyed by oxidation or reduction, and the products of destruction are removed from the water in the form of gases or precipitation.

The main purification methods of various nature are used both to purify wastewater from suspended and emulsified impurities, and to purify from dissolved impurities.

In turn, the first group of purification of heterogeneous systems is divided into methods of purification from coarse impurities, which include methods of settling, straining and filtration, flotation, centrifugal precipitation; and methods of purification from fine impurities by coagulation, flocculation and electroflotation.

The second group includes methods of water purification from mineral impurities by distillation, ion exchange, reverse osmosis, electrolysis; methods of purification from organic impurities, including regenerative methods of extraction, rectification, adsorption, reverse osmosis and ultrafiltration, and destructive methods: biochemical, liquid and vapor phase oxidation, radiation and electrochemical oxidation; as well as methods purification from dissolved gases, including blowing, heating and reagent methods.

Mechanical methods for removing suspended particles from wastewater are based on the laws of hydromechanical processes.

Physico-chemical methods of wastewater treatment are used to remove fine solid and liquid suspended particles, soluble gases, mineral and organic substances from wastewater. The mechanisms of these methods are based on the use of the laws of physico-chemical hydromechanics, physical and colloidal chemistry, electrochemistry, and chemical technology processes.

Chemical methods are used to remove soluble substances in closed water supply systems.

Biochemical methods are used to purify household and industrial wastewater from dissolved organic and inorganic substances. The process of biochemical purification is based on the ability of microorganisms to use pollutants for their nutrition in the process of vital activity.

Thermal methods are used to neutralize wastewater containing mineral salts.

The choice of the purification method is made taking into account the sanitary and technological requirements for the quality of treated waters, the amount of wastewater, the availability of necessary energy and material resources, and the effectiveness of the neutralization process.

Methods of protection of the lithosphere

Protection of the lithosphere includes not only the disposal of waste by placing it in landfills and landfills, but also the processing of liquid and solid waste using various methods.

Mechanical dewatering of industrial wastewater sediments can be carried out by extensive and intensive methods. Extensive methods are carried out in various types of seals, intensive dewatering and thickening is carried out by filtration, centrifugation, hydrocycloning, etc.

In the practice of industrial wastewater sludge treatment, chemical (reagent) treatment methods are most often used.

When using the thermal oxidation method, all organic substances polluting wastewater are completely oxidized by air oxygen at high temperatures to non-toxic compounds.

Many solid waste disposal processes are based on the use of leaching (extraction), dissolution and crystallization of recyclable materials.

In the practice of recovery of solid industrial waste, methods of enrichment of recyclable materials are used:

-gravity,

-magnetic,

-electric,

-flotation,

- special ones.

Methods of environmental protection from energy impacts

The choice of methods of protection from energy influences depends on the type and form of energy manifestation.

When protecting against mechanical and acoustic vibrations, the main methods of reducing the level of their impact are reducing the energy parameters in the source, optimal orientation of the source of vibrations relative to the object of impact, absorption of part of the generated vibration energy, reducing the energy of vibrations along the path of their propagation from the source by isolation, shielding and damping, increasing the distance.

The choice of methods and means of protection against the effects of electromagnetic fields and radiation is largely determined by the characteristics of the sources in frequency. The methods also include protection by increasing the distance, shielding, partial absorption of radiation power, reducing the level of energy exposure by scattering and diverting part of the energy into the environment.

Protection from ionizing radiation is achieved mainly by increasing the distance, screening methods and limiting the release of radionuclides into the environment.

§ 3 PROTECTION OF THE ATMOSPHERE. AIR PURIFICATION FROM AEROSOL IMPURITIES AND GAS EMISSIONS. DISPERSION OF EMISSIONS IN THE ATMOSPHERE

3.1 Legislation on the protection of atmospheric air

Atmospheric air is one of the main vital components of the environment. Its quality directly affects human health, life expectancy, as well as the qualitative state of other elements of the environment, especially the animal and plant world.

Air protection legislation unites the normative acts of the former USSR, acts adopted by the highest bodies of representative and executive power of the Russian Federation, its subjects, local governments, federal departments and other bodies.

The main legislative act is the Federal Law of the Russian Federation "On the Protection of Atmospheric Air", adopted by the State Duma 2.04.99. In accordance with it, other acts of the legislation of the Russian Federation and the subjects of the Russian Federation have been issued. They regulate the competence of state and other bodies in the field of atmospheric air protection, state accounting of harmful effects on it, monitoring, control, dispute resolution and responsibility in the field of atmospheric air protection.

The Law "On the Protection of Atmospheric Air" contains provisions on the protection of atmospheric air from pollution and noise, from electromagnetic, radiation and other effects, prevention of depletion of oxygen reserves, rational use of air for economic purposes, reproduction of its reserves; contains norms prohibiting the operation of any production facilities if they are not equipped with cleaning devices and facilities as well as on the prohibition of the operation of vehicles in whose emissions the content of pollutants exceeds the established norms.

The Law further developed the rules on the regulation of maximum permissible concentrations of pollutants in the atmosphere, provides for a permissive procedure for emissions of pollutants and other impacts, including effects on weather and climate. Special sections of the Law are devoted to state control in the field of atmospheric air protection and the responsibility of officials and citizens for violations of air protection legislation.

The norms of laws regulating air management issues are detailed and specified in decrees of the President of the Russian Federation and resolutions of the Government of the Russian Federation. Federal agencies have developed numerous state standards, sanitary norms and rules; methodological recommendations for the determination of toxic substances and their concentrations in the atmosphere, as well as for the determination of harm and damage caused as a result of emissions of pollutants into the atmosphere.

The Federal Law of May 4, 1999 "On the Protection of Atmospheric Air" provides the following definition:

Atmospheric air is a vital component of the natural environment, which is a natural mixture of atmospheric gases located outside residential, industrial and other premises.

Analyzing the air protection legislation, the following types of air management can be distinguished:

-the use of air for the life support of people and other organisms;

-use of air for production needs as raw materials;

-using the atmosphere to release pollutants and absorb harmful physical influences;

-use of the atmosphere for the purpose of artificial climate change, prevention of natural disasters.

The legislation establishes a permissive procedure for the use of air, with the exception of the first type, which is realized by virtue of the very existence of humans and other organisms.

In order to preserve the favorable quality of atmospheric air, the state establishes standards for its impact in the form of:

-production standards: maximum permissible emissions (MPI) of pollutants into the atmospheric air; standards for noise, thermal, vibration, radiation, electromagnetic and other physical influences; temporarily agreed emissions (limits) of pollutants;

-territorial standards - the values of critical aggregate loads on atmospheric air from various economic and other facilities, both stationary and mobile, taking into account the transboundary and interregional transport of pollutants within the territorial administrative entity.

In addition, standards for maximum permissible concentrations (MPC) of various pollutants in the atmospheric air and standards for maximum permissible levels of harmful physical effects are established.

The institution of payment for harmful effects on atmospheric air, enshrined in legislation, contributes to the improvement of the air basin to a certain extent. Thus, a fee is charged for air pollution from stationary sources: for emissions of pollutants within the established limits and in increased amounts - for emissions of these substances in excess of the established limits.

The rational use of air is facilitated by the payment established by law for its use for industrial purposes. Paying for air pollution and its consumption does not exempt the nature user from carrying out air protection measures and compensation for damage caused by violation of environmental requirements.

The nature user, in particular, is obliged to:

-ensure compliance with established standards for emissions of pollutants and other harmful effects;

-organize the capture, disposal, neutralization of harmful substances or the complete elimination of their emissions;

-equip enterprises with equipment for cleaning emissions of harmful substances into the atmosphere, as well as means of controlling the amount and composition of emitted substances;

-provide for the organization of sanitary protection zones around the economic facility;

-ensure the removal of waste polluting atmospheric air to enterprises using them as raw materials or to specialized landfills;

-develop and implement a set of measures to prevent and reduce emissions of pollutants into the atmosphere from mobile vehicles and installations;

- to provide timely, complete and reliable information on the issues of atmospheric air protection to the bodies exercising state control over the use and protection of atmospheric air;

-to comply with the instructions of the bodies exercising state control over the use and protection of atmospheric air, to eliminate violations of air protection legislation.

The prohibitions established by the legislation are intended to contribute to the protection of atmospheric air.

The nature user is prohibited from:

-the implementation of emissions of pollutants without the appropriate permission of the State Committee for Environmental Protection;

-exceeding the established standards for emissions of pollutants and other harmful effects;

- implementation of actions aimed at artificially changing the state of atmospheric air, if they lead to adverse effects on the weather and climate;

-production and use of chemicals and industrial waste that adversely affect the Earth's ozone layer;

-incineration of various types of garbage and waste of production and consumption, including toxic, in an open manner and without cleaning waste gases in special installations;

-operation of vehicles and other mobile means exceeding the established standards for emissions of pollutants;

-placement of landfills, landfills, storage of industrial waste, household garbage and other waste that are sources of atmospheric air pollution in populated areas.

In order to maintain the quality of atmospheric air at a safe level for people, specialized control bodies carry out state accounting (inventory) of adverse effects on it, as well as monitoring (monitoring) the state of atmospheric air and sources of its pollution.

The prevention of atmospheric air pollution is served by the right of representative and executive authorities, specialized control bodies to make decisions on the suspension of operation or even on the closure of enterprises, workshops, sites, as well as mobile vehicles polluting the atmosphere.

The legislation also provides for the creation of green zones around polluting enterprises, carrying out forest plantations in order to neutralize harmful emissions.

State control over the protection of atmospheric air

State control over the protection of atmospheric air and over compliance with air protection legislation is carried out by state authorities and management bodies at all levels, local governments and specially authorized state interdepartmental bodies. Its tasks are to ensure that all ministries, committees, enterprises and other bodies, as well as officials and citizens, strictly comply with the requirements of air protection legislation.

Representative and executive authorities, in accordance with the Law of the Russian Federation "On the Protection of Atmospheric Air", ensure the development and implementation of measures for the protection of atmospheric air, participate in the planning of its protection and monitor its protection. The authorities in question plan and coordinate measures to improve the air environment in the region, monitor the progress of implementation of plans for the construction of environmental protection facilities. Within the limits of their competence and under the authority of the highest state authorities, representative bodies have the right to make decisions on the use and protection of atmospheric air, including the suspension, closure or conversion of enterprises under their jurisdiction that pollute the atmospheric air with harmful emissions.

The State Committee of the Russian Federation for Environmental Protection, its bodies in the regions, both directly and through departments, inspections or sectors for the protection of the atmosphere, carry out state control over the use and protection of atmospheric air, compliance with environmental standards in this area; coordinate the activities of other environmental authorities, ministries, departments, enterprises aimed at improving the air environment; implement a unified scientific and technical policy in the field of atmospheric protection; issue permits for the consumption of atmospheric air for industrial needs; develop and approve environmental regulations, rules and standards in the field of atmospheric air protection; participate in atmospheric air monitoring, as well as in state accounting of adverse effects on the atmosphere.

The Federal Service of Russia for Hydrometeorology and Environmental Monitoring, its bodies in the regions monitor the state of atmospheric air and take into account harmful effects on it, i.e. the formation of an air monitoring system. The bodies of the Federal Hydrometeorological Service daily make a forecast of adverse weather conditions that can cause a sharp increase in air pollution and bring relevant information to the enterprises that source its pollution. The latter, in turn, make changes to the operating mode of the corresponding workshops, units in order to stop or reduce emissions of pollutants.

The Department of Sanitary and Epidemiological Supervision of the Ministry of Health of the Russian Federation and its bodies in the regions carry out state supervision of the state and protection of atmospheric air in terms of compliance with sanitary and hygienic rules. According to the Law of the Russian Federation "On Sanitary and Epidemiological welfare of the population", one of the tasks of the sanitary and epidemiological supervision bodies is to carry out sanitary and hygienic and sanitary anti-epidemic measures aimed at preventing or eliminating atmospheric air pollution by harmful industrial emissions and household waste. Sanitary and epidemiological supervision bodies develop and approve norms and rules in the field of atmospheric air, which are mandatory for all bodies, officials and citizens.

The Main Directorate of the State Automobile Inspection and its bodies carry out state control over the implementation of measures to protect atmospheric air in terms of compliance with the standards of maximum permissible emissions of pollutants for motor vehicles.

The heads of ministries, committees, associations, firms, enterprises, institutions, organizations, cooperatives and other bodies also monitor compliance with legislation on atmospheric air protection within the scope of their competence, both personally and through special environmental structural units (inspections, services, departments, laboratories, workshops, sites, etc.) or officials persons directly responsible for environmental issues.

3.2 Sources of atmospheric pollution

There are two ways to pollute the atmosphere:

-natural;

- artificial.

Atmospheric pollution naturally occurs as a result of: dust storms, volcanic eruptions, forest fires, soil erosion, biological decomposition, in particular, the vital activity of soil bacteria. In this case, both solid and gaseous substances enter the atmosphere.

Dust rising from the surface of the earth consists of small particles of rocks, soil remnants of vegetation and living organisms. The sizes of dust-like particles, depending on their origin, range from 1 to several microns. At an altitude of 1-2 km from the earth's surface, the content of dust particles in the air ranges from 0.002 to 0.02 g/m^3, in some cases this concentration can increase tens or hundreds of times, during dust storms up to 100 g/m^3 or more.

There is also dust in the atmospheric air, which appears as a result of forest, steppe and peat fires. It consists of ash particles formed during the combustion of organic masses.

When volcanoes erupt, a large amount of ash is emitted in the atmosphere along with gaseous products. The composition of volcanic gases includes HCl, HF, NH_3, Cl_2, SO_2, H_2S, CO_2, H_2O, solid particles consist mainly of SiO_2.

In addition to these sources, cosmic dust enters the atmospheric air from interplanetary space. It is deposited on land and on the water surface in the form of tiny particles with a diameter of 50 to 100 microns.

In addition to particles of inorganic origin, the atmosphere contains the smallest microorganisms, fungi, bacteria, and spores.

Pollution of the air basin from natural sources should be taken into account when determining the overall level of pollution.

Artificial pollution of the atmosphere occurs as a result of practical human activity.

The largest amount of harmful substances is emitted into the atmosphere by CHP plants burning solid, liquid or gaseous fuels in furnaces. A significant amount of harmful substances are released into the atmosphere during the smelting of ferrous and non-ferrous metals, the production of acids, alkalis, fertilizers, cement, soda, artificial fibers, ammonia, pesticides, dyes, rubber products, organic solvents, etc.

Significant atmospheric pollution occurs from the exhaust gases of motor vehicles. They contain a large range of toxic substances, the main of which are: CO, NO_X, hydrocarbons, carcinogenic substances. The pollutants of the air basin from motor transport should also include rubber dust, which is formed as a result of the abrasion of tires.

A special type of pollution is represented by radioactive substances – products of the development of the nuclear industry and tests of atomic and hydrogen weapons.

Currently, more than 100 atmospheric pollutants have been identified. The most widespread are: SO_2, CO_2, NO_2, hydrocarbons and dust. They account for 85-90% of the gross emissions of harmful substances.

The main sources of atmospheric pollution by dust and SO2 are thermal power plants burning high-sulfur solid and liquid fuels.

The most characteristic emissions of ferrous and non-ferrous metallurgy enterprises are: dust, SO_2, CO_2, NO_2, hydrocarbons.

Less high-tonnage, but in some cases significantly more toxic emissions into the atmosphere from chemical industry enterprises.

The spread of pollution in the atmosphere

Harmful substances entering the atmosphere dissolve in a large volume of air and are transported over considerable distances. As a result, the concentration of harmful substances in the air decreases, but the volume of areas with atmospheric pollution increases significantly.

Due to the horizontal movement of air (wind), harmful substances can travel thousands of kilometers. At low wind speeds, harmful substances accumulate in a small volume of air, which can lead to a dangerous increase in concentration near the source.

Temperature inversion associated with vertical air movements can lead to the same consequences.

Clouds, rain, snow, and high humidity have a beneficial effect on the air environment. Under the influence of precipitation, the spread of atmospheric pollutants is localized, they are washed out of the atmosphere and fall to the ground.

In turn, aerosols polluting the atmosphere can serve as effective condensation nuclei of water vapor, which leads to precipitation.

Ordinary rain with an intensity of 1 mm of precipitation per hour for 15 minutes removes 30-50% of dust particles larger than 10 microns from the air. Under the influence of precipitation, gaseous impurities are also washed out of the atmosphere, which dissolve in water or interact with it.

Thus, the process of self-purification of the atmosphere takes place, the peculiarity of which is that it spreads over significant spaces.

In addition to the listed meteorological factors, the spread of atmospheric pollutants is influenced by the terrain, forests and reservoirs near emission sources, which contribute to the absorption of harmful substances from the atmosphere.

Classification of pollution sources

Pollution sources can be classified according to the following principles:
- the type of systems from which harmful substances are emitted;
- location of sources in the wind flow;
- method of release into the atmosphere;
- the temperature of the emitted gas-air mixture;
- time mode of operation;
- the degree of centralization;
- the range of propagation.

According to the type of system, the sources are divided into:
- technological,
- ventilation.

Technological gases include tail gases of trapping plants (adsorption, recovery), emissions during purging, leaks through equipment leaks and oil seals. They are characterized by small volumes and high concentrations, and, as a rule, they need to be cleaned.

Ventilation emissions - emissions of mechanical and natural general exchange ventilation and local exhaust ventilation. They are characterized by large volumes and low content of harmful substances. Emissions from local suction systems are close to technological in their characteristics.

By location, the sources are divided into:
- high,
- low.

The effective discharge height (H) is understood as the sum of the geometric height of the pipe (N_{tr}) and the height of the rise of the jet (Δh) of polluted air above the mouth of the source under the action of an upward initial pulse of the jet.

$$H = N_{tr} + \Delta h.$$

High (unshaded) sources include point sources - pipes with a height of more than 3.5Nzd from the height of buildings N_{zd}. At such a height, the influence of wind flow deformation caused by buildings on the propagation of impurities can be neglected. The turbulence of the flow formed during disruptions at the sharp edges of the building also has little effect on the spread of harmful substances, and the turbulence of the atmosphere itself is decisive.

With an effective ejection height within $2.5N_{zd} < H < 3.5N_{zd}$, a transition region takes place. In this area, the spread of harmful substances is affected by atmospheric turbulence and turbulence due to disruption of the wind flow at the edges of buildings.

Low (shaded) sources include those whose effective discharge height is less than the height of the circulation zone arising above and behind the building. In this case, the release primarily pollutes the circulation zone and the maximum concentration of the harmful substance is observed within this zone.

Sources located in the circulation zone, from which the air exits, having an upward initial impulse, depending on the wind speed, may turn out to be low or high. Such sources belong to group I.

At high speed, the rise of the jet above the mouth of the source is small, and the jet of polluted air is blown by the wind flow into the circulation zone. In this case, the source should be considered as low. As the velocity decreases, the rise of the jet increases and at a certain speed the jet will be distributed outside the circulation zone. Thus, a low source becomes high at low speeds, which is of great importance for protecting the surface layer of the atmosphere from pollution.

During calm conditions in the surface layer, the concentrations of harmful substances emitted from low sources of group I are close to zero.

Low emissions placed in the circulation zone are assigned to group II, from which polluted air with a temperature close to ambient temperature enters the atmosphere without having an upward initial impulse.

Group II emissions are low and do not change to high at low wind speeds. This group includes emissions through pipes and roof fans with hoods, through leaks in open equipment and pipelines. Such sources are most dangerous in relation to the surface layer of the atmosphere at low wind speeds.

According to the method of releasing polluted air into the atmosphere, the sources are divided into:

- sewer (organized),
- unanalyzed (unorganized).

Sewer emissions include emissions from pipes and shafts. Non-analyzed ones include emissions from flashlights, the release of harmful substances through equipment leaks, emissions as a result of the absence or unsatisfactory operation of gas suction equipment at the places of loading, unloading and storage of substances, evaporation from the open surface of the liquid.

Sewage emissions can be cleaned and controlled. Unanalyzed ones, as a rule, are not cleaned, and their control is difficult.

According to temperature, gas-air mixtures (DHW) are divided into:

-highly heated $\Delta t = t - t_{ocd} > 100\ ^oC$;

-heated $20\ ^oC < \Delta t < 100\ ^oC$;

-slightly heated $5\ ^oC < \Delta t < 20\ ^oC$;

-isothermal $\Delta t = 0$;

-chilled $\Delta t < 0$.

An isothermal process is a thermodynamic process that occurs in a physical system at a constant temperature.

The first group includes flue gases, burning flares at petrochemical plants (NHZ), emissions from dryers and other equipment, processes in which occur at high temperatures. The lifting force lifts such emissions above the mouth of the pipe, which contributes to their dispersion.

Chemical industry enterprises are characterized by emissions of 2-4 groups.

Cooled DHW enters the atmosphere from equipment in which a low temperature is maintained; when gases flow out of equipment in which the medium is under pressure and at low temperatures, from air-conditioned rooms. Such emissions sink down and dissipate weakly. A similar phenomenon is observed when air polluted with gases and vapors with a density higher than air density is released into the atmosphere.

According to the operating mode, emissions are divided into:

-constantly operating with uniform gross emissions or changing according to a certain law (emissions from technological equipment);

-periodic (purging of devices);

-salvo, when a large amount of harmful substances is released in a short period of time.

According to the degree of centralization, emissions are divided into:

-centralized,

-decentralized.

In the first case, the discharge is collected in one or two pipes. High centralized emissions ensure clean air at the industrial site itself and good dispersion in high atmospheric layers.

In the second case, an independent discharge is arranged from each unit. In such a situation, there are a large number of low pipes, emissions from which pollute the surface layer and make it difficult to take in clean air for the supply ventilation systems of buildings.

Decentralized emissions include emissions from lanterns, air from chemical devices and containers, leakage of harmful gases and vapors through leaks of equipment located at factory sites.

Composition of emissions

The composition of volatile industrial emissions is as diverse as the sources and conditions of their formation. The priority emissions that deserve the most attention when monitoring the state of the air environment are the following: sulfur oxides; nitrogen oxides; carbon oxides; phosphorus compounds (P_2O_5, PH_3); arsenic compounds (As_2O_3, As_2O_5); resins of various origin; acid mists; odorous substances of DPV (mercaptans and hydrogen sulfide); hydrocarbons, vapors of volatile organic solvents ENT (gasoline, benzene, alcohols, toluene, carbon disulfide); mercury vapor; fluorine and its compounds; chlorine and its compounds; soot; ash; vozgones and metal oxides, solid particles of various sizes - from submicrons to hundreds of microns of various chemical composition and various morphology (compact, flake-like, fibrous , etc.).

Only some of the listed emissions are unambiguously related to the sources of their release: mercury vapor, fumes and metal oxides, soot.

The remaining emissions can be products of many processes in the chemical industry, energy, metallurgy, mechanical engineering, etc.

The properties of emissions are their inherent natural qualitative manifestations, such as toxicity (including embryonotoxicity), mutagenicity, carcinogenicity, etc.

Classification of emissions

Due to the variety of aspects of atmospheric protection, there is no single, let alone official classification of volatile industrial emissions. From the point of view of the role and significance of emissions in the purification process, the following classification has been adopted.

All emissions can be divided into two groups:

-combined cycle gas;

- aerosol.

Combined–cycle gases are a mixture of vapors or gases that do not contain solid or liquid suspended particles. This group can be divided into two subgroups:

1a. Emissions that cannot be cleaned either because of their harmlessness, or for reasons of economic expediency of dispersion through pipes; or because of the complete lack of technical cleaning capabilities in a given period of time. The latter can only be allowed temporarily.

1b. Emissions subject to mandatory cleaning.

Aerosol emissions are a mixture of gases (vapors) carrying solid or liquid suspended particles. The following subgroups can be distinguished in this group:

2a. Aerosols in which the dispersed phase is to be captured, and the vapor-gas (dispersion) phase belongs to subgroup 1a and at the same time does not affect the operation of the gas purification plant (GOU), i.e. it is neutral in the purification process.

2b. Aerosols in which the dispersed phase is to be captured, and the vapor-gas phase, belonging to subgroup 1a, at the same time has a certain effect on the course of purification. For example, the negligible content of sulfur dioxide in the gas does not require its capture, but acid condensate may form inside the gas treatment path, causing corrosion.

2b. Aerosols in which the dispersed phase is subject to capture, and the combined-cycle phase belongs to subgroup 1b. In this case, either combined cleaning in one device is required, or a combination of sequentially arranged devices for selective capture of the dispersed phase and harmful impurities of the dispersion medium.

2g. Aerosols in which the dispersion medium belongs to subgroup 1b, and the dispersed phase is not subject to capture (for example, due to its low concentration) and at the same time does not affect the purification process.

2d. Aerosols in which the dispersion medium belongs to subgroup 1b, and the dispersed phase is not subject to capture, but may affect the purification process (for example, gradually contaminate a liquid or solid absorbent sorbent).

2e. Aerosols in which the dispersion medium belongs to subgroup 1a, and the dispersed phase belongs to 2g or 2d. Such an aerosol does not need to be cleaned.

Emissions rationing

Rationing is the most important means of regulating environmental management. By its very nature, it refers to administrative methods of regulation.

Environmental rationing is understood as a scientifically based limitation of the impact of economic and other activities on the resources of the biosphere, ensuring both the socio-economic interests of society and its environmental needs.

Environmental rationing involves taking into account the so-called permissible load on the ecosystem.

Such a load is considered acceptable, under the influence of which the deviation from the normal state of the system does not exceed natural changes and, therefore, does not cause undesirable consequences for living organisms and does not lead to deterioration of the quality of the environment.

Currently, sanitary and hygienic standards are of decisive importance for environmental quality control and management.

All types of MPC refer to individual substances in their isolated action. In real situations, several dozen harmful substances may be present in the air. To account for the combined effect of harmful substances in all environments, the principle of integrated hygienic rationing is used. Thus, for the atmospheric air of populated areas, combined action coefficients have been established for 36 binary mixtures and 20 mixtures of 3-5 components.

In the practice of rationing and for the sanitary assessment of the degree of air pollution, the following types of MPC are used:

-in the air of the working area (MPCr.z., mg/m^3) – the concentration of a substance that does not cause diseases or health abnormalities in working people with daily inhalation within 8 hours during the entire work experience;

-average daily (MPCp.z., mg/m^3) – the concentration of a substance in the air of a populated area, which does not have a direct or indirect harmful effect on a person under conditions of indefinitely long round-the-clock inhalation;

-the maximum single (MPCm.r., mg/m^3) concentration of the substance in the air of the settlement, which, with short–term exposure (within 20-30 minutes) it does not cause reflex reactions in the human body.

Currently, according to the World Health Organization, up to 500 thousand chemical compounds are used in industry, of which 40 thousand are harmful to human health and 12 thousand are toxic. In the Russian Federation, MPCs have been installed for about 1300 compounds in the air.

In order to eliminate the disproportions between the number of new chemicals and the number of hygiene standards being developed, temporary indicative safe exposure levels (MPC) and approximate permissible levels (ODE) have been introduced into sanitary legislation along with the MPC. The justification of the time standards is carried out using accelerated experimental and computational methods, as well as by analogy with previously normalized structurally similar compounds.

Despite the leading role of hygiene standards for environmental quality assessment, it is necessary to introduce environmental standards that establish requirements directly to the source of pollution, limiting its activities to a certain threshold value. Such an environmental standard is the maximum permissible emission of harmful substances into the atmosphere (MPI).

MPD is the maximum amount of pollutants allowed to be released into the atmospheric air by a given source of pollution per unit of time.

The maximum permissible concentration of harmful substances into the atmosphere is set for each source of pollution, provided that emissions from the source in question and a combination of other sources of the enterprise or locality, taking into account the prospects for the development of the enterprise and the dispersion of harmful substances in the atmosphere, do not create a surface concentration of this substance C exceeding the maximum permissible concentration of the locality.

For populated areas, the following ratio is required:

$$C/MPC < 1.$$

When determining the maximum permissible concentration for the source of atmospheric pollution, the values of background concentrations of harmful substances in the air C_f (mg/m^3) from other sources of the settlement, i.e., established by calculation or experimentally, are taken into account:

$$C = C_p + C_f,$$

where C_p is the maximum calculated concentration of the harmful substance, mg/m^3.

The MPD is determined for each source of pollution. For unorganized emissions and nearby small single sources, the total MPI is set. As a result of summing up the MPI of individual sources of atmospheric pollution, the MPI for the enterprise as a whole is determined.

When establishing the MPI, it is necessary to take into account the perspective of the development of the enterprise, the physical, geographical and climatic conditions of the area, the mutual location of the enterprise and residential development, etc.

If concentrations of harmful substances in the air of populated areas exceed the MPC, and the MPC value for objective reasons cannot currently be achieved, then a phased reduction in emissions of harmful substances to values that ensure the MPC is introduced. At each stage, prior to the provision of MPD, a temporarily coordinated emission (VSWR) is established at the level of enterprises with the best achieved production technology, similar in capacity and technological process.

3.3 Ways to eliminate air pollution

The main measures to reduce atmospheric air pollution are:

-technological,

-architectural and planning,

-organization of a sanitary protection zone.

Technological activities

A radical measure to combat atmospheric pollution is the creation of closed technological processes in which there is no emission of harmful emissions into the atmosphere. The principle of integrated use of natural raw materials with the creation of low-waste technologies is also promising.

One of these measures is measures in the field of basic technology, either suppressing completely or reducing emissions of harmful substances.

These measures are specific for each type of production. However, there are general conditions that apply to many industries.

To reduce emissions of harmful substances in fuel combustion products, it is necessary to improve the technology of its combustion.

Complete combustion of combustible components must be ensured in all combustion devices without exception. This will eliminate the presence of soot and carbon monoxide in emissions. For this purpose, special injectors are designed to completely mix fuel with air.

If volatile combustible components (resins, carbon monoxide, etc.) are inevitably released in the processes of the main technology, it is necessary to provide afterburning devices directly in the design of the main technological equipment.

Switching to the combustion of crushed fuel reduces ash emissions by 2-2.5 times, and emissions of submicron particles responsible for the release of heavy metals into the atmosphere are reduced by an order of magnitude.

In combustion devices, exceeding the temperature in excess of the regulation and the volume of blast air in excess of the calculated one should be avoided in order to reduce the emission of nitrogen oxides. For this purpose, two-stage fuel combustion, flue gas recirculation, furnace conversion, fluidized bed combustion, and special burner designs are used.

A fluidized bed is a physical phenomenon that occurs when a solid substance in the form of particles is in such conditions that it behaves like a liquid.

The usual way to obtain a fluidized bed is to inject liquid under pressure into the particles. The resulting medium has many properties and characteristics of conventional liquids, such as the ability to flow freely under gravity or be pumped using liquid technologies.

In order to reduce emissions of sulfur dioxide, it is necessary to pretreat the fuel (desulfurization), improve the quality of the fuel used (enrichment). In addition, for the same purposes, sulfur is bound during the combustion of fuel by the introduction of alkaline additives.

The emission of sulfur dioxide is completely eliminated when converting boilers from solid and liquid fuels to gaseous fuels, when replacing flame heating with electric (replacing foundry wagons with induction furnaces, melting scrap in induction furnaces instead of mine furnaces, the use of electric furnaces in the glass industry).

To reduce the dust formation of dusty materials, it is necessary to seal the emission source units, as well as to seal the dust and gas paths as much as possible. In drying units, overdrying of the material should not be allowed, since this will increase dust formation during subsequent processing and transportation of the material. When processing dusty materials, they should be moistened, if this does not contradict the requirements of the basic production technology.

In dust and gas cleaning devices, there should be no instability of technological modes beyond the tolerances established by the regulations, since at the same time the composition and amount of emissions change.

Replacing periodic processes with continuous ones makes it possible to eliminate the salvo emissions characteristic of periodic processes.

If, for objective reasons, it is impossible at this stage to create a rational technology that suppresses emissions of harmful substances, then enterprises are obliged to build sewage treatment plants.

However, cleaning methods have not been developed for all emissions; in many cases, it requires high costs, so often polluted emissions are diverted to a higher height by constructing high pipes. At the same time, harmful substances, reaching the surface layer of the atmosphere, disperse and create a surface concentration not exceeding the standard values.

Architectural and planning activities

Architectural planning measures (APM), if they are carried out at the stage of choosing the area of construction of the enterprise and the layout of buildings and structures on the general plan of an existing enterprise, do not require capital expenditures, but in the future they will help save on gas purification measures and the organization of a sanitary protection zone.

It is necessary to avoid the construction of enterprises with high emissions of harmful substances in places of air stagnation, in lowlands and ditches, as well as in areas with frequent fogs and elevated temperature inversions.

Special attention should be paid to the mutual location of enterprises and residential areas. For each variant of the location of the enterprise, it is necessary to determine the standard of MPD, taking into account the remoteness of residential areas, terrain and climatic conditions. When choosing the final construction site, it is necessary to proceed from the minimum cost of building an enterprise in this place and cleaning costs.

Organization of a sanitary protection zone (SPZ)

A sanitary classification is provided for enterprises, taking into account the capacity of the enterprise, the conditions for the implementation of technological processes, the nature and amount of harmful emissions, vibration, electromagnetic waves, ultrasound, and other harmful factors.

There are 5 classes of enterprises in total:

Class	I	II	III	IV	V
The size of the zone, m	1000	500	300	100	50

The sizes of the SPZ, established in Sanitary Standards, must be confirmed by calculations of emission dispersion in accordance with current methods. At the same time, at the border of the SPZ, the concentration of harmful substances in the surface layer should not exceed the $MPC_{m.r}$.

The calculated sizes of the SPZ should be specified depending on the wind rose of the enterprise location area according to the formula:

$$L = L_o P/P_o \text{ by } P > P_o,$$

where L - the estimated size of the SPZ, taking into account the wind rose, m; L_o

- the calculated distance from the source to the boundary of the SPZ without taking into account the correction for the wind rose, m, i.e. the distance from the source to the point at which C = $MPC_{m.r.;}$ P (%) - the average annual repeatability of the wind directions of the considered rumba; P_o(%) – the repeatability of the wind directions of one rumba with a circular wind rose.
It is recommended that the size of the SPZ be taken at least according to the sanitary classification.

Methods of gas purification from aerosols

The reliability and efficiency of dust cleaning systems largely depend on the physico-chemical properties of the captured dust.

Let's consider the basic properties of suspended particles.

The particle density is divided into:

- the true one,
- bulk,
- apparent.

Bulk density is the density of a powdery material in a loosely packed state.

When tracking, the bulk density increases by 1.5 times.

Apparent density is the mass of a particle related to the volume it occupies, including pores, voids and irregularities.

The true density is the density of particles that do not have pores.

A decrease in apparent density relative to the true one is observed in dusts prone to coagulation or sintering of primary particles, for example, in soot, metal oxides, etc.

The methods of dust capture depend on its dispersion, i.e. the quantitative distribution of dust particles by size. Depending on the particle size, dust is divided into several types - macroscopic - more than 10 microns; microscopic 0.25-10 microns; ultramicroscopic 0.01-0.25 microns; submicroscopic - less than 0.01 microns.

The adhesive properties of the particles determine their tendency to stick together. Increased particle adhesion can lead to clogging of dust collecting devices. The smaller the particle size, the easier they stick to the surface of the device.

According to the degree of adhesion, the dust is roughly divided into 4 groups: non-sticking, slightly sticking, medium sticking, strongly sticking.

Another characteristic of dust is closely related to stickiness - its fluidity. The flowability is estimated by the angle of the natural slope, which accepts dust in a freshly filled state. Determines the nature of the dust movement in the bins.

The abrasiveness of dust characterizes the intensity of metal wear at the same gas velocities and dust concentrations. It depends on the hardness, shape, size and density of the particles.

The wettability of particles with water has a certain effect on the effectiveness of wet dust collectors. Smooth particles are wetted better than particles with an uneven surface, since the latter are more covered with an absorbed gas shell, which makes wetting difficult.

Let's look at some definitions.

Wetting is the physical interaction of a liquid with the surface of a solid or other liquid.

Wetting depends on the relationship between the forces of adhesion of liquid molecules with molecules (or atoms) of the wetted body (adhesion) and the forces of mutual adhesion of liquid molecules (cohesion).

Hygroscopicity is the ability of some substances to absorb water vapor from the air.

The hygroscopicity and solubility of the particles contribute to their capture in wet-type devices. They are determined by the chemical composition of the particles, their size, shape and degree of roughness.

Electrical resistivity (resistivity) is a physical quantity that characterizes the ability of a material to prevent the passage of electric current, expressed in Ohms · meter.

The electrical resistivity of the dust layer (UES) depends on the properties of individual particles, as well as on the structure of the layer and the parameters of the gas flow. It has a significant effect on the operation of electrofilters.

The electrical charge of the particles (EHR) depends on the method of their formation, chemical composition, as well as the properties of the substances with which they come into contact. EHR has an effect on the behavior of particles in flues and the efficiency of capture in GO. EHR affects the explosive and adhesive properties of particles.

For example, in the bins of electrofilters, freshly caught dust, while retaining a charge, has a natural slope angle of about 0 ° C, i.e. it behaves almost like a liquid. After a few hours, with the loss of charge, the angle increases to 50 ° C, and sometimes up to 90 ° C.

The ability of dust to self-ignite and form explosive mixtures with air.

Spontaneous combustion or self-ignition is a type of combustion that occurs by self-heating (temperature rise due to exothermic internal reactions), followed by thermal acceleration (self-heating, which is rapidly accelerated to high

temperatures) and finally spontaneous combustion. Gorenje

The combustible mixture, due to the highly developed surface of contact of particles with oxygen, is capable of spontaneous combustion and the formation of explosive mixtures with air. The intensity of the dust explosion depends on its chemical and thermal properties, on the size and shape of the particles, their concentration in the air, on the moisture content and composition of gases, the size and temperature of the ignition source and on the relative content of inert dust. When the temperature rises, ignition sometimes occurs spontaneously. Some dusts of organic substances formed during the processing of grain, dyes, plastics, fibers, as well as metal dust (magnesium, aluminum, zinc) have the ability to ignite.

The minimum explosive concentrations of dust suspended in the air are 20-500 g/m^3, the maximum are 700-800 g/m^3. The higher the oxygen content in the gas mixture, the more likely an explosion is, if the oxygen content is less than 16%, the dust cloud does not explode.

Deposition in a gravitational field

Dust deposition under the influence of gravity occurs in dust-settling chambers (POK). The gas velocity in the POK is 0.2 - 1.5 m/s. The hydraulic resistance is 50-300 Pa. They are used to capture large particles larger than 50 microns in size. The degree of purification does not exceed 40-50%. The advantages of the POK are simplicity of design, low cost and energy consumption, the ability to capture abrasive dust, and the absence of temperature restrictions on the gases being cleaned. The efficiency of capturing highly dispersed dust (less than 6 microns) is close to zero. It is usually used for rough cleaning. In addition, it has limited use due to the difficulty of removing trapped dust from the interstitial space.

The simplest type of gravitational precipitator is POC, where particles of the dispersed phase are deposited under the action of gravity during the slow movement of the dust and gas flow through the chamber volume (Fig. 1 a).

To improve separation, horizontal chambers are equipped with partitions or caps, which can be pivoted or inclined for the convenience of removing trapped dust (Fig. 1b).

An increase in the efficiency of the POK is achieved by reducing the height from which the particle descends to the bottom of the chamber. This idea is implemented in a multi-band (multi-section) chamber (Fig. 1 in).

Deposition in an inertial field

With a sharp change in the direction of movement of the gas stream, dust particles under the action of inertial forces will tend to move in the same direction and can later be isolated from this stream. A number of dust collectors (PU) work on this principle.

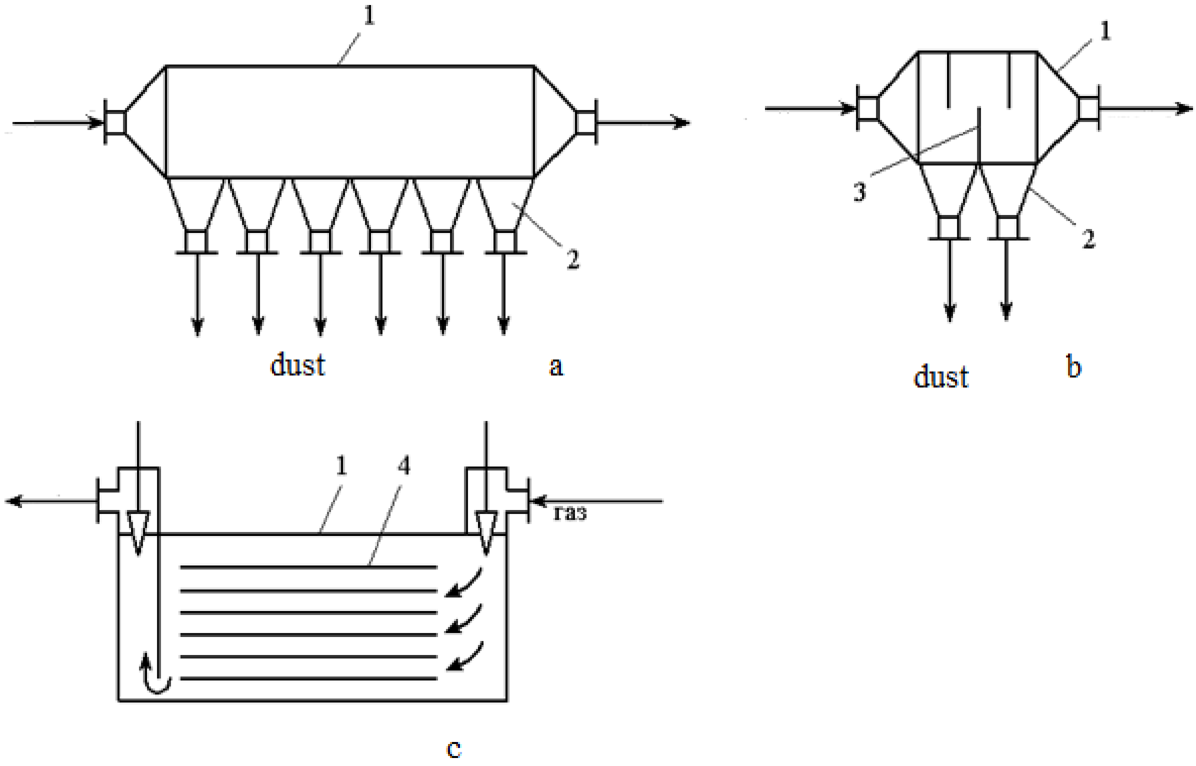

Fig. 1 Dust-settling chambers: a - the simplest chamber; b - a chamber with partitions; c - multi-shelf chamber 1 - housing; 2 - bunkers; 3 - partition; 4 – shelf

The chamber with a partition is not much different in efficiency from the POC, but has a higher hydraulic resistance (Fig. 2a).

A smooth rotation in the chamber reduces the hydraulic resistance (Fig. 2b).

In a chamber with an expanding cone, dust particles are subjected to additional force, which provides additional acceleration of the order of g/3. Secondary particle entrainment is reduced. The gas velocity in the free section of the chamber is 1 m/s, in the inlet pipe 10 m/s. Particles larger than 25-30 microns are captured by 65-85% (Fig. 2 in).

The efficiency of PU with a buried hopper, depending on the gas velocity at the inlet (5 - 15 m/s) is 50-80% (Fig. 2 g).

The principle of a sudden change in the direction of the gas flow when colliding with a grate consisting of inclined plates is used in louver type PU, Fig. 3. It is widely used for pre-purification of gases before cyclones or before bag filters. In it, about 90% of the gases are partially cleared of dust when passing through the blinds, and the rest of the gas stream with trapped dust is diverted to the cyclone for cleaning. The gas velocity is 12-15 m/s. The hydraulic resistance of the grid is 100-500 Pa. It is used to capture dust particles larger than 20 microns. Disadvantages: wear of the grating plates at high concentrations and the possibility of deposits when gases are cooled to the dew point.

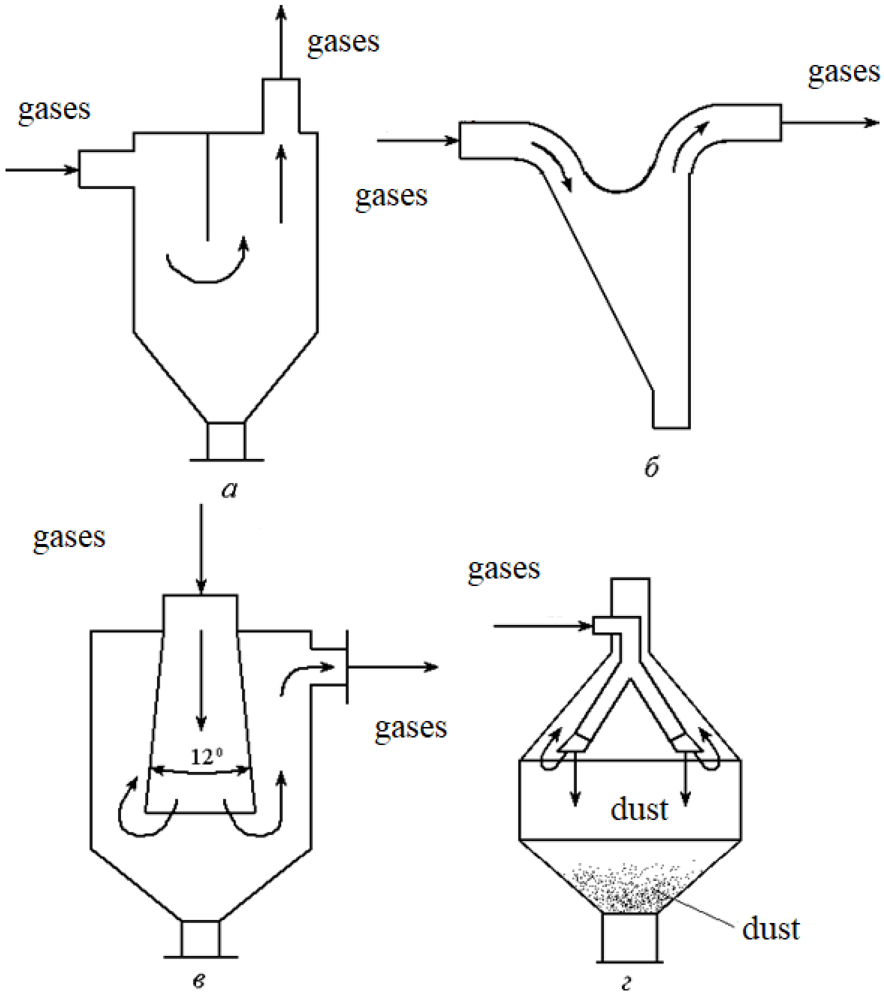

Fig.2 Inertial dust collectors: a – a chamber with a partition; b – a chamber with a smooth rotation of the gas flow; c - a chamber with an expanding cone; d - a chamber with a buried hopper

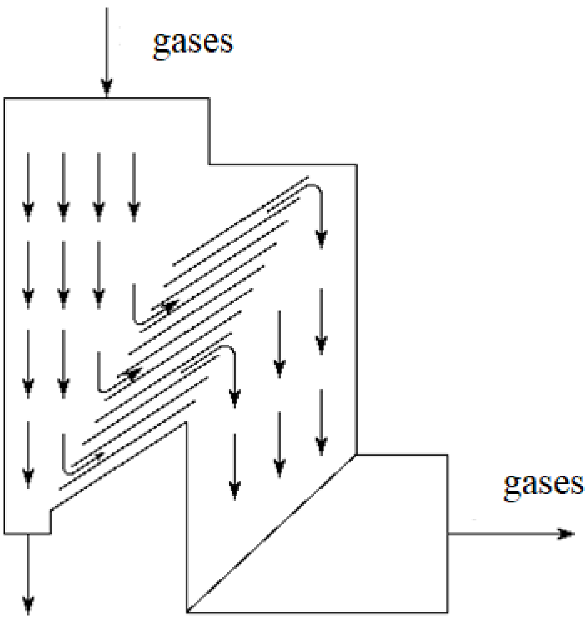

Fig. 3 Louver dust collector 1 - louver grate; 2 - purified gases; 3 - dusty gases

Precipitation in a centrifugal field

This method of separation of inhomogeneous dust and gas mixtures is more efficient than gravitational deposition, therefore it is used to separate smaller (up to 5 microns) dust particles.

Two principles are used in the hardware design of the separation processes of heterogeneous systems in a centrifugal field: rotation of the dust and gas flow in a stationary apparatus (cyclone); movement of the dust and gas flow in a rotating rotor (centrifugal rotary dust collector).

In both cases, in addition to gravity and centrifugal forces, inertial forces have a significant effect on the separation.

Cyclone machines are the most common in industry.

The cyclone action (Fig. 4) is based on the tangential injection of a dusty stream at a speed of 15-20 m/ s into the cylindrical part of the apparatus, where a rotating stream is formed, descending along the inner walls of the cylindrical and conical parts of the body.

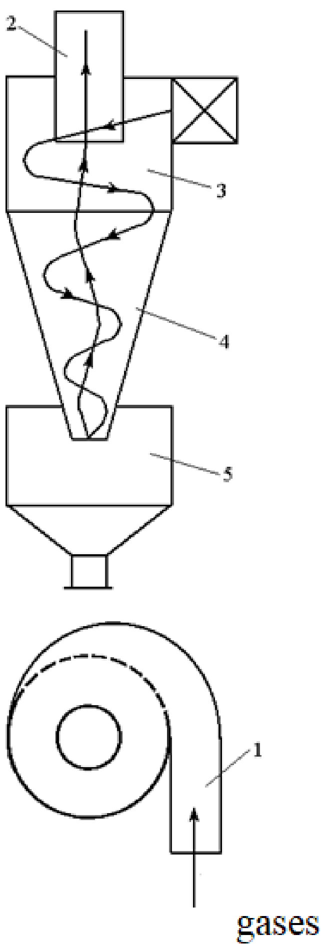

Fig. 4 Diagram of the cyclone operation
1 - inlet pipe; 2 - exhaust pipe; 3 - cylindrical part; 4 - conical part 5 - hopper

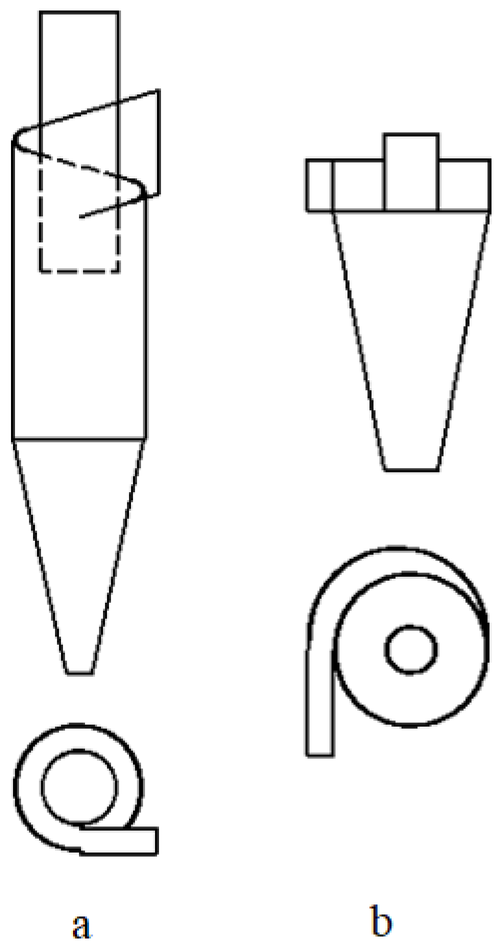

Fig. 5 NIIOGas cyclones:
a - cylindrical cyclone;
b - conical cyclone

Dust particles are separated by centrifugal force from the main gas flow to the periphery, settle on the inside of the cyclone and slide under gravity into the conical part of the apparatus, from where they enter the hopper. The separation of particles from gases entering the hopper occurs under the action of inertia forces when the direction of movement of gases changes by 180o.

In industrial practice, it is customary to divide cyclones into high-performance and highly efficient ones (Fig. 5).

The first type of apparatus includes cylindrical cyclones of NIIOGAZ brand TSN type TSN-11, TSN-15, TSN-15u, TSN-24.

A feature of the devices of this group is the elongation of the cylindrical part, the angle of inclination of the inlet pipe, respectively, 11o, 15o and 24o, and the same ratio of the exhaust pipe diameter to the diameter of the cyclone, equal to 0.59. The diameter of the cyclones does not exceed 2000 mm, it is characterized by low hydraulic resistance, high productivity.

The second type of apparatus includes conical cyclones NIIO- GAZ grade C type SDK-TSN-33, SK-TSN-34 and SK-TSN-22. They are distinguished by a long conical part, a spiral inlet pipe and a small ratio of exhaust pipe diameters to the cyclone body. The diameter of the cyclone does not exceed 3000 mm, the pressure loss is higher than in cylindrical ones.

When creating dust cleaning systems in relation to large or changing gas flow rates, the problem arises of increasing the unit capacity of cyclone equipment. With an increase in the overall dimensions of cyclones, on the one hand, the efficiency of dust collection decreases, and on the other hand, the construction height of the installation increases. This problem is solved by a group or battery arrangement of cyclones.

Battery cyclones are the combination of a large number of small cyclones with a diameter of 150-250 mm into a group. Reducing the diameter of the cyclone element is aimed at increasing the cleaning efficiency. In this type of installation, the battery of cyclone cells is located in a common housing, which has a common collector for supplying and discharging gases and a common hopper for collecting dust.

The so-called direct-flow cyclones (with a lower outlet of purified gas) are also of interest, the main advantages of which are low hydraulic resistance and the possibility of assembling dust collecting devices.

The advantages of cyclones are:

-no moving parts in the device;

-reliable operation at high temperatures (up to 500 °C) and at high pressures;

-the ability to capture abrasive materials while protecting the inner surfaces of cyclones with special coatings;

-dust capture in dry form;

-almost constant hydraulic resistance of the device;

-ease of manufacture;

-maintaining high fractional efficiency while increasing the dust content of gases.

Disadvantages of cyclones:

-high hydraulic resistance of 1250-1500 Pa;

-low efficiency of capturing particles smaller than 5 microns;

-the inability to use it to catch clumping dust.

A special place in gas cleaning technology is occupied by vortex dust collectors (VPUs), which also belong to direct-flow centrifugal devices. They make it possible to extract up to 99% of dust with a noticeable content of fine particles with a diameter of 3-5 microns from ventilation emissions. VPUs are widely used for cleaning gases after mills, dryers, as well as in the mining industry.

The main difference between vortex dust collectors and cyclones is the presence of an auxiliary swirling gas stream.

The advantages of the VPU are:

-higher efficiency of catching fine dust;

-absence of abrasive wear on the inner surfaces of the device;

-the possibility of purifying gases with a higher temperature by using secondary cold air;

-the possibility of regulating the dust separation process by changing the amount of secondary gas.

Disadvantages of VPU:

-the need for an additional blowing device;

-increase in the total amount of gas passing through the device; complexity of the hardware design

Centrifugal dust collectors include dynamic (rotary) dust collectors. In these devices, gas purification from dust is carried out due to centrifugal forces and Coriolis forces arising from the rotation of the impeller. Dynamic PU, in addition to depositing dust particles from the gas stream, act as a draft device.

In devices of the CPR type (centrifugal rotary PU), the captured particles move in the opposite direction to the movement of gases in the fan (Fig. 6). The cleaned gases are sucked through holes located on the side surface of the rotating drum. In the boundary layer, the rotation frequency of the dust and gas flow reaches the circumferential rotation frequency of the drum. Due to this, dust particles are released from the gas stream in the radial direction.

The most widespread of the dynamic dust collectors is the smoke exhaust dust collector (DP), which is most often paired with a cyclone. DP is used for cleaning flue gases of small boiler houses, in foundries for cleaning aspiration emissions and in asphalt concrete plants for cleaning gases of drying drums.

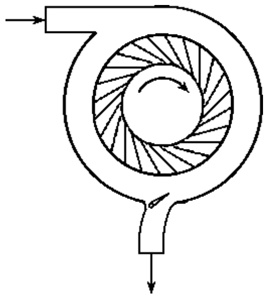

Fig. 6 Centrifugal rotary dust collector

The advantages of dynamic dust collectors in comparison with other centrifugal devices are compactness, reduction of metal consumption, combination of a smoke pump and a separator in one device.

The disadvantages are the danger of abrasive wear of the exhaust fan blades, the possibility of deposits on the blades, and difficulty in manufacturing.

Aerosol filtration

When dusty streams are passed through porous partitions, woven and non-woven, the suspended particles contained in them are cleaned.

Filter baffles used in gas purification technology can be divided into the following types:

- flexible porous partitions,
- semi-rigid porous partitions,
- rigid porous partitions,
- granular layers.

Flexible porous partitions can be made of fabric materials of natural, synthetic or mineral fibers, non-woven fibrous materials (felt, cardboard), porous sheet materials (sponge rubber, polyurethane foam, membrane filters).

Semi–rigid porous partitions are layered structures made of fibers, shavings, knitted nets, located on support devices or sandwiched between them.

Rigid porous partitions are, as a rule, granular materials (porous ceramics or plastics, sintered or pressed metal powders), fibrous materials (layers of glass or metal fibers); metal grids and perforated sheets;

Granular layers are layers of coke, gravel, quartz sand.

Depending on the purpose and the value of the input and output concentrations, filters can be divided into the following classes:

- industrial,
- filters for cleaning atmospheric air,
- fine filters.

Industrial filters (fabric, granular, coarse-fiber) are used to purify industrial gases with a high concentration of the dispersed phase (up to 60 g/m^3).

Filters for cleaning atmospheric air (air filters) are installed in supply ventilation and air conditioning systems. They are designed to operate at a dust concentration of less than 50 mg/m^3 and a high filtration rate (2.5-3 m/s).

Fine filters (high-efficiency or absolute filters) are designed to capture with very high efficiency (above 99%) mainly submicron particles from industrial gases and air at low input concentration (less than 1 mg/m^3) and low filtration rate (less than 10 cm/s).

Requirements for fabrics for filter baffles:

-high dust capacity during filtration and the ability to retain after regeneration;

-maintaining optimally high breathability in an equilibrium dusty state;

-high mechanical strength and resistance to bending abrasion;

-stability of dimensions and properties at elevated temperatures and aggressive environmental influences;

-the ability to easily remove accumulated dust;

- low cost.

Bag filters are widely known. The inventor of the bag filter can rightfully be called Hippocrates. Around 500 BC, he created the first device, representing a crate with cotton woven bags attached to it, to filter mechanical impurities from water. Historians have nicknamed the first bag filter the "Hippocratic Sleeve".

The appearance and dimensions of the devices may vary significantly. But, regardless of the design, orientation, type and material of the bags, each bag dust collector assumes the presence of the following nodes, Fig. 7.

The body is usually a steel or, less often, a plastic casing. If the device is designed to filter flammable or flammable dusts, the housing can be equipped with soft anti-explosion membranes or plates, which, collapsing during an explosion of the internal environment, quickly reduce internal pressure and keep the housing intact, minimizing possible damage.

A sleeve block is a compartment with flat, cylindrical or rarely ellipsoidal frames installed in the so–called sleeve plate (frame), on which filter sleeves are fixed.

A bump plate or deflector is installed immediately after the inlet valve and "beats off" coarse dust, which immediately falls into the dust collector hopper.

A pyramidal (cone) type dust collector. All dust gets into the hopper – both after rebounding from the chop plate and after cleaning the dust sludge from the sleeves. Optionally, the hopper can be equipped with a vibration drive and a screw for continuous removal of mechanical sludge.

The sleeve regeneration mechanism can be based on the use of a cam (or other) vibration shaking mechanism, on the principles of back purging with compressed air, acoustic-vibration effects and other self-cleaning technologies.

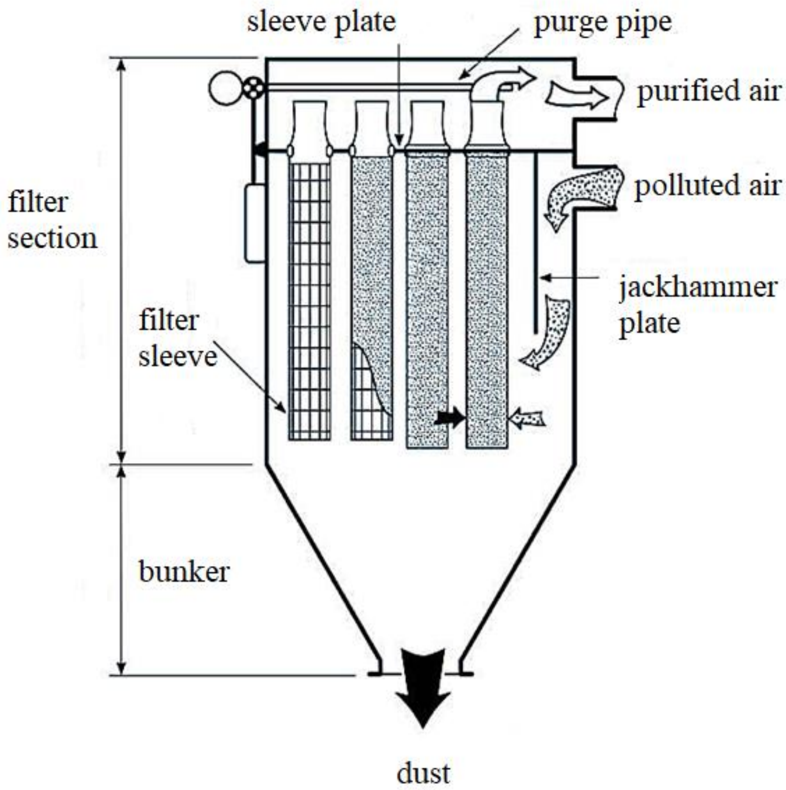

Fig. 7 Schematic diagram of the bag filter

The degree of clogging of the filter can be determined both by a timer (if the properties of the cleaned flow are known and unchanged over time) and by a differential pressure gauge, which operates with the difference between the readings of the incoming and outgoing flow.

Among other things, it is customary to conditionally separate clean and dirty chambers in bag filter designs.

The dirty chamber includes a dusty air inlet compartment, a dust collector, a bunker area and the entire outer surface of the textile sleeves, on which, in fact, dust inclusions are trapped and deposited.

The clean chamber is separated from the rest of the unit by an installation frame in which the ends of the frames with bags are fixed.

From the clean chamber – in various technological variations – the flow goes to the outlet valve. It also contains, in whole or in part, elements of the sleeve regeneration mechanism – pulse purge valves, nozzles, shaker rods, vibrating membranes.

The principle of operation. The dusty flow is supplied to the inlet valve of the device. In this case, auxiliary elements can be used – pneumatic pumps, compressors, pressure fans, and other superchargers. In the case of high-temperature flow treatment, mixing of clean cool atmospheric air into the filter can be realized. The air flow contacts the outer surface of dense non-woven sleeves, while dust particles settle outside the bags, while clean air passes inside the frames and enters a clean chamber, from where it is discharged into the production room or into the external atmosphere.

As dust inclusions settle on the surface of the hoses, it becomes increasingly difficult for air to pass through the increasing mechanical barrier, and the productivity of the device decreases. Depending on the type of regeneration system, reverse pulse purging, shaking or other effects on the filter elements are performed, which allows them to free their surface from dust and restore the nominal efficiency of the device. The dust falls into the hopper, the cycle repeats.

Bag filters according to the method of entering the purified air into the sleeve are divided into:

-countercurrent (air input from below through the hopper (Fig. 8),

-direct-flow (air input from above).

The rate of gas filtration through the filter baffle is relatively low - from 0.007 to 0.08 m^3/m^2 s under the condition of continuous tissue regeneration.

The number of sleeves is large and they are installed tightly. The diameter of the sleeves is 135-350 mm, however, designs are known in which they reach 600 mm. The length of the sleeves is usually 2400-3500 mm, and in some PU exceeds 10 m. The maximum ratio of sleeve length to diameter is 50:1.

To capture highly dispersed aerosols with an efficiency of at least 99% for the most penetrating particles (0.05-0.5 microns in size), filter materials in the form of thin sheets or bulk layers of thin or ultrathin fibers (with a diameter of less than 2 microns) are widely used.

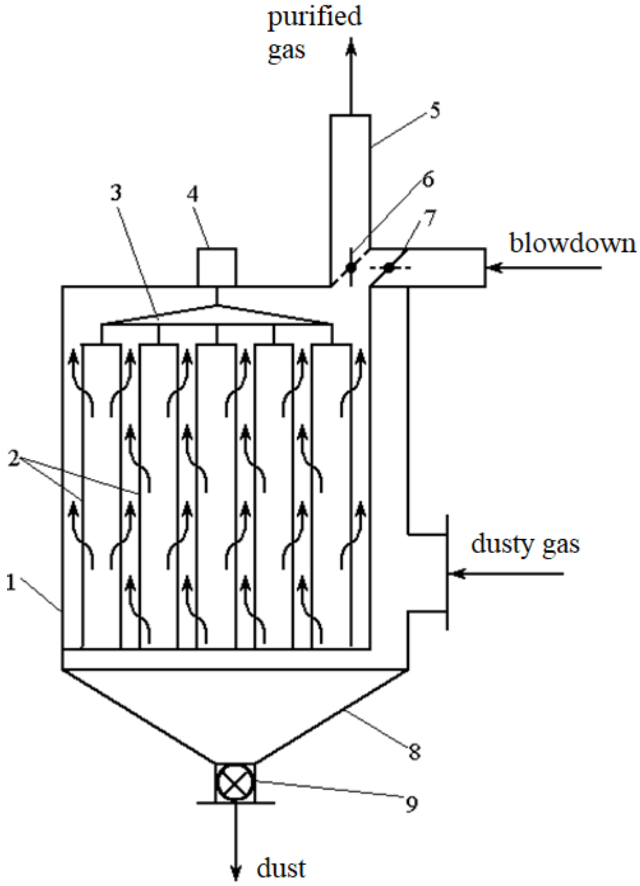

Fig. 8 Diagram of the bag filter: 1-housing; 2-sleeves; 3-frame; 4-shaking mechanism; 5-collector of purified gas; 6,7-valves; 8-hopper; 9-auger

The filtration rate in them is 0.01-0.15 m/s, the resistance of clean filters is 200-300 Pa, and those clogged with dust are 700-1500 Pa. Regeneration of spent fine filters is usually unprofitable or impossible. After working for 0.5-3 years, they must be replaced. The input dust concentration should not exceed 0.5 mg/m^3; as the concentration increases, the service life of the filters is shortened. As a rule, simpler dust collection devices are installed in front of fine filters to reduce the concentration to 0.5 mg/m^3.

As fine-fiber media, filter materials of the FP type (Petryanov filters) made of polymer resins are widely used. They are layers of synthetic fibers with a diameter of 1-2.5 microns, applied during the production process to a gauze substrate made of thicker fibers bonded together.

The small thickness of the AF layers (0.2-1 mm) makes it possible to obtain a filtration surface of up to 100-150 m^2 per 1 m^3 of the device.

The most widely used design of fine filters is the frame filters. The filter material in the form of a tape is placed between the frames, alternating between open and closed sides when assembling the package. Polluted gases enter one of the open sides of the filter, pass through the material and exit from the opposite side (Fig. 9).

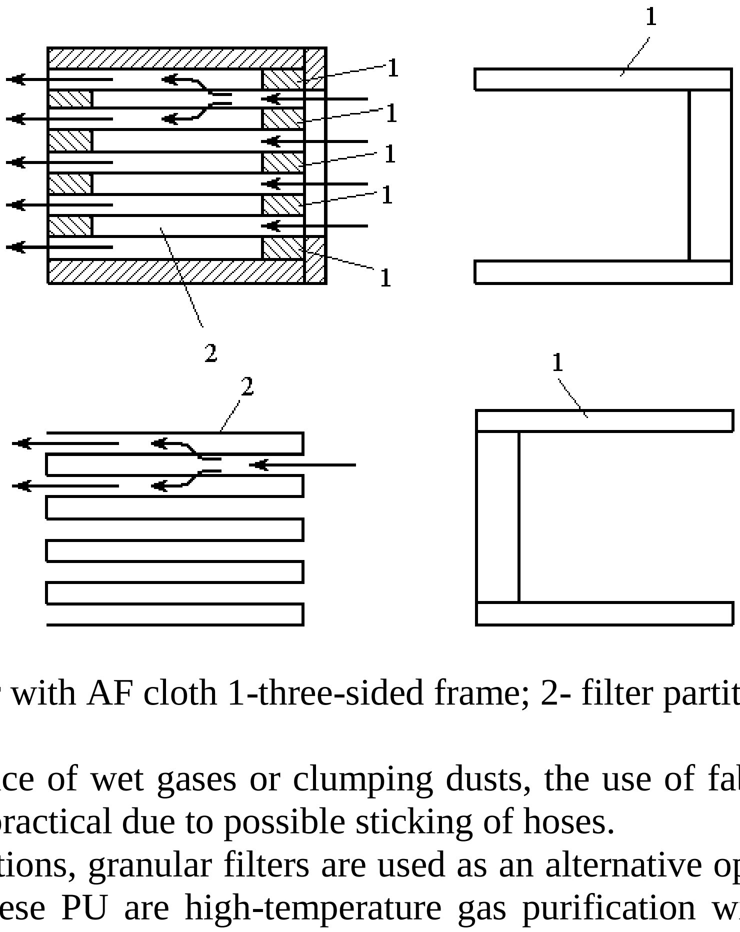

Fig. 9 Frame filter with AF cloth 1-three-sided frame; 2- filter partition (AF cloth)

In the presence of wet gases or clumping dusts, the use of fabric filters for gas purification is impractical due to possible sticking of hoses.

In such situations, granular filters are used as an alternative option. The optimal applications of these PU are high-temperature gas purification without pre-cooling with heat recovery and dry comprehensive cleaning of dust and gaseous impurities with a bulk layer of adsorbent or catalyst.

The advantages of such filters are the low cost and availability of materials, the ability to work with high-temperature and aggressive media under significant mechanical loads and pressure drops.

Disadvantages of the devices: periodicity of action, bulkiness, low productivity and imperfection of some components, such as filter layer regeneration devices.

Granular filters are divided into two groups, Fig. 10:

-bulk,

- hard porous.

Grain filters include:

-static (fixed) layer filters;

-dynamic (movable) layer filters with gravitational displacement of the bulk medium;

-fluidized layers.

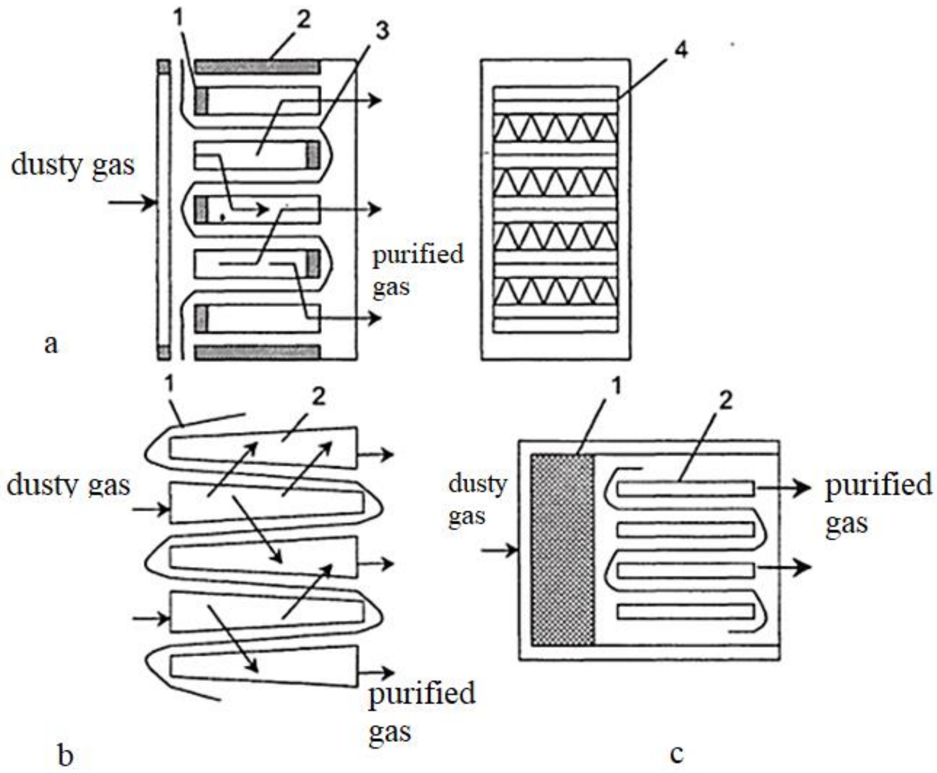

Fig. 10 Fine filters: a-frame: 1-U-shaped bar; 2 -side wall; 3 - filter material; 4 - separator; b- with wedge-shaped separators of type D-CL: 1 - filter material; 2 - frame-wedge-shaped separator; c - combined: 1 - section with a printed fiber layer; 2 - fine cleaning section

Bulk filters use sand, pebbles, slag, crushed rocks, sawdust, coke, crumbs of rubber, plastics, graphite, etc. The choice of material depends on the required thermal and chemical resistance, mechanical strength and accessibility.

There are granular filters regenerated by stirring or vibrating the granular layer inside the device, as well as filters with a moving medium (Fig. 11). The material moves between the grids or louvered grilles. The regeneration of the material from dust is carried out in a separate apparatus by screening or washing. If the filter medium consists of the same material as the dust, then the contaminated granules are removed from the system and used in the technological process.

Granular rigid filters. In these filters, the grains are firmly connected to each other as a result of sintering, pressing or gluing and form a solid stationary system. These include porous ceramics, porous metals, and porous plastics. The filters are resistant to high temperature, corrosion and mechanical stress and are used for filtering compressed gases.

Disadvantages of such filters: high cost, high hydraulic resistance and difficulties of regeneration, which is carried out in four ways: 1) by blowing air in the opposite direction; 2) by passing liquid solutions in the opposite direction; 3) by passing hot steam; 4) by tapping or vibrating a pipe grate with elements.

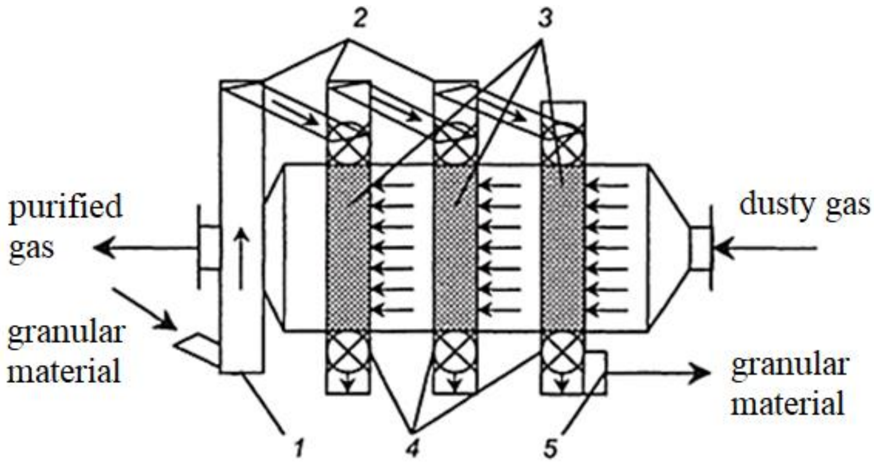

Fig. 11 Filter with moving layers of granular material: 1-a box for feeding fresh granular material; 2- feeders; 3- filter layers; 4 - closures; 5 - a box for removing granular material

Deposition in an electric field

The deposition of solid and liquid particles suspended in a gas under the action of an electric field has advantages over other deposition methods. The effect of an electric field on a charged particle is determined by the magnitude of its electric charge. During electrodeposition, small particles manage to communicate a significant electric charge and thus carry out the deposition process of very small particles, which cannot be carried out under the influence of gravity or centrifugal force.

The principle of electric purification of air (gases) from suspended particles consists in charging particles in the corona discharge field, followed by their release from the weighing medium under the influence of an electric field.

The physical essence of electrodeposition is that the gas stream containing suspended particles is pre-ionized, while the particles contained in the gas acquire an electric charge. The charging of particles in the corona discharge field occurs under the influence of an electric field and due to ion diffusion. The maximum charge of particles larger than 0.5 microns is proportional to the square of the particle diameter, and particles smaller than 0.2 microns are proportional to the particle diameter.

If a certain voltage is created in the electric field between the corona (negative) and precipitation (positive) electrodes (Fig. 12), then the charge carriers, i.e. ions and electrons, receive significant acceleration, and when they collide with molecules, the latter ionize.

Ionization is the endothermic process of ion formation from neutral atoms or molecules.

Ionization consists in the fact that one or more external electrons are knocked out of the orbit of a neutral molecule. As a result, the neutral molecule is converted into a positive ion and free electrons. This process is called shock ionization.

When an ionized gas flow passes in an electric field between two electrodes, charged particles under the action of an electric field move to oppositely charged electrodes and settle on them.

When colliding with dust particles, the ions inform them of their charge, as a result of which these particles also begin to attract to the precipitation electrode. The speed of movement of a dust particle to the electrode depends largely on the magnitude of the charge it receives, which, in turn, is determined by the forces acting on gas ions near the particle associated with the external field, particle polarization, electrostatic attraction and repulsion of the charges of the same name.

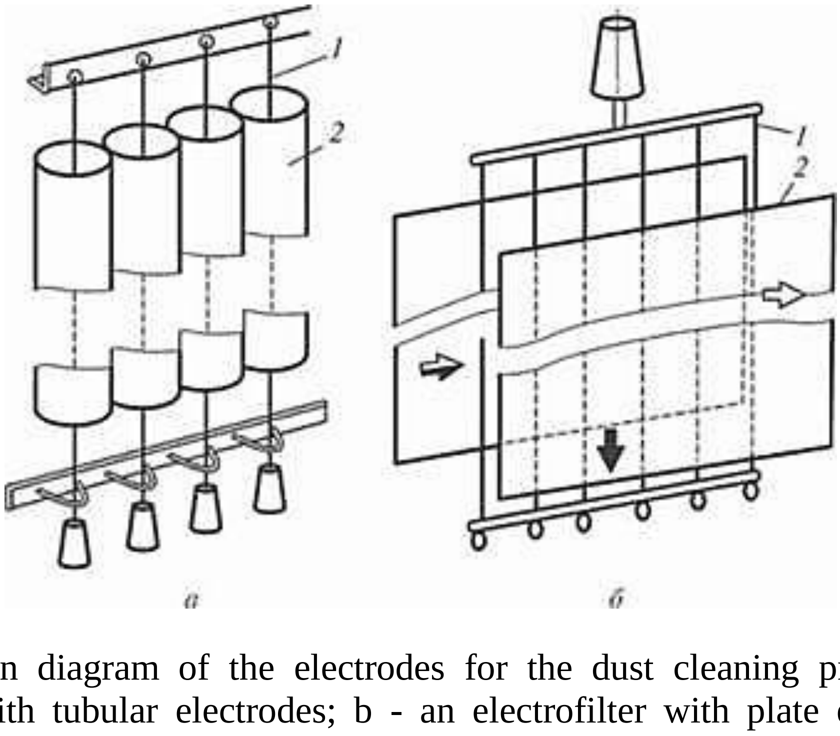

Fig. 12 Design diagram of the electrodes for the dust cleaning process: a - an electrofilter with tubular electrodes; b - an electrofilter with plate electrodes; 1 - corona electrodes; 2 - precipitation electrodes

If you create a potential difference of 4 on the electrodes...6 kV / cm and provide a current density of 0.05 ...0.5 mA / m of the cathode length, then the dusty gas, when passed between the electrodes, is almost completely freed from suspended particles.

Electric gas purification has the following main features:

-depending on the specific conditions and requirements, it is possible to design electrofilters (EF) for any degree of purification (up to 99.9%) and for a wide range of performance (from several cubic meters/hour to several million cubic meters/h);

-EFS have the lowest hydraulic resistance of all known gas purification equipment;

-The EF is designed to operate both at atmospheric and at pressures above and below atmospheric;

-the concentration of suspended particles in the gases to be cleaned can range from fractions of g/cubic meter to 50 g/cubic meter. m or more, and their temperature can reach 500 ° C and above; gas purification can be both dry and wet;

-EF captures particles ranging in size from 100 to 0.01 microns;

-EFS can be made of materials resistant to acids, alkalis and other aggressive substances;

-the process of gas purification in the EF can be fully automated;

-the energy consumption for gas purification is usually less than when using other types of gas cleaning devices.

The design of an electrofilter for a specific purpose is mainly determined by the technological conditions of its operation: the composition and properties of the gases to be cleaned and the suspended particles contained in the gases, the temperature, pressure and humidity of the gases to be cleaned, the required degree of purification, etc.

Electrofilters are classified:

according to the method of removing deposited particles:

-dry,

-wet;

by the number of fields or sections that make up the active zone of the EF:

-single-section,

-multi-section);

in the direction of the gas flow in the core:

-horizontal,

- vertical;

by type of electrode system:

-lamellar,

-tubular.

The type of precipitation electrodes used in them has a significant influence on the design and operating conditions of the EF. Plate electrodes are used in horizontal and vertical EF, and tubular electrodes are used only in vertical ones. EFS with a tubular electrode system provide better conditions for particle capture compared to a plate one due to the better characteristics of the electric field, as well as due to the absence of passive zones. However, it is difficult to ensure good shaking of tubular electrodes and therefore they are rarely used in dry EF; in wet EF they are widely used.

Devices for "wet" gas purification

"Wet" cleaning is used for fine and highly efficient gas purification. The basis of "wet" dust collection is the contact of a dusty gas stream with a liquid that captures suspended particles and carries them out of the apparatus in the form of sludge.

"Wet" cleaning is used in cases where humidification and cooling of the gas is acceptable, and the particles separated from the gas are of no value.

"Wet" dust collectors (PU) have the following advantages over other PU:

- relatively low cost of manufacture;

- high efficiency;

- the possibility of using gases at high temperature and high humidity, as well as in case of danger of spontaneous combustion or explosion of the gases being cleaned or the dust being captured;

- the possibility of simultaneous purification of gases from suspended particles, extraction of gaseous impurities (absorption) and cooling of gases (contact heat exchange).

Disadvantages of wet PU:

-spray removal, which leads to the need to include droplet separators in the cleaning scheme;

-the captured product is released in the form of sludge, which is associated with the need for wastewater treatment and, consequently, with an increase in the cost of the purification process;

-in the case of cleaning aggressive gases, equipment and communications must be made of anticorrosive materials or coatings must be applied.

In order to reduce the amount of waste liquid, a closed irrigation system is used.

The most accepted classification of wet PU is based on their mode of action and includes:

-hollow gas washers;
-nozzle scrubbers;
-with a movable nozzle;
-centrifugal scrubbers;
-poppet gas washers (bubbling and foam);
-high-speed gas washers;
-impact-inertial scrubbers.

Dust recovery

Depending on the method of capture (dry and wet), nature, quantity, physico-chemical properties, concentration of a potentially useful component, its toxicity, cost, prospects for subsequent processing and a number of other indicators, there are methods for recovery, elimination and isolation of industrial dusts.

Naturally, the most rational is the recovery of dust.

Possible ways to use industrial dusts:

-use as target products;

-return to production, in the technology of which this type of dust is formed;

-processing in another production in order to obtain marketable products;

-disposal for construction purposes;

-recycling with the extraction of foam components;

-agricultural use (in some cases as fertilizers);

-utilization in processes where individual physico-chemical properties (or a combination of such properties) of pulverized materials are used. Let's look at some examples.

The use of dust as a target product.

As a rule, this refers to a technology aimed at special production of products in the form of fine-dispersed material.

A typical example of such a technology is the production of soot. Soot is widely used in many industries: rubber and tire (>90% of the total amount produced), paint and varnish, etc. It is obtained in the process of burning petroleum products or combustible gases with a lack of air (in a smoky flame).

A special feature of soot is the high dispersion of its constituent particles (0.01-5.5 microns) and their low electrical resistivity. The density of soot is in the range of 1750-2000 kg/m^3, and its bulk density is 40-300 kg/m^3. Depending on the method of production of soot and its grade, various schemes of soot extraction from process gases of soot production are used.

Return of dust to production. This is one of the most common and rational methods of ensuring waste-free production while increasing its efficiency and solving environmental problems. The technology of returning captured dust materials to the main production is usually determined by the gas purification methods used (dry, wet, one- and two-stage, combined) and the expediency of introducing these products into a certain apparatus of the technological scheme in one or another aggregate state.

Recycling of dust caught in one production as raw materials for another production. It is also a very common technique for using pulverized waste in chemical and other industries. Thus, the cinder dust captured in battery cyclones and dry electrofilters, after appropriate treatment or without it, can be used in a charge for smelting cast iron. The soot released during the purification of process and waste gases from a number of industries can be used to prepare pellets or briquettes serving as boiler fuel.

For example, in the processes of gasification of liquid fuels during wet purification of the resulting synthesis gas used as raw materials for various chemical syntheses, soot dust is removed in the form of an aqueous solution, the sludge of which (sludge) is processed.

The first method refers to industries where the target product is obtained in the form of a finely dispersed material (soot production).

In a number of industries, accompanied by dust formation of products at certain stages, various recovery schemes are used. Thus, during the production of ammonium nitrate, dust-air mixtures with a high content of these substances are formed at the stages of cooling the dried product and drying the finished product. For their capture and purification of air before its release into the atmosphere, wet absorption devices are used, irrigated with aqueous solutions of the extracted components circulating in the purification system until a certain concentration is reached, after which the resulting brines are returned to one or another device of the technological scheme.

An example of the disposal of dust captured in one production as a raw material for another production is the cinder dust captured during the purification of the firing gas during the production of sulfuric acid from pyrite, which is used after appropriate treatment in a mine for smelting cast iron.

§ 4 PROTECTION OF THE HYDROSPHERE. METHODS OF WASTEWATER TREATMENT. THE EQUIPMENT USED

Water is one of the most important substances on Earth, on which the state of the animal and plant world depends. It is the most common inorganic component of living matter. In humans, water makes up 63% of body weight, in fungi – 80%, in jellyfish – 98%, plants contain up to 95% water.

4.1 Types of water pollution

Water pollution manifests itself in changes in physical and organoleptic properties, an increase in the content of sulfates, chlorides, nitrates, toxic heavy metals, a decrease in oxygen dissolved in water, the appearance of radioactive elements, pathogenic bacteria and other pollutants. It is estimated that more than 420 km^3 of wastewater is discharged annually in the world.

The main sources of pollution of the hydrosphere are:
-industrial wastewater;
-household waste water;
-drainage water from irrigated lands;
-agricultural fields and large livestock complexes;
- water transport.

All wastewater pollutants are divided into three groups:
-biological pollutants;
-chemical pollutants;
-physical pollutants.

Chemical pollution can be organic (phenols, pesticides), inorganic (salts, acids, alkalis), toxic (mercury, arsenic, cadmium, lead), non-toxic.

Eutrophication is a phenomenon associated with the entry into reservoirs of a large number of biogenic elements (nitrogen and phosphorus compounds) in the form of fertilizers, detergents, and animal husbandry waste.

In Russia, concentrations of pollutants exceed MPC in many water bodies. When deposited to the bottom of reservoirs, harmful substances are sorbed by rock particles, oxidized, reduced, and precipitated. However, as a rule, complete self-purification does not occur.

Bacterial contamination is expressed in the appearance of pathogenic bacteria, viruses, protozoa, fungi, etc. in the water.

Physical contamination can be radioactive, mechanical, or thermal.

The content of radioactive substances in water, even in small concentrations, is very dangerous. Radioactive elements enter surface reservoirs when radioactive waste is dumped into them, waste disposal, etc. Radioactive elements enter groundwater as a result of their precipitation on the earth's surface and subsequent seepage deep into the earth, or as a result of the interaction of groundwater with radioactive rocks.

Mechanical pollution is characterized by the ingress of various mechanical impurities into the water (sludge, sand, silt, etc.), which can significantly worsen organoleptic parameters.

Thermal pollution is associated with an increase in the temperature of natural waters as a result of their mixing with process waters. When the temperature rises, the gas and chemical composition in the waters changes, which leads to the proliferation of anaerobic bacteria, the release of toxic gases – H_2S, CH_4. There is a flowering of water, accelerated development of microflora and microfauna.

4.2 Environmental protection measures

To protect surface waters from pollution, the following environmental protection measures are provided.

-The development of waste–free and waterless technologies, the introduction of recycled water supply systems - the creation of a closed cycle of industrial and domestic wastewater use, when wastewater is in circulation all the time, and its ingress into surface reservoirs is excluded.

-Wastewater treatment.

-Purification and disinfection of surface waters used for water supply and other purposes.

Wastewater is the main pollutant of surface waters, therefore, the development and implementation of effective wastewater treatment methods is an urgent and environmentally important task.

Methods of wastewater treatment

-Mechanical cleaning

-Physical and chemical cleaning

- Biological purification

Mechanical cleaning

It is used to remove suspended solids from wastewater (sand, clay particles, fibers, etc.).

Mechanical cleaning is based on four processes:

-straining,

-settling,

-processing in the field of centrifugal forces,

-filtration.

Straining is carried out in gratings and fiber traps. It is used to remove large and fibrous inclusions from wastewater (wastewater from the pulp and paper and textile industries). The width of the gaps is 10-20 mm.

Settling is based on the free settling of impurities with a density less than the density of water or the surfacing of impurities with a density less than the density of water. The process is implemented in sand traps, settling tanks, grease traps.

Sand traps are used to purify wastewater from metal and sand particles larger than 250 microns.

Settling tanks are used to purify wastewater from smaller suspended particles or fatty substances, petroleum products.

Wastewater treatment in the field of centrifugal forces is carried out in hydrocyclones and centrifuges. The mechanism of action is similar to the mechanism of action of gas-cleaning cyclones.

Filtration is used to purify wastewater from fine impurities with a low concentration.

Two types of filters are mainly used:

granular – quartz sand, crushed slag, gravel, sulfocarbon, etc. are used as filter material;

fabric–filter partitions are made of cotton materials, wool, ceramic.

Physico-chemical methods of purification

They are used to remove soluble impurities from wastewater, and in some cases – to remove suspended solids.

The following methods are most often used:

-flotation,
-coagulation,
-reagent method,
-neutralization,
-extraction,
-ion exchange purification, etc.

Flotation consists in enveloping particles of impurities (oil products, fine suspensions) with small air bubbles supplied to wastewater and lifting them to the surface, where a foam layer is formed.

In the case of electroflotation, gas bubbles are formed as a result of the electrolysis of water when an electric current (hydrogen, oxygen) is passed.

Coagulation is a physico–chemical process of enlargement of the smallest colloidal and dispersed particles under the action of molecular attraction forces.

Aluminum sulfate and iron chloride are used as coagulants. If the aluminum or iron ions necessary for coagulation are obtained electrochemically (by electrolysis), then this process is called electrocoagulation.

The reagent method consists in the fact that wastewater treatment is carried out with chemical reagents, which, entering into a chemical reaction with dissolved toxic impurities, form non–toxic or insoluble precipitates. For example, calcium hydroxide and calcium chloride are used to purify fluorinated waters. As a result of a chemical reaction with toxic fluorine compounds, poorly soluble calcium fluoride CaF2 is formed, which can be removed from the water by settling.

Neutralization is a type of reagent method designed to reduce the concentration of free H+ or OH ions to set values corresponding to pH = 6.5–8.5. Neutralization of acidic wastewater is carried out by adding soluble alkalis NaOH, Ca(OH)2, Mg(OH)2, and alkaline – by adding acids (hydrochloric, sulfuric).

Extraction is the extraction of a substance from a solution or dry mixture using a solvent (extractant) that practically does not mix with the initial mixture.

Extraction is based on the redistribution of wastewater impurities in a mixture of two mutually insoluble liquids (wastewater and organic liquid). It is used to isolate phenols, fatty acids, non–ferrous metals - copper, nickel, zinc, cadmium, etc.

Ion exchange purification consists in passing wastewater through ion exchange resins, which contain mobile and exchangeable ions – cations (more often H+) or anions (more often OH–). When wastewater passes through resins, mobile resin ions are replaced by ions of toxic impurities of the corresponding sign.

In recent years, new effective methods of wastewater treatment have been actively developed:

-ozonation,

-membrane purification processes (ultrafiltration, electrodialysis),

-electric discharge methods of water treatment,

-magnetic treatment, etc.

Let's look at some of them.

Ozonation is a method of purifying water by saturating it with ozone.

The gas is produced by forming electrical discharges. After that, it enters the liquid through a pipe system. Once in the water, ozone reacts with metal impurities, causing them to precipitate out. In addition, it penetrates the membranes of bacteria and viruses, killing them by destroying them at the DNA level.

The water that has passed through the ozone filter is not only purified, but also acquires a number of useful properties. Most of them are due to the increased oxygen content in the liquid.

The liquid that has passed through the ozonator and is properly infused after that does not contain O_3 impurities in a dangerous amount for humans. Therefore, its use does not cause side effects and does not cause any harm. Unpleasant symptoms occur due to breakdowns and violations of the operating conditions of the ozonating equipment.

Ozonation is contraindicated in the presence of impurities of bromites in filtered liquids. This leads to the formation of bromates, which are considered carcinogens.

Membrane water purification. As the name suggests, membrane water purification is the filtration of water using a membrane. The contaminated liquid is passed through a special film (semi-permeable membrane), in which many tiny pores are made. This technology is used in water filtration from mechanical and organic impurities, bacteria and viruses, in the separation of solutions, water softening, wastewater treatment and the production of sterile liquids.

The quality of membrane water treatment directly depends on the material from which the membrane is made; it can be:
-polymer of natural origin;
-synthetic polymer;
-ceramic materials;
-materials of biological properties;
-composite materials;
-silicate glasses

Baromembrane processes are a subsection of membrane water purification. The main difference is that in the baromembrane method, purification takes place against the background of external pressure. In a baromembrane installation, the liquid to be cleaned is forced through a semi-permeable membrane at a temperature of 5 to 30 degrees.

The methods of baromembrane purification include:
-reverse osmosis;
-microfiltration;
-ultrafiltration;
- nanofiltration.

Under the influence of external pressure, only water molecules and some salts pass through the membrane, while other substances are retained in the filtered solution. The cleaner the liquid needs to be obtained, the smaller the micropores in the membrane should be and, accordingly, the higher the external pressure.

4.3 Wastewater treatment equipment

The device and the principle of operation of grates for straining wastewater

Straining, the primary stage of wastewater treatment, is designed to isolate large insoluble impurities up to 25 mm in size from wastewater, as well as smaller fibrous contaminants that interfere with the normal operation of wastewater treatment equipment during further wastewater treatment. Wastewater filtration is carried out by passing water through grates. Grids are used regardless of the performance of wastewater treatment plants at the first stage of wastewater treatment to detain large inclusions.

The ingress of large, undissolved, floating contaminants into subsequent treatment facilities can lead to clogging of pipes and channels, breakage of moving parts of equipment, i.e. to disruption of normal operation. The main element of the grids is a frame with a number of metal rods arranged parallel to each other and creating a plane with openings through which water is filtered. Rods of rectangular, rectangular with a rounded part, round and other shapes are used for the device of gratings. Rectangular rods are used more often than others. The thickness of the rods is usually 6-10 mm, the width of the openings between the rods is usually assumed to be 16 mm. Grilles with openings of more than 16 mm wide are used in pumping stations and rainwater treatment plants. For gratings of new designs of domestic and foreign production, the thickness of the rods (plates) is 3-10 mm, the width of the openings is 3-16 mm.

Gratings are installed at treatment plants when wastewater flows to them by gravity.

Gratings are divided into: movable and fixed; with mechanical or manual cleaning; installed vertically or obliquely (both with gravity and with pressure intake of wastewater).

The grilles are installed in expanded channels called chambers. The movement of water occurs by gravity. The grilles are placed in separate rooms equipped with lifting devices.

Grilles requiring manual cleaning are installed if the amount of contamination does not exceed 0.1 m^3/day (Fig. 13). For the convenience of removing dirt, grilles are often installed at an angle to the horizon of 60-70 °.

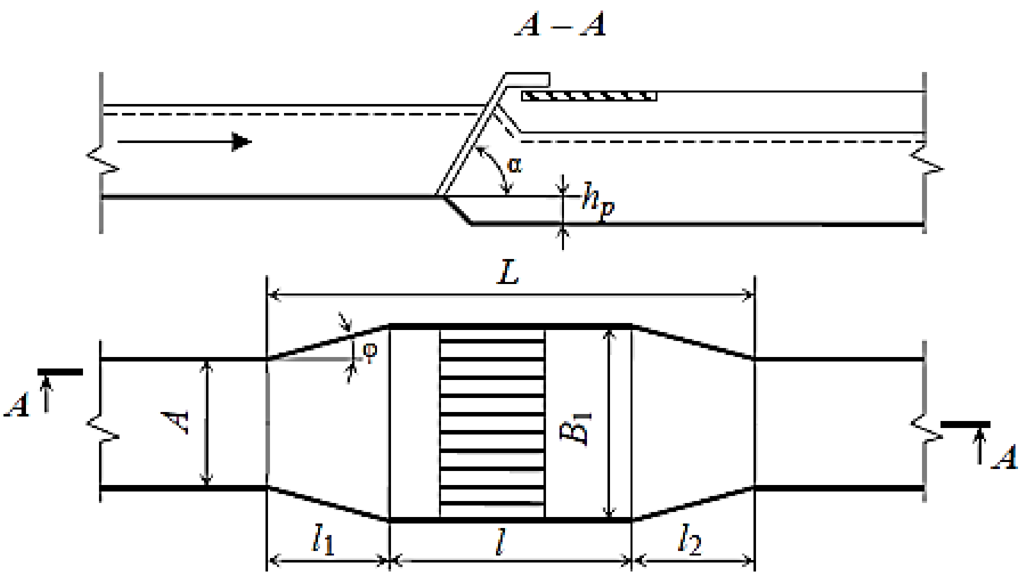

Fig. 13 Grid with manual cleaning

With a large amount of contamination, grates with mechanical rakes are installed (Fig. 14, a). The impurities caught on the grates are crushed in special crushers and returned to the water stream in front of the grates. Grate designs combined with crushers have been developed – grate crushers in which the crushing of trapped waste occurs under water.

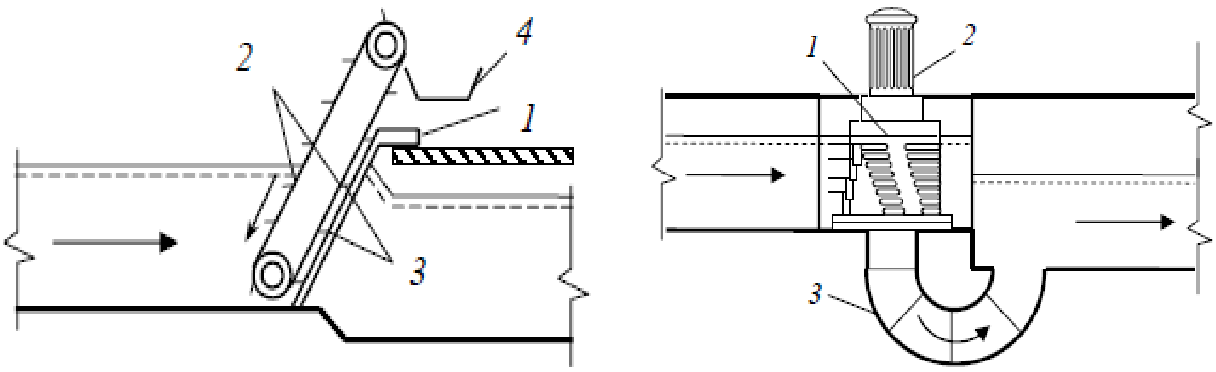

Fig. 14 Grid crushers of RD type: a – grid with mechanical rakes: 1 – grid; 2 - endless chain; 3 – rakes; 4 – conveyor; b – grid crusher RD: 1 - slot drum; 2 – drive mechanism; 3 – outlet ducker

The domestic industry produces grid crushers of the RD brand and round grid crushers of the KRD brand.

Grid crushers of the RD type consist of a rotating slot drum with cutting plates and cutters, a fixed housing with trepole ridges and a drive mechanism (Fig. 14, b). Crushing of waste occurs when the plates and cutters interact with the trepole ridges of the housing.

The type of grates is determined depending on the performance of the treatment plant and the amount of waste removed from the grates. The technological parameters of the grids are accepted according to the requirements of SP 32.13330.2012 and according to the recommendations of equipment suppliers.

If the amount of waste is more than 0.1 m^3 /day, mechanized cleaning of the grates is provided, with a smaller amount of waste – manual. Waste from the grates can be collected in a container and then exported to a landfill, or crushers can be installed to grind the waste. Waste is removed to compost sites every five days. The crushed mass is sent back to the wastewater in front of the grates or for joint processing with sewage treatment plants. At low and medium productivity of the treatment plant, grate crushers are used.

The amount of waste retained on the grids is 16-50 liters per 1,000 m^3 of water, their humidity is 80%, ash content is 7-8%, density is about 750 kg/m^3. The specific amount of retained waste depends on the width of the openings of the grids (Table 3).

For crushing waste extracted from wastewater, hammer crushers are used, which operate when process water is supplied to them (after primary or secondary settling tanks) at the rate of 40 m^3 per 1 ton of waste.

Table 3 Specific amount of delayed waste

The width of the openings, mm	16–20	25–30	40–50	60–80	90–125
Specific amount of waste, l/(year-person)	8	3	2,3	1,6	1,2

In order to increase the degree of impurity retention, two stages of gratings are used – coarse (30-50 mm) and fine (3-10 mm) purification. The longitudinal section of an automatic fine–cleaning grid of a stepped type with openings of 6 mm, - Fig. 15, a. The use of such grids allows to reduce blockages on sand traps and pumps several times, to ensure trouble-free operation of mechanical cleaning facilities. Together with such grids, an automatic complex is usually installed for the mechanical removal and dewatering of solid waste from the grids. For structures of small capacity up to 10,000 m^3/day, fine-grained or screw gratings are recommended (Fig. 15, b).

Gratings with mechanized cleaning have the brands MG (mechanical rake), RMU (universal mechanized gratings), RMN (inclined mechanized gratings), RDG (hydraulic arc grating), RSF (stepped mechanical grating), RS (stepped mechanical grating of the company "MEVA" (MEVA). The option of placing mechanized grids in the building is Fig. 16.

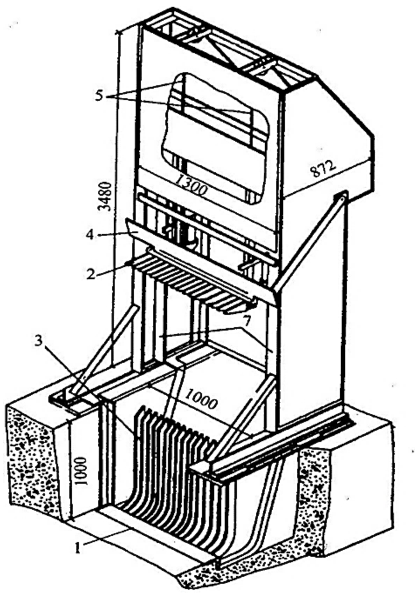

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Fig. 15 The option of placing mechanized grids in the building: a – grid with openings of 6 mm (longitudinal section): 1 – supply channel; 2 – rake; 3– grid rods; 4 – dumper; 5 – rope; b – screw grid design

Fig. 16 The option of placing mechanized grids in the building: a – grid with openings of 6 mm (longitudinal section): 1 – supply channel; 2 – rake; 3– grid rods; 4 – dumper; 5 – rope; b – screw grid design

For sewage treatment plants with a capacity of more than 10,000 m^3/day, rake and multistage grids produced by domestic and foreign companies are used. Rake grates are designed to remove large (more than 8 mm) waste from urban wastewater. The rake grate is a filter cloth assembled from rods inserted into the frame. Shaped rolled rods have a cross-section shape close to a teardrop, which improves the hydraulic characteristics of the filter cloth. Also, the filter cloth of the grid can be assembled from rods with a rectangular cross-section shape. The gap between the rods of the filter cloth can be set from 5 to 70 mm.

In screw (drum) grids, a combination of separation, flushing and pressing of waste occurs in one module (Fig. 17).

The principle of operation is based on filtering wastewater through the lower separating part of the grid located inside the channel or container. Separation can be performed from a perforated plate or grate, which has the shape of a tray, where a small diameter spiral is located, transporting the screening upward, separating it from water. The spiral is equipped with a brush of internal filter holes to prevent clogging. From the sifting tray, the module is transformed into an auger, which is included in a fully enclosed stainless steel housing. In the screw, the screening is washed and transported to unloading. Water for flushing organic matter is supplied in the opposite direction to the movement of the spiral. Before unloading, the screening is squeezed out to a humidity of 55% and crushed into small parts. A large amount of organic matter is formed in the pressing area, which is effectively washed off with spray nozzles, which requires minimal maintenance of the screw grate.

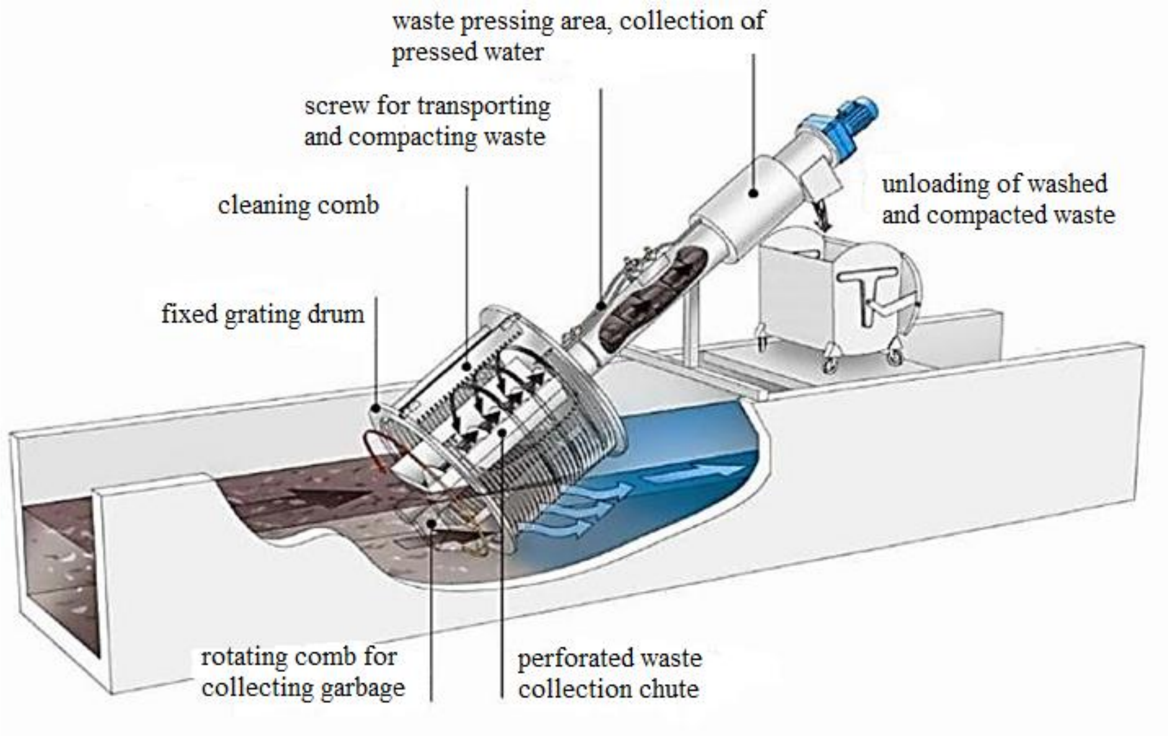


Fig. 17 Huber Rotaman drum grilles (HUBER ROTAMAT)

A number of companies produce not only a wide range of basic sizes of rake and step grids, different in technical characteristics and performance, but also manufacture equipment in accordance with the customer's technical specifications.

Given the complex profile design of the grating webs, when choosing them, it is necessary to focus on the parameters of equipment suppliers. The standard range of manufactured grids is quite wide – in terms of productivity from 5 to 10,000 m^3/h.

Devices for the separation of insoluble impurities from wastewater under the influence of gravitational forces

Sand traps

Sand traps are provided at stations with a capacity of more than 100 m^3/day. As a rule, they are placed after the grids. The choice of the type of sand traps depends on the specific local conditions, plant performance, wastewater treatment scheme and precipitation treatment.

For stations with a capacity of up to 10 thousand m^3/day, it is recommended to use tangential and vertical sand traps, for stations with a capacity of over 10 thousand m^3/ day – horizontal, and over 20 thousand m^3/day – aerated.

Horizontal sand traps can be with rectilinear or circular movement of water. For approximate calculations, the depth of the sand trap H = 0.25–1 m is taken, the ratio of width and depth In / H = 1:2.

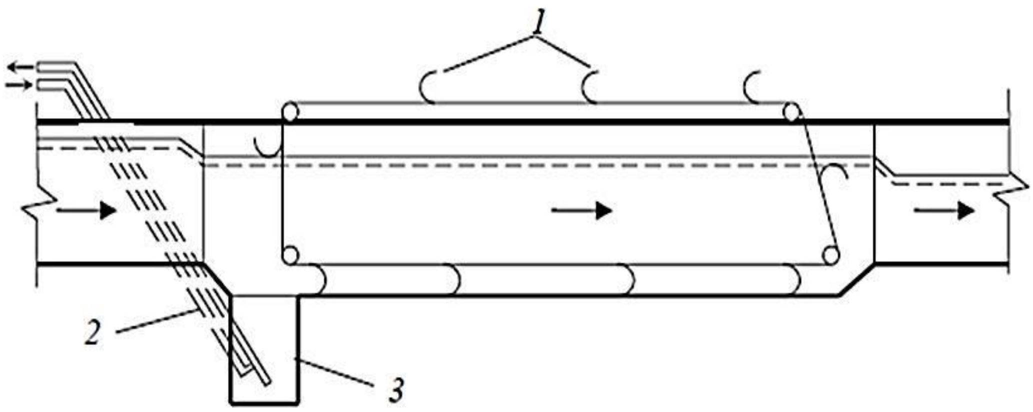


Fig. 18 Horizontal sand trap with rectilinear movement of water: 1 – chain scraper mechanism; 2 – hydraulic elevator; 3 – hopper

A general view of a horizontal sand trap with a mobile sand scraper "ConClar" is shown in Fig. 19.

Fig. 19 General view of a horizontal sand trap with a mobile sand scraper "ConClar" (ConClar)

A sand trap with a circular movement of water is a round conical tank with a peripheral tray for the flow of wastewater (Fig. 20). The captured sediment falls through the gap into the sedimentary part. Hydraulic elevators are used to unload sediment. Such sand traps are used to remove sand particles larger than 0.2–0.25 mm, they are recommended for station capacity up to 100 thousand m^3/day.

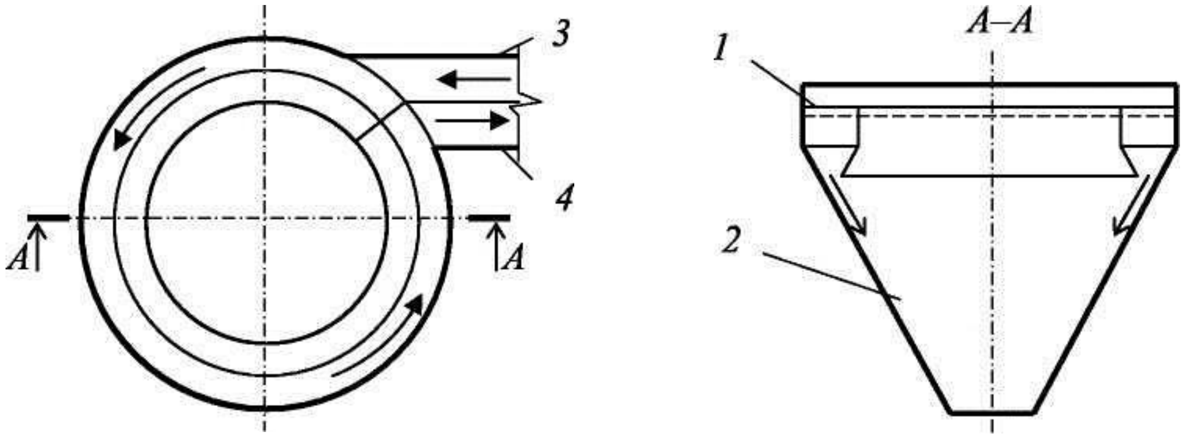


Fig. 20 Diagram of a horizontal sand trap with a circular movement of water: 1 – an annular trough; 2 – a sedimentary cone; 3 – an inlet channel; 4 – an outlet channel

As a rule, it is envisaged to install 2-4 sand traps with common water distribution chambers. The advantage of this type of sand traps is the absence of devices for collecting sand, since the latter settles and accumulates in the conical part of the sand trap. Speeds of 0.15–0.30 m/s are maintained in the annular trays of the sand traps; the duration of water stay in the tray is at least 30 seconds.

The optimal speed of water movement in horizontal sand traps is 0.15–0.3 m/s, the hydraulic size of the retained sand is u = 18-24 mm/s.

Vertical sand traps (Fig. 21) are used in semi-separate sewerage systems and at surface water treatment plants, since they are convenient for the accumulation of large amounts of sediment. The maximum wastewater consumption for vertical sand traps is 10 thousand m^3/day. The sand traps have a cylindrical shape with a water supply tangentially on both sides, and a discharge by an annular tray. The disadvantage of these sand traps is the long duration of water stay in the structure.

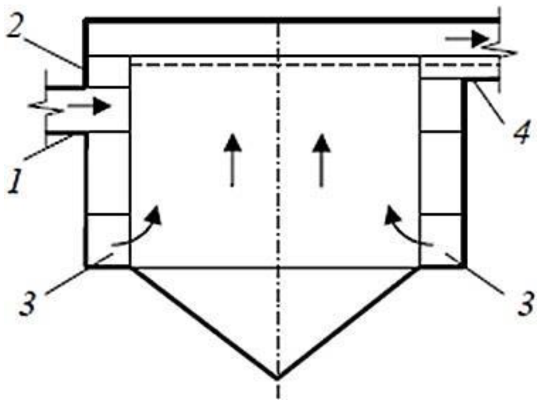


Fig. 21 Vertical sand trap with rotational movement: 1 – inlet channel; 2 – collecting ring tray; 3 – water inlet into the working area; 4 – outlet channel

Tangential sand traps (fig. 22-23) have a diameter of no more than 6 m. Water is supplied to them tangentially. The depth of the sand trap is assumed to be equal to half the diameter. The flowing part of the sand trap has a shallow depth. At a water flow rate of 0.6–0.8 m/s in the main tray, approximately 90% of the sand is retained in the sand trap. The deposited sand is removed with an auger, a hydraulic elevator. The sand collector is placed at the beginning of the sand trap and is calculated for a two-day accumulation of sand. The taper of the collector is 55-60°, the bottom width is 0.5 m.

The principle of operation of the sand trap uses gravitational forces to precipitate heavy mineral impurities while slowing down the flow rate of water. Since sand is heavier than water, it tends to fall down.

One of the important points in the design of a sand trap is the calculation of the water flow velocity. It should be such that heavy mineral impurities settle to the bottom during passage through the sand trap, and light organic ones do not have time to do this and are carried away by the stream. In this case, mineral impurities are separated from organic ones.

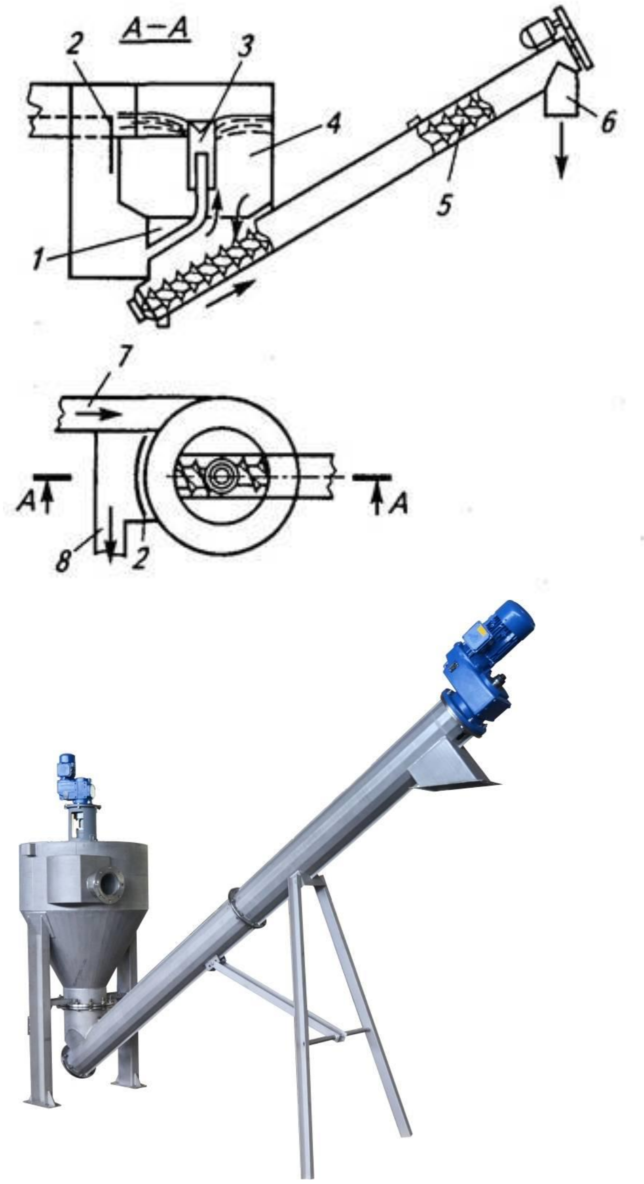


Fig. 22 Tangential sand trap: 1 – sedimentary part; 2 – movable spillway; 3 – telescopic tube; 4– working part; 5 – auger; 6 – sand removal; 7 – feed tray; 8 - discharge tray

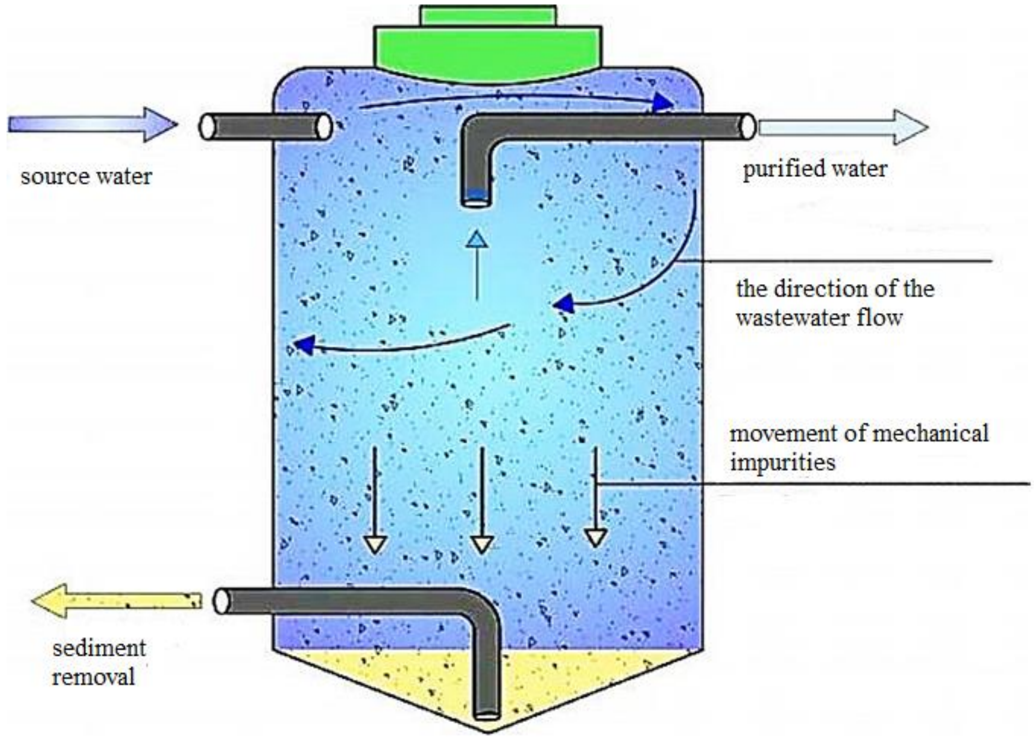


Fig. 23 The principle of operation of the sand trap

According to practice, the best speed for effective operation in sand traps with horizontal water movement is in the range from 0.15 to 3.0 mm/s. If the velocity is closer to the low limit, then a lot of organic impurities have time to fall into the sediment, which is extremely undesirable. Therefore, it is necessary to maintain a speed close to its upper limit, i.e. 3.0 m/s.

However, water consumption does not remain constant during the day, therefore, its flow rate sometimes decreases, organic inclusions manage to precipitate along with sand. To solve this problem, sand traps are made of several working compartments, and the automatic closing and opening of one of them regulates the speed of water movement.

Horizontal aerated sand traps (Fig. 24) are used to remove sand with a grain size of more than 0.15–0.20 mm from wastewater, they are recommended for station productivity of more than 15-20 thousand m^3/day and especially with a significant content of fatty substances, petroleum products and surfactants in urban runoff. Sand traps are designed as a block consisting of at least two independent departments (all workers). As a rule, sand traps are equipped with a hydromechanical sand collection system; sand is removed from the sand traps at least two days later by a hydraulic elevator. In sand traps, the speed of movement is no more than 0.08–0.12 m/s.

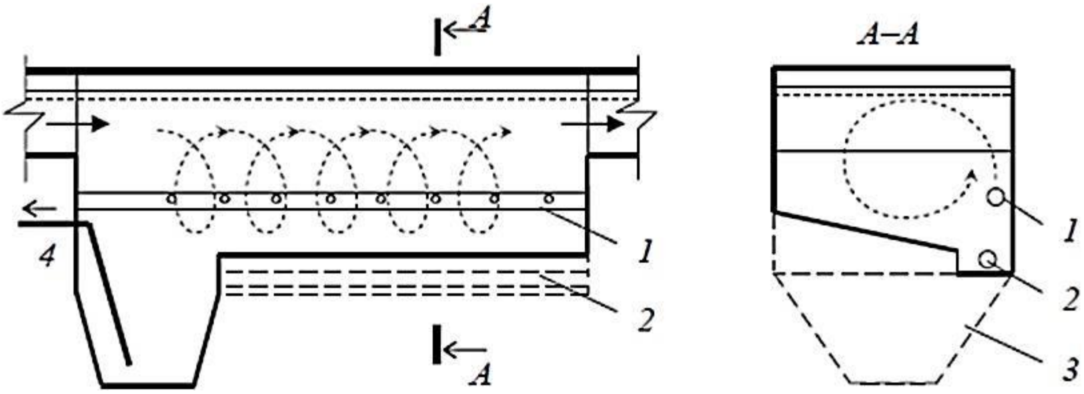


Fig. 24 Aerated sand trap: 1 – hole aerator; 2 – sludge hydraulic washing pipeline; 3 – sedimentary part; 4 – hydraulic elevator

When designing aerated sand traps, they accept: the installation of an aerator made of perforated pipes to a depth of 0.7 N along one of the longitudinal walls above the sand collection tray; the aeration intensity is 3-5 m3/ m2h; the transverse slope of the bottom to the sand tray is 0.2–0.4; the water inlet coincides with the direction of rotation of the water in the sand trap, the outlet is flooded; the ratio of width to the depth of the compartment In:H = 1:1; 1:1.5.

Sand is removed from sand traps with a large volume of water and therefore needs to be dehydrated. For this purpose, bunkers, sand platforms or sand storage facilities are arranged.

Table 4 - Parameters of different types of sand traps

Sand catcher	Hydraulic sand size, mm/s	The speed of wastewater movement v_s, м/с, at the inflow		Depth N, m	The amount of retained sand, l/person.day	The humidity of the sand, %	The content of sand in the sediment, %
		the minimum	the maximum				
Horizontal	18,7–24,2	0,15	0,3	0,5–2	0,02	60	55–60
Aerated	13,2–18,7	–	0,08–0,12	0,7–3,5	0,03	–	90–95
Tangential	18,7–24,2	–	–	0,5	0,02	60	70–75

Settling tanks

The sump is the main facility for mechanical wastewater treatment, used to remove settling or floating coarse substances. There are primary settling tanks, which are installed in front of biological or physico-chemical treatment facilities, and secondary settling tanks for the separation of activated sludge or biofilm. Depending on the direction of movement of the water flow, the settling tanks are divided into horizontal, vertical and radial. Sedimentation tanks also include clarifiers, in which, simultaneously with sedimentation, wastewater is filtered through a layer of suspended sediment, as well as clarifiers-rotters and two-tier sedimentation tanks, where, simultaneously with the clarification of water, the precipitate is compacted.

The choice of the type and design of settling tanks depends on the amount and composition of industrial wastewater entering the treatment, the characteristics of the resulting sediment (compactness, transportability). In each specific case, the choice of the type of settling tanks should be determined as a result of a technical and economic comparison of several options. The number of settling tanks should be taken at least two, but also no more than four, following the path of increasing the dimensions of the settling tanks, since the cost per unit volume of large-sized settling tanks is less than small-sized ones.

Horizontal settling tanks are used as part of treatment plants for domestic and industrial wastewater close to them in composition and are designed to separate suspended solids from waters that have passed grates and sand traps. Horizontal settling tanks are usually used at medium and high-capacity stations (15 thousand m^3/day or more). The cleaning effect in them averages 50-60%. The depth of the settling tanks H reaches 1.5–4 m, the ratio of length to depth is 8-12 (up to 20). The width of the sump depends on the method of sediment removal and is usually within 6-9 m.

Settling tanks equipped with trolley-type or belt-type scraper mechanisms (Fig. 25) are also used, shifting the precipitated sediment into the pit. The volume of the pit is equal to two days (no more) the amount of precipitation. Sediments are removed from the pit by pumps, hydraulic elevators, grapples or under hydrostatic pressure. The angle of inclination of the pit walls is assumed to be 50-60 °.

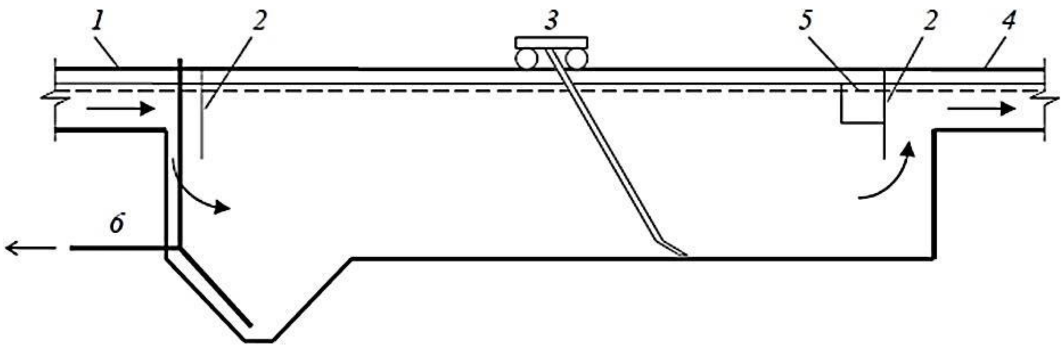


Fig. 25 Diagram of a horizontal sump: 1 – inlet tray; 2 – semi–submersible board; 3 scraper trolley; 4 – discharge tray; 5 – grease collecting tray; 6 - sediment removal

Vertical primary settling tanks (fig. 26) are designed to clarify domestic and industrial wastewater (as well as mixtures thereof) containing coarse impurities. They are used at stations with a capacity of up to 20 thousand m^3/day. These are round tanks with a diameter of 4-9 m with a conical bottom. The effect of water clarification in vertical settling tanks is 40-50%.

Radial settling tanks are used for wastewater consumption of more than 20 thousand m^3/day. Compared with horizontal ones, they have some advantages: simplicity and reliability of operation, cost-effectiveness, the possibility of building high-performance structures. The disadvantage is the presence of a movable farm with scrapers. Radial settling tanks of three design modifications are known – with a central inlet, with a peripheral inlet and with rotating prefabricated distribution devices. Settling tanks with a central liquid inlet have become the most widespread (Fig. 27).

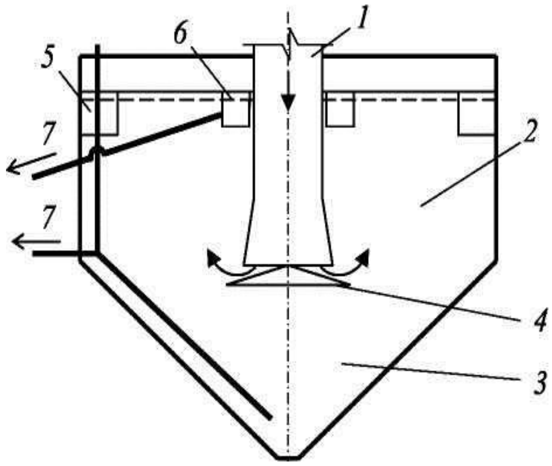


Fig. 26 Vertical sump with central wastewater inlet: 1 – central pipe; 2 – sedimentation zone; 3 – sedimentary part; 4 – reflective shield; 5 – peripheral collecting tray; 6 – annular tray; 7 – sediment removal

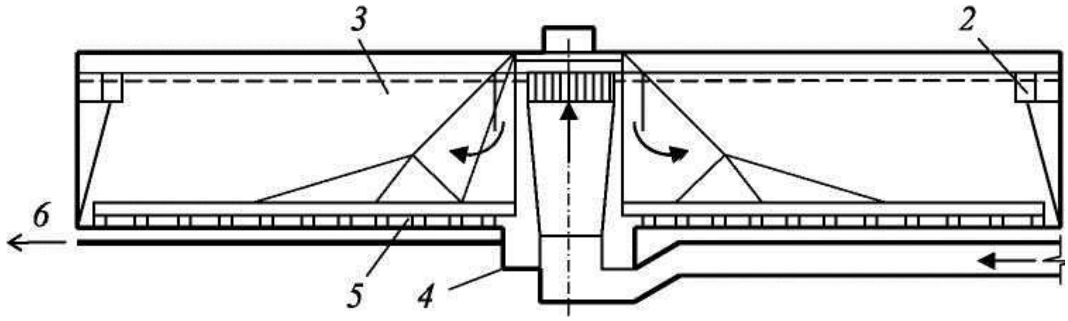


Fig. 27 Diagram of the radial primary sump: 1 – sewage supply; 2 – collecting tray; 3 – settling zone; 4 – silt pit; 5 – scraper mechanism; 6 – sediment removal

Primary radial settling tanks are equipped with mud scrapers that shift the precipitated sediment to the pit located in the center. The sediment is removed from the pit by a pump or under the action of hydraulic pressure. The diameter of the settling tanks is assumed to be at least 18 m; the ratio of the diameter to the depth of the flowing part is 6-30; the depth of the flowing part is 15-5 m; the height of the neutral layer is 0.3 m

To increase the efficiency of settling, thin–layer settling tanks are used. They can be horizontal, vertical, radial; they consist of water distribution, drainage and settling zones. The settling zone in them is divided by tubular or lamellar elements into a number of layers of shallow depth (up to 150 mm). At a shallow depth, settling proceeds quickly, which makes it possible to reduce the size of the settling tanks.

Thin-layer settling tanks are classified:

-according to the design of inclined blocks – for tubular and shelving;

-mode of operation – periodic (cyclic) and continuous operation;

-mutual movement of clarified water and displaced sediment – with direct flow, countercurrent and mixed (combined) movement.

The cross section of the tubular sections can be rectangular, square, hexagonal or round. Shelf sections are mounted from flat or corrugated sheets and have a rectangular cross section. The elements of the sump are made of steel, aluminum and plastic (polypropylene, polyethylene, fiberglass).

The slope of the blocks in the sedimentation tanks of periodic (cyclic) action is small. The accumulated sediment is removed by flushing with a reverse current of clarified water. The slope of the elements in the continuous settling tanks is 45-60°. The efficiency of tubular and shelf settling tanks is almost the same.

There are three schemes for the arrangement of modules in the sump (Fig. 28). In the case of a cross-flow scheme, the separated sediment moves perpendicular to the movement of wastewater, and in the case of direct-flow and counter-flow, respectively, along the flow of wastewater or in the opposite direction.

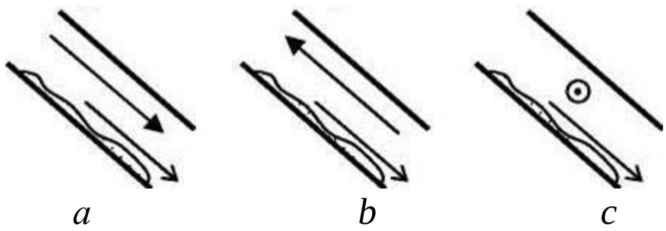


Fig. 28 Diagrams of the movement of water in a thin layer: a – straight-flow; b – countercurrent; c – cross (arrows show the movement of water and the movement of sediment)

Thin-layer sedimentation is used when it is necessary to reduce the volume of treatment facilities with a constant clarification effect, or, conversely, if it is necessary to increase the efficiency of existing settling tanks. In the first case, thin–layer settling tanks are independent structures, in the second case, existing settling tanks are complemented by thin-layer modules located in a modified settling tank.

Thin-layer blocks can be built into horizontal, vertical or radial settling tanks. The angle of inclination of the block plates is 45-60°, the height of the tier is 2.5–20 cm. The plates are made mainly of plastic. A horizontal sump with thin-layer blocks, a thin-layer sump with a cross-flow operation scheme, a thin-layer sump with a countercurrent scheme, a radial sump with thin-layer modules, a vertical sump with thin-layer modules and thin-layer modules are shown in Fig. 29-30.

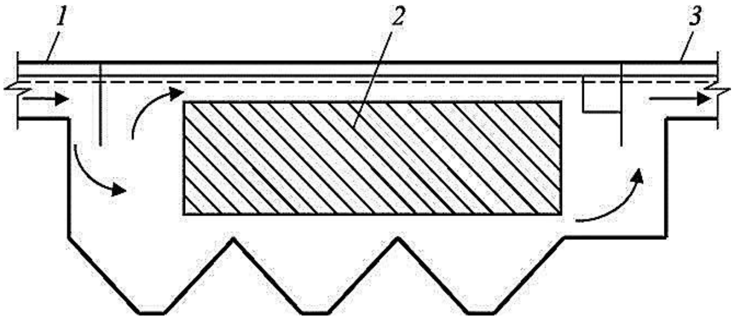


Fig. 29 Horizontal sump with thin–layer blocks: 1 – sewage supply; 2 – thin-layer block; 3 - clarified water drainage

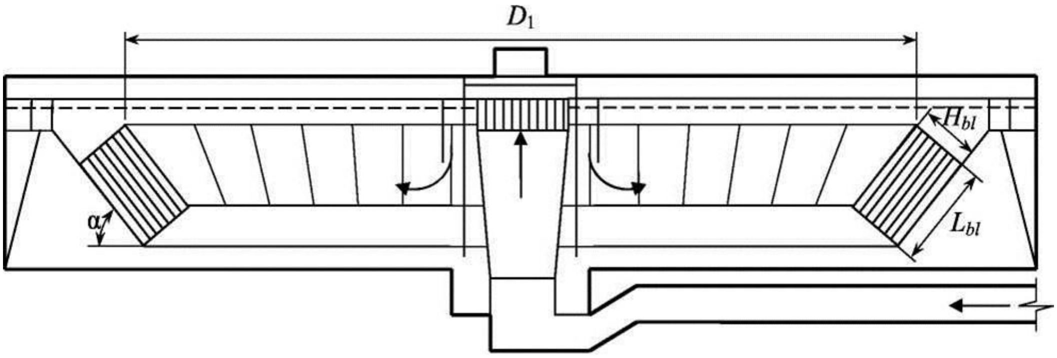


Fig. 30 Radial sump with thin-layer modules

Oil traps

Types of oil traps. For the treatment of industrial wastewater containing floating coarse dispersed impurities (oil, light resins, oils) at concentrations above 100 mg/l, specialized settling facilities called oil traps, resin traps, oil traps are used. Product traps are used for the same purpose to settle certain specific substances from the water, for example, paraffin from the effluents of the production of synthetic fatty acids, as well as to precipitate solid mechanical impurities.

Oil traps are rectangular elongated reservoirs in which oil and water are separated due to the difference in their densities. Oil and petroleum products float to the surface, and the mineral impurities contained in the wastewater settle to the bottom of the structure. The release of floating impurities from wastewater is essentially similar to the deposition of suspended solids; the only difference is that the particle density in this case is less than the density of wastewater and the particle floats instead of precipitation.

Oil traps are constructed of three constructive types:

-horizontal,

-multi-tiered (thin-layered),

-radial.

The horizontal oil trap (fig. 31) is a sump divided by longitudinal walls into parallel sections. Wastewater from a separately located distribution chamber flows through independent pipelines through a slit partition into each section. The oil-free water at the end of the section passes under the flooded wall and flows through the spillway into the discharge pipeline. The surfaced oil is driven by a scraper mechanism to the slotted rotary pipes and is removed from the section through them. The sediment falling to the bottom is raked by the same conveyor to the pit, from where it is periodically removed by hydraulic elevators through the sludge pipeline. The residual content of petroleum products in the wastewater after the oil trap is 100 mg/l.

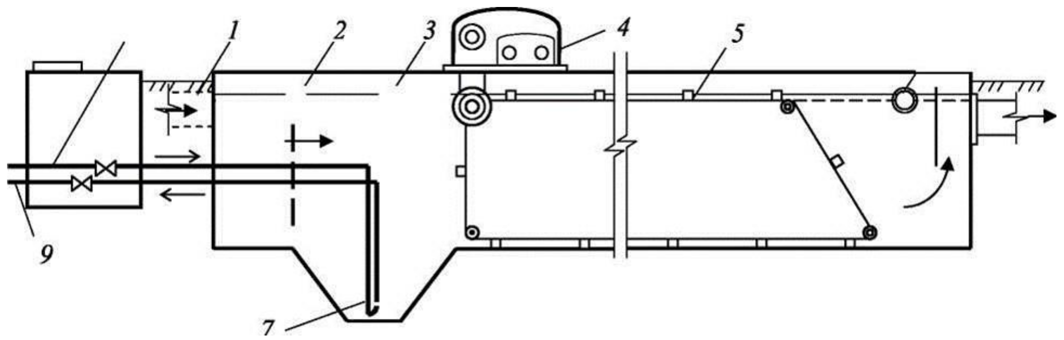


Fig. 31 Horizontal oil trap: 1 – supply pipe; 2 – slit distribution partition; 3 – oil collecting pipe; 4 – scraper movement mechanism; 5 – scraper conveyor; 6 – clarified water drainage pipeline; 7 – hydraulic elevator; 8 – water supply to the hydraulic elevator; 9 -sediment removal

The estimated duration of settling should be at least 2 hours, the speed of water movement is assumed to be 3-10 mm/s.

The multi-tiered (thin-layer) oil trap is an improved design of a horizontal trap, has smaller dimensions, and is more economical. Let's consider the scheme of operation of a multi-tiered oil trap, Fig. 32.

Wastewater from a separately located distribution chamber flows through pipelines into the sections of the oil trap and through a transverse horizontal distribution pipe with vertical nozzles and diffusers is distributed over the width and depth of the rough cleaning zone. Here, the main amount of coarse dispersed oil and sediment is released within 1-4 minutes.

The flow then passes through a proportional water distribution device and enters the shelf unit. The block works in a cross-sectional pattern. The flow of clarified water passes under a semi-submersible partition and is discharged through a spillway and a drainage tray.

Oil products that have surfaced in the rough cleaning zone are constantly discharged through a slotted rotary pipe, scrapers are constantly driven over thin-layer blocks in the direction of flow towards the end of the settling zone and periodically removed from the structure through a second rotary pipe. The sediment is removed using a hydraulic elevator.

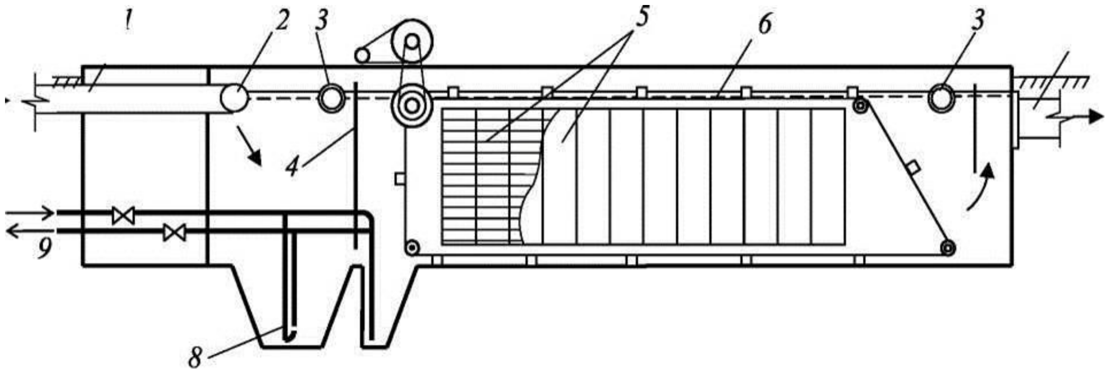


Fig. 32 Multi–tier oil trap: 1 – supply pipe; 2 – water distribution pipe; 3 –oil collecting pipe; 4 – proportional water distribution device; 5 – thin–layer module; 6 – scraper conveyor; 7 – clarified water drainage pipeline; 8 - hydraulic elevator; 9 - sediment drainage

Devices for the separation of insoluble impurities from wastewater under the action of centrifugal forces

Open and pressure hydrocyclones

The device and the principle of operation of hydrocyclones. Hydrocyclones and centrifuges use the principle of precipitation in the field of centrifugal accelerations, which significantly reduces the volume and increases the hydraulic load compared to settling facilities.

Hydrocyclones are devices for clarification of industrial wastewater (for separation of suspensions), fig. 33. The principle of operation of a hydrocyclone is based on the deposition of solid particles under the action of centrifugal forces in a rotating liquid flow. Centrifugal forces are about a hundred times higher than gravity (gravitational).

The main advantages of hydrocyclones include:

-high productivity and high quality of separation processes;

-compactness and simplicity of the device;

-relatively low costs for the construction and operation of installations;

-the absence of rotating mechanisms designed to generate centrifugal force (the centrifugal field is created due to the tangential supply of wastewater).

Hydrocyclones are divided into two main types:

-open,

-pressure.

The rotational motion in the working area of the hydrocyclones is created by the tangential supply of water to the cylindrical body. Sediment accumulates in the conical (lower) part of the hydrocyclones, which is deposited as a result of agglomeration of suspended particles.

Open hydrocyclones are used to isolate from wastewater both sedimentary, mainly heavy and coarse impurities (mainly of mineral origin) with a hydraulic size of more than 20 mm/s, such as sand, coal, scale, ceramic components, glass, building materials, etc., and floating impurities. They can also be used to isolate coagulated suspended solids.

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

To reduce the loss of water with the sediment being removed, the slurry nozzle of the first-stage hydrocyclone is hermetically connected to the slurry tank. At the first stage, large hydrocyclones are used to detain the bulk of suspended solids and large particles of suspension, which can clog the small hydrocyclones used at subsequent stages of the installation.

Open hydrocyclones are divided into five types:

-without internal devices (inserts);

-with a conical diaphragm;

-with a conical diaphragm and an inner cylinder (partition);

-multi-tiered with a central release;

-multi-tiered with peripheral water drainage.

Multi-tiered hydrocyclones are used to intensify the cleaning process. In them, the working volume is divided into separate tiers by freely inserted conical diaphragms. As a result, the height of the settling layer decreases. The rotational motion allows for a fuller use of the volume of the tier and promotes agglomeration of suspended particles. Each tier of the hydrocyclone works independently.

The design of a multi-tiered hydrocyclone combines the principles of operation of an open hydrocyclone and a thin-layer sump, which allows for high cleaning efficiency at specific hydraulic loads of 8-10 times or more exceeding the loads on conventional sump tanks.

The sediment from the conical part of the hydrocyclones is pumped out by pumps, hydraulic elevators or removed under hydrostatic pressure.

Pressure hydrocyclones (fig. 34, a) should be used to isolate coarse impurities from wastewater, mainly of mineral origin. For example, for wastewater disposal:

-sand, clay and other mineral components (glass factories and car farms);

-components of the molding earth (foundry);

-fat and solid phase of mineral and organic origin (meat processing plants);

-petroleum products and sludge (oil fields);

-particles of mineral origin (pig-breeding industrial complexes).

Depending on the specifics of the technological tasks being solved, two-product and multi-product pressure hydrocyclones can be used. In the latter case, the devices have several drain pipelines diverting the target products from various zones of the ascending vortex flow.

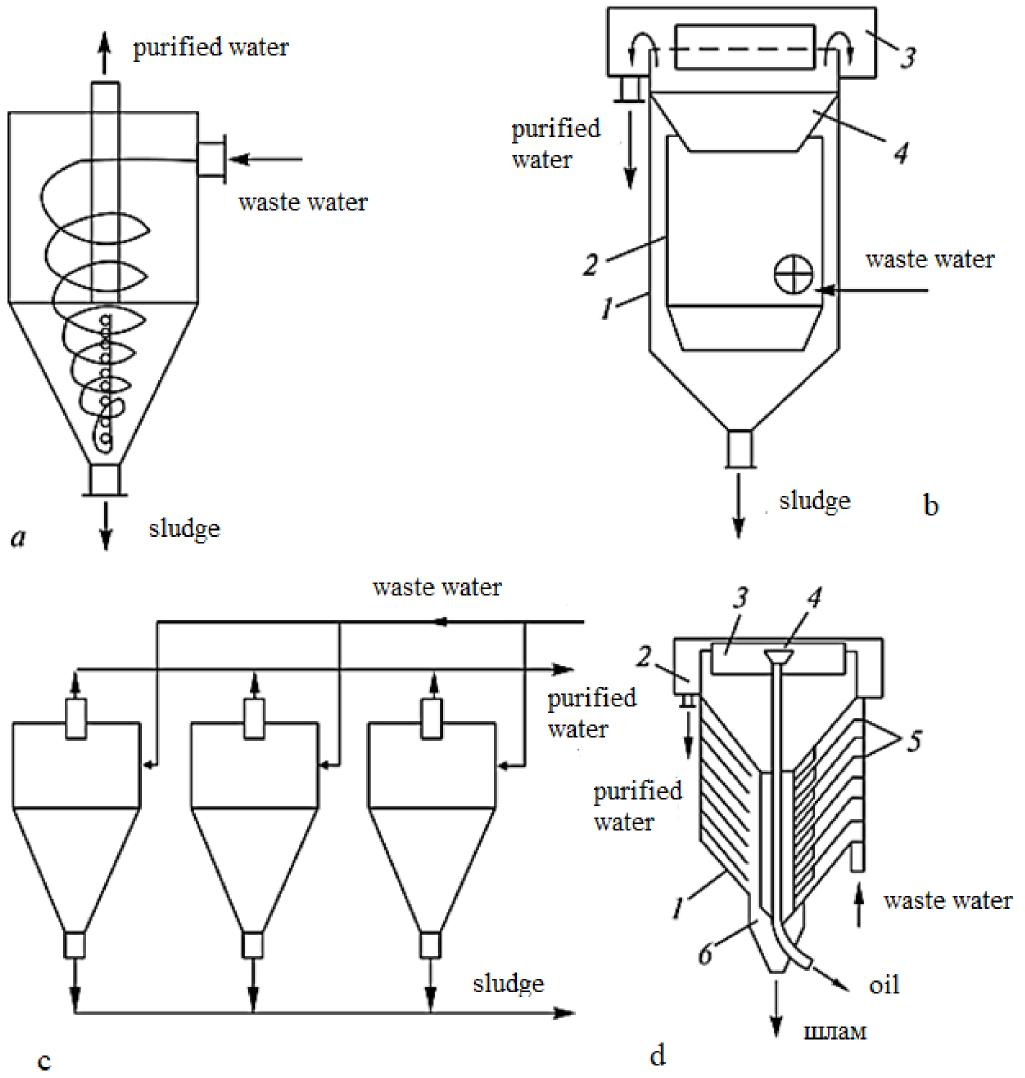
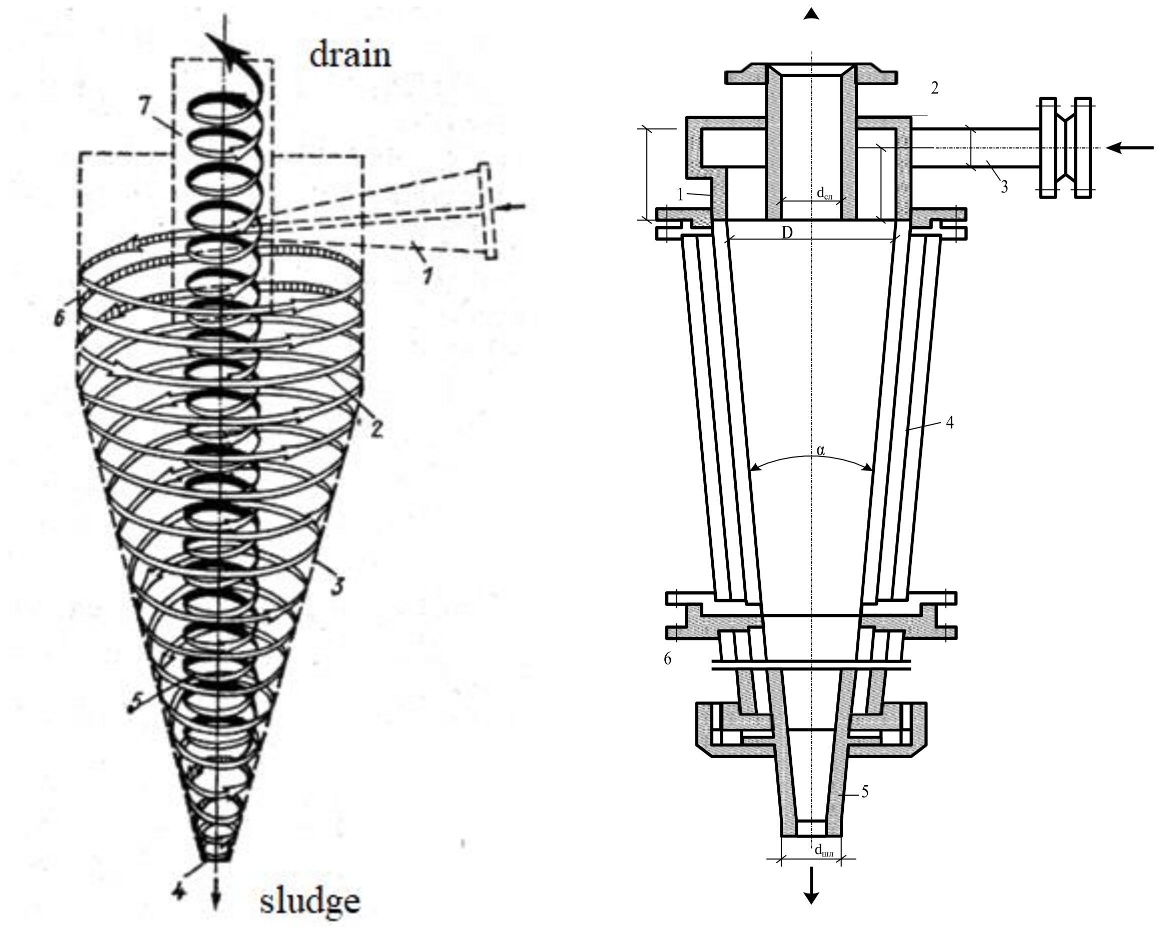


Fig. 33 Hydrocyclones. a – pressure; b – with an inner cylinder and a conical diaphragm: 7 – body; 2 – inner cylinder; 3 – annular tray; 4 – diaphragm; c – block of pressure hydrocyclones; d – multi–tiered hydrocyclone with inclined nozzles for the discharge of purified water: 7 - conical diaphragms; 2 – tray; 3 – spillway; 4 – oil collecting funnel; 5 – distribution trays; 6 – sludge drain slot



a *b*

Figure 34. Hydrocyclone: a – design of a pressure hydrocyclone with removable elements of the working chamber: 1 – cylindrical part; 2 – drain pipe; 3 – feeding pipe; 4 – housing; 5 – slurry pipe; 6 – removable insert; b – schematic diagram of the movement of water in a pressure hydrocyclone: 1 – feeding pipe; 2, 5 – respectively descending and ascending streams; 3, 6 – respectively conical and cylindrical parts; 4 – slurry hole; 7 – drain pipe

If deeper wastewater treatment is necessary, the sequential operation of hydrocyclones of various sizes is used. The devices of the first stage remove coarse suspensions from the water, and the devices of the subsequent stages are used to isolate smaller particles.

Pressure hydrocyclones are used to isolate only sedimentary impurities. Wastewater is supplied tangentially through a pipe located in the upper cylindrical part of the tank and acquires rotational motion. The sediment is discharged through the hole, and the clarified water is discharged through the drain pipe.

The movement of water occurs along helical spatial spirals (fig. 34, b). Under the action of centrifugal forces, solid particles are thrown from the center to the periphery, accumulate near the walls, then collect in the lower conical part, slide to the slurry hole, and then are removed. In a pressure hydrocyclone, external and internal spiral streams of water are formed, the direction of rotation of which coincides. The clarified liquid moves in an internal spiral flow from bottom to top to the drain pipe. The pressure determines the circumferential velocity in the hydrocyclone and affects the cleaning effect. These hydrocyclones are produced with diameters of the cylindrical part of 100-500 mm.

For finer cleaning, it is necessary to reduce the diameter of the device, but this leads to a decrease in its performance. Therefore, hydrocyclones of small diameters (25-100 mm) are combined into battery-powered (multihydrocyclones) consisting of a large number of cyclone elements (24-48 pcs.) installed in parallel and having a single power supply system. Such hydrocyclones are used for cleaning from fine impurities. Pressure hydrocyclones can be connected in 2-3 stages and sequentially to improve the cleaning effect (first large diameter devices, and then small ones).

The disadvantages of pressure hydrocyclones include significant power consumption and rapid wear of the device (when working with coarse impurities).

The choice of the type of hydrocyclone in each specific case should be determined by a technical and economic comparison of the options.

The main criteria for judging the operation of a hydrocyclone are productivity, the size of the boundary grain, the degree of purification and water loss through the slurry hole.

The size of the boundary grain is understood as the size of such particles, which, being in equilibrium under the action of centrifugal force and the force of resistance of the liquid, rotate at a certain radius of the hydrocyclone, and then are distributed equally between the separation products. All larger particles enter the slurry nozzle, and smaller particles enter the upper layers.

The efficiency of the hydrocyclone depends on the flow rate and properties of the clarified water, the concentration of suspended particles in the water and their granulometric composition, the density and viscosity of the water, and the geometric dimensions of the hydrocyclone.

Centrifuges are structurally divided into:

-horizontal,

-vertical.

By appointment:

-production,

-laboratory.

According to the principle of operation:

-precipitating,

-brightening.

The method of unloading sludge from centrifuges can be:

-manual,

-screw type,
- throbbing.

There are centrifuges:
- lame,
-filtering.

In wastewater treatment processes, filter centrifuges are used to separate coarse–dispersed systems, settling centrifuges are used to separate difficult-to-filter fine and coarse-dispersed suspensions, as well as to classify suspensions by particle size and density. Settling centrifuges are the most promising for industrial wastewater treatment.

Centrifuges are distinguished:
-continuous,
-periodic.

Continuous centrifuges are used for wastewater treatment with a flow rate of up to 100 m^3/h, when it is necessary to isolate particles with a hydraulic size of 0.2 mm/s (countercurrent) and 0.05 mm/s (direct-flow).

It is advisable to use batch centrifuges when the concentration of insoluble impurities in wastewater is no more than 2-3 g /l and in cases where the resulting sediments are cemented or characterized by high abrasive properties. Batch centrifuges are used for wastewater treatment, the flow rate of which does not exceed 20 m^3/h, if necessary, the separation of particles with a hydraulic size of 0.05–0.01 mm /s.

Of the continuous centrifuges in water treatment systems, horizontal auger centrifuges of the OGSh type have become the most widespread (Fig. 35). The selection of the required standard size of the precipitation centrifuge is carried out according to the catalog.

The principle of operation of a continuously operating horizontal sedimentation centrifuge with auger discharge of sludge of the OGSh brand is as follows. The waste liquid is fed through a pipe into the rotating rotor, while the heaviest sediment particles are pressed to the inner surface of the rotor. The screw and the rotor rotate at different frequencies, as a result of which the deposited solid phase is discharged from the rotor. The fugate (clarified water) flows out through the drain pipe. If the solid phase of wastewater has abrasive properties, the working part of the screw is protected from abrasion by a special coating, for example, cermet.

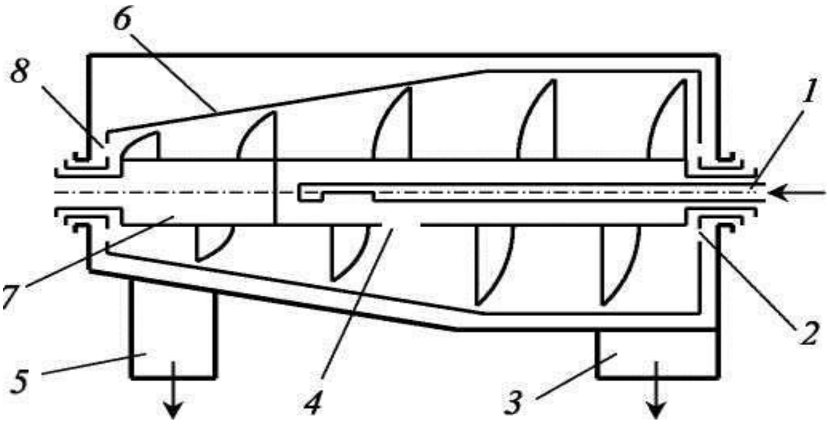


Fig. 35 Diagram of the OGSh centrifuge: 1 – feed pipe; 2 – drain holes; 3 – drain pipe; 4 – sludge hole; 5 – sludge pipe; 6 – rotor; 7 – hollow auger; 8 – windows

The quality of cleaning in centrifuges can be adjusted by changing the hydraulic load, the rotor speed and the diameter of the drain threshold.

Deep wastewater treatment on filters with granular and floating loads

Filtration facilities and installations are used for deep purification (post-treatment) of urban and industrial wastewater that has undergone biological or physico-chemical treatment. They are divided into granular loading filters and mesh drum filters.

Filters with granular loading are classified:

-in the direction of flow (there are cases with descending (from top to bottom) and ascending (from bottom to top) flow, in some cases – with horizontal flow);

-structures (single-layer, double-layer, aerated and bulk frame);

-the type of filter material (natural materials (quartz sand, gravel, granite rubble, blast furnace slag, expanded clay, anthracite, burnt rocks, marble chips) or artificial materials (polymers – polyurethane foam, polystyrene, polypropylene, etc.)).

Mesh drum filters used as independent deep cleaning facilities are called microfilters, and those installed in front of granular deep cleaning filters are called drum nets.

As a result of wastewater aftertreatment, fine suspended particles and activated sludge removed from sedimentation tanks or clarifiers, as well as some specific components characteristic of the effluents of individual industrial enterprises (petroleum products, phosphorus, etc.), are retained in the filter loading.

There are working and forced modes. Forced mode occurs when individual filter sections are turned off for flushing and repair. With the forced mode, the filtering speed increases.

The regeneration of granular filter media is carried out by rinsing with water or water and air, synthetic materials are usually pressed for regeneration. Tap water or water after the drum nets and filters can be used to flush the filters.

Below we will consider the main design types of filters.

Single-layer filters with a downward flow of water are used for post-treatment of industrial wastewater after mechanical treatment to detain fine suspended particles, as well as biologically treated urban wastewater (Fig. 36). The filter is loaded with quartz sand (up to 2 mm in size and a layer thickness of 1.2–1.3 m) with a supporting layer of gravel (with a grain size of 2-40 mm and a layer height of 0.5–0.7 m). In the presence of local granite rubble, the filter can be loaded with rubble of 3-10 mm in size, with a layer thickness of 1.2 m.

For the regeneration of filters, water-air or water flushing with an upward flow is provided. Water-air flushing is performed in four stages: initial loosening of the top layer of the load by mechanical or hydraulic means; air purging to equalize the hydraulic resistance over the entire filter area; water-air joint flushing; additional flushing with water to loosen the load and restore its original porosity. The aftertreatment effect for fine–grained filters for suspended solids is 70-75%, for BPC_P - 50-60%, for coarse-grained (with loading from crushed stone) 45-50% and 35-40%, respectively. The duration of the filter cycle is 12 hours.

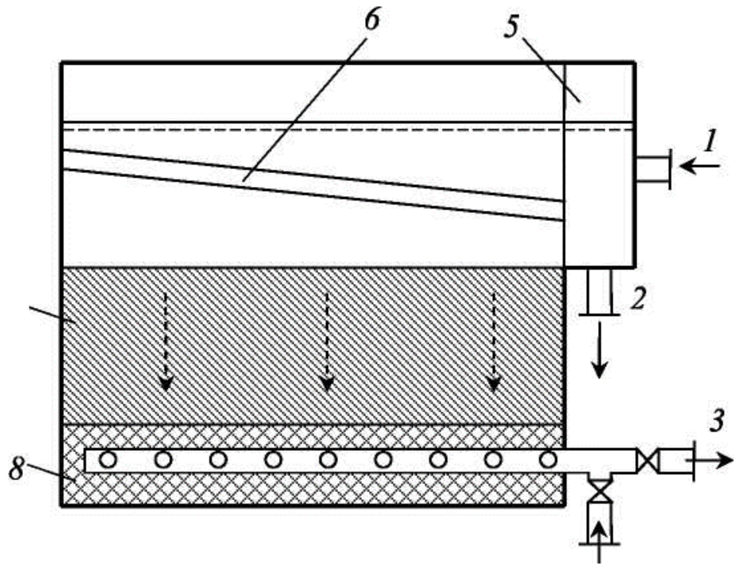


Fig 36 - Granular filter with a downward flow: 1 – water supply; 2 – flushing water outlet; 3 – filtrate outlet; 4 – flushing water supply; 5 – distribution pocket; 6 – chute for supplying source water; 7 – sand loading; 8 - supporting layer

In upstream filters, filtering water from the bottom to the top significantly improves the working conditions of the filter due to the implementation of the principle of decreasing grain size along the stream (Fig. 37). As a result, the dirt capacity of the filter increases, the duration of the filter cycle, and siltation of fine-grained layers is eliminated. The disadvantage of upstream filters is siltation of the drainage, which leads to unreliability of their operation and complications in operation. The filter loading consists of river sand with a grain size of 1.2–2 mm and a layer height of 1.5–2 m, as well as an underlying layer of gravel up to 0.95 m thick. Air-water flushing is provided for the regeneration of filters. The aftertreatment effect for such filters for suspended solids is 70-85%, for BPC_P – 50-65%.

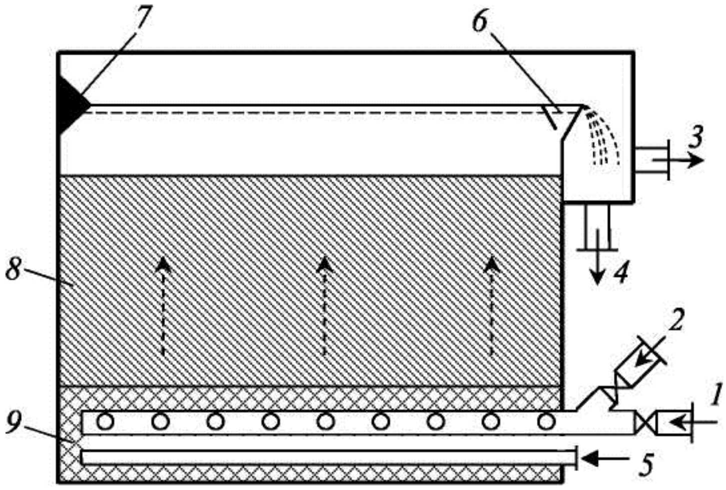


Fig. 37 Filter with an upward flow of water: 1 – water supply; 2 – flushing water supply; 3 – filtrate outlet; 4 – flushing water outlet; 5 – air supply; 6 – sand collecting chute; 7 – directional projection; 8 – loading; 9 – supporting layer

Double-layer filters use the principle of filtering in the direction of decreasing grain size from top to bottom. The upper loading layer with a thickness of 0.4–0.5 m consists of quartz sand with a grain size of 1.2–2 mm, the lower layer (quartz sand) has a thickness of 0.6– 0.7 m and a grain size of 0.7–1.6 mm. In addition to quartz sand, crushed anthracite or expanded clay can be used in the upper layers. The supporting layer with a height of 0.55–0.8 m consists of gravel with a grain size of 2–400 mm (fig. 38).

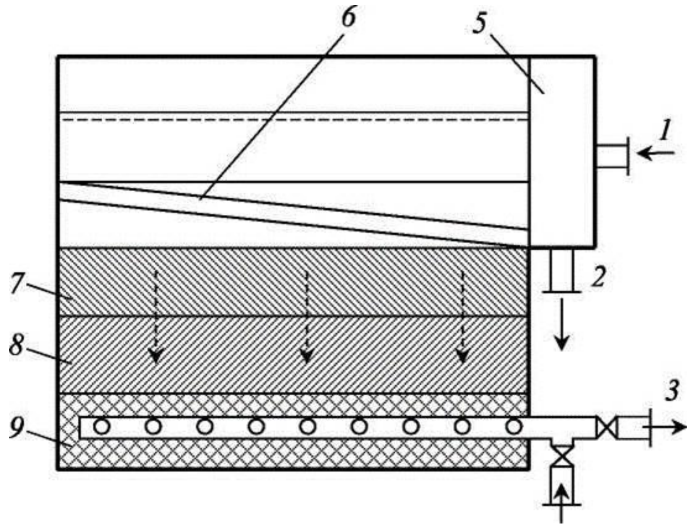
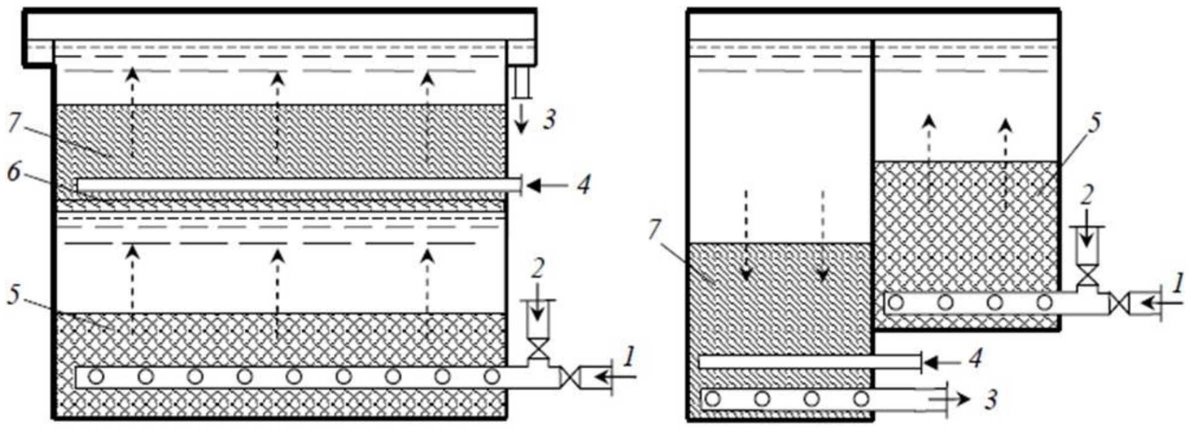


Fig. 38 Two-layer filter: 1 - feed of source water; 2– discharge of washing water; 3 – discharge of filtrate; 4 – supply of washing water; 5 – distribution pocket; 6 – chute for supply of source water; 7 - loading from anthracite; 8 – loading from sand; 9 – supporting layer

The two-layer loading ensures a more uniform distribution of impurities along the filter height, increasing the duration of operation. The filter cycle is 24 hours. The filters are flushed with a current of water from the bottom up. The disadvantages of such filters include the difficulty of creating a two-layer loading, an overestimated filter volume, and the possibility of carrying away grains of the upper loading layer. The aftertreatment effect for such filters for suspended solids is 70-80%, for BPCp – 60-70%.

In an aerated granular filter, compressed air or oxygen is introduced and distributed in the loading column during the filtration process, which contributes to the intensification of the biochemical process inside the filter. The process of cleaning from contamination in aerated filters takes place in two stages, the first is used to remove suspended solids, the second for dissolved and colloidal organic pollutants (Fig. 39).

Frame–backfill filters by design are a two-layer filter with a downward flow of water (Fig. 40). The loading of the frame-filling filter consists of a frame, which uses gravel or crushed stone with a fraction size of 40-60 mm, and a filling consisting of quartz sand with a grain size of 0.8–1 mm. The purified water passes first through the frame layer, where it is cleaned of the bulk of impurities, and then enters the lower layers for post-treatment.



a *б*

Fig. 39 Aerated filters: a – two–tier, b - two-stage: 1 – supply of source water; 2 – supply of rinsing water; 3 – removal of filtrate and rinsing water; 4 – air supply; 5 – loading of the first tier (steps); 6 – perforated partition; 7 – loading of the second tier (steps)

The advantages of the frame-fill filter are: stability of water purification with significant fluctuations in the quality and quantity of source water; the possibility of using contact coagulation, which allows at the same filtration rate to achieve concentrations of suspended solids 3 mg/l and petroleum products 1-1.5 mg/l. The duration of the filter cycle is 20 hours. The filter flushing can be water-air or water. During water-air rinsing, the water in the filter is lowered to the sand level, air and water are supplied for rinsing, followed by additional rinsing with water. The aftertreatment effect for such filters for suspended solids is 70-80%, for BPCp – 70%.

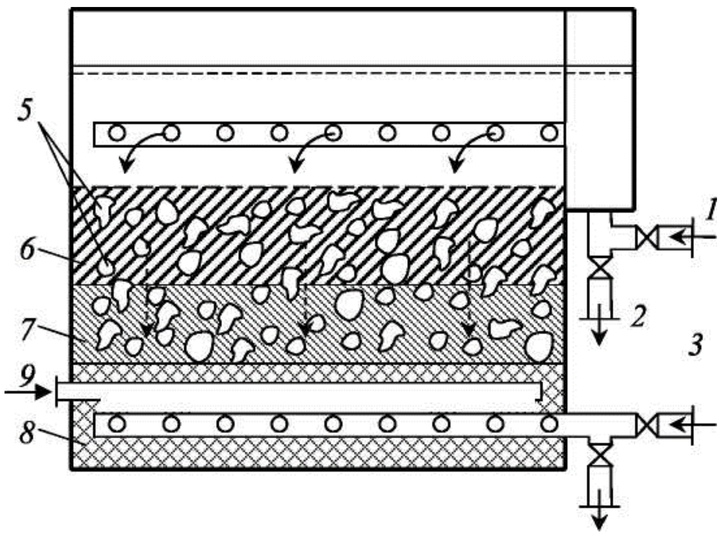


Fig. 40 Frame-filling filter: 1 – water supply; 2 – flushing water outlet; 3 – flushing water supply; 4 – filtrate outlet; 5 – gravel frame; 6 and 7 – coarse and fine-grained loading; 8 – supporting layer; 9 – air supply

One of the ways to intensify wastewater filtration is the use of new filtering materials. The use of filters with floating loading made of various polymeric materials with sufficient mechanical strength, chemical resistance, high active free surface area and porosity is promising.

The advantages of polymer filters are: high dirt capacity, which is 40-200 kg/m^3 of loading; small pressure losses; extended duration of the filter cycle; simplicity of design, reliability of operation.

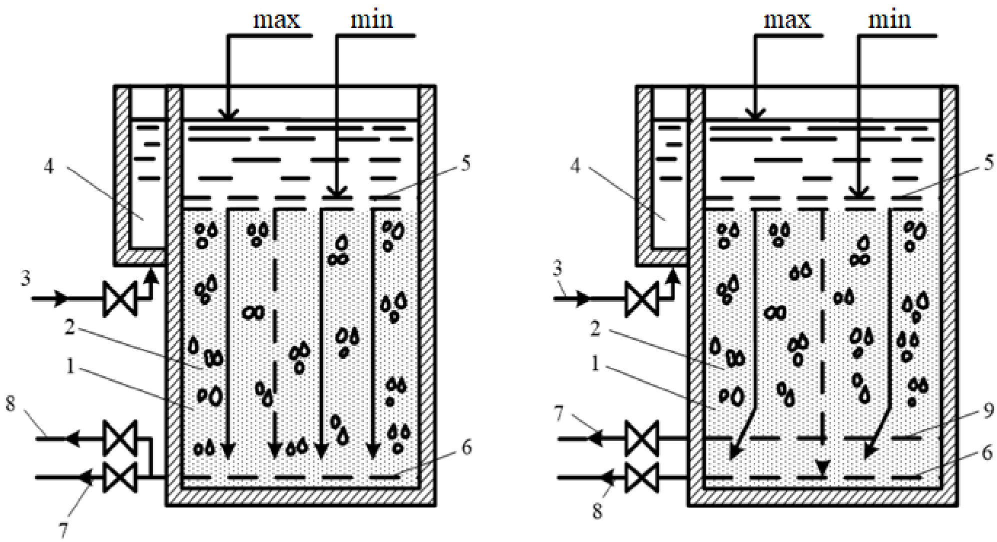
Polymer materials include polystyrene of various grades (including expanded polystyrene), polyurethane foam, as well as expanded clay granules, boiler and metallurgical slags. Polymer materials with porosity up to 95% can significantly increase the filtration rate, reduce the duration of the filter cycle and reduce cleaning costs.

Filters with floating polystyrene foam loading are used for wastewater treatment from suspended solids. Foamed polystyrene granules are used as a floating filter loading in them. This material is wear–resistant, waterproof, non-toxic, has sufficient mechanical strength and high adhesive ability (density 0.01-0.03 g/cm^3).

Inside the filter there are two layers of granules separated by retaining grids. In the lower layer, which serves for pre–filtration, granules with a diameter of 2-5 mm are used, the upper loading layer with granules with a diameter of 0.3-2 mm is designed for deeper filtration. Intensive water-air washing is carried out to regenerate granular filter materials.

Several filter designs have been developed with a load of crushed polyurethane foam with granule sizes of 0.5–12 mm and pores of 0.8–1.2 mm, of which filters of the FPZ-3 and FPZ-4 brands are the most effective for wastewater treatment (Fig. 41).

The loading of the FPZ-3 and FPZ-4 filters consists of granules, the size of which decreases in the direction of water movement, i.e. from top to bottom. The height of the loading layer is 1.0–1.2 m. Such filters can be used for post-treatment of both mechanically treated industrial wastewater (metallurgical, chemical and light industry) and biologically treated urban wastewater or their mixtures with industrial wastewater. The filter is regenerated by rinsing with water when the maximum pressure loss is reached, equal to 1.5–2.5 m. The aftertreatment effect for such filters for suspended solids is 70-85%, for BPC_P – 65-75%.



a *b*

Fig. 41 Filters with floating loading: a – FPZ-3; b – FPZ-4: 1 – housing; 2 – floating loading; 3 – feed water supply; 4 – filter pocket; 5 – retaining grate; 6 – lower drainage system; 7 – filtrate outlet; 8 – flushing outlet water; 9 – medium drainage pipe

4.4 Fundamentals of chemical and physico-chemical wastewater treatment

Chemical and physico-chemical treatment is usually used for industrial wastewater at local sewage treatment plants of enterprises. In most cases, chemical methods are preferred for the local treatment of industrial wastewater. Chemical purification is used in cases where the release of impurities is possible only as a result of a chemical reaction between the impurity and the reagent.

Chemical treatment of industrial wastewater can be applied:

-as an independent method before their supply to the circulating water supply system;

-before lowering them into a reservoir or into a city drainage network;

-for pre-treatment of wastewater before biological or physico-chemical treatment;

-as a method of deep wastewater treatment for the purpose of disinfection, discoloration or extraction of various components from them.

The main chemical methods of purification include neutralization, oxidation, and reduction. Electrochemical treatment also applies to oxidative methods.

Neutralization installations

Neutralization processes. Industrial wastewater from the technological processes of many industries contains alkalis and acids, as well as salts of heavy metals. To prevent corrosion of sewage treatment plant materials, violations of biochemical processes in biological oxidants and in reservoirs, as well as for precipitation of heavy metal salts from wastewater, acidic and alkaline effluents are neutralized. Since metal ions are almost always present in acidic and alkaline industrial wastewater, the dose of reagents is determined taking into account the release of heavy metal salts into the sediment. Wastewater is most often contaminated with mineral acids: sulfuric, nitric, hydrochloric, as well as their mixtures.

Mixtures with pH = 6.5–8.5 are considered practically neutral. Therefore, wastewater with a pH of less than 6.5 and more than 8.5 must be neutralized, while taking into account the neutralizing ability of the reservoir, as well as the alkaline reserve of urban wastewater. The greatest danger is posed by acidic effluents, which are also much more common than alkaline ones. Most often, wastewater is contaminated with mineral acids: sulfuric, hydrochloric, nitric, as well as their mixtures. Typically, the concentration of acids in wastewater does not exceed 3%, but there are also more concentrated mixtures.

There are the following ways to neutralize wastewater:
-Mutual neutralization of acidic and alkaline wastewater,
-Neutralization with reagents,
-Neutralization of acidic wastewater by filtration through neutralizing materials,
-Neutralization of alkaline wastewater with flue gases.

1. Mutual neutralization of acidic and alkaline wastewater. The discharge modes of wastewater containing acid and spent alkali are usually different. Acidic waters are usually discharged into the sewer evenly throughout the day and have a constant concentration. Alkaline waters are discharged periodically as the alkaline solution is discharged. In this regard, it is often necessary to arrange a regulating reservoir for alkaline waters. From the reservoir, these waters are uniformly released into the reaction chamber, where, as a result of mixing them with acidic wastewater, mutual neutralization occurs. This method is widely used in the chemical industry.

2. Neutralization with reagents (slaked Ca(OH)2 and quicklime CaO lime, calcined Na2CO3 and caustic NaON soda are used). Lime for neutralization is used in the form of lime milk of 5% concentration or in powder form. The reagent method is used if industrial enterprises have only acidic or only alkaline wastewater, or if it is impossible to ensure mutual neutralization. This method is most widely used to neutralize acidic waters. Since metal ions are almost always present in acidic and alkaline industrial wastewater, the dose of the reagent is determined taking into account the release of heavy metal salts into the sediment. The processes of reagent neutralization of industrial wastewater are carried out at neutralization plants or

stations. The contact time of wastewater and reagent should be at least 5 minutes. For acidic wastewater containing dissolved heavy metal ions, this time should be at least 30 minutes.

3. Neutralization of acidic wastewater by filtration through neutralizing materials (lime, limestone, chalk, magnesite, dolomite). The neutralization of hydrochloric, nitric, and sulfuric acid wastewater at a concentration of sulfuric acid of no more than 1.5 g / l is carried out on continuously operating filters with vertical movement of the neutralized waters. At an acid concentration of more than 1.5 g / l, the amount of calcium sulfate formed exceeds its solubility (2 g / l), and it begins to precipitate, as a result of which neutralization stops. The use of such filters is possible provided that dissolved salts of heavy metals are not present in acidic wastewater, since at pH > 7 they will precipitate in the form of insoluble compounds that completely clog the pores of the filter.

The main parameters of the neutralization process:

-the size of the fractions of the loading material is 3-8 cm;

-the calculated filtration rate depends on the type of feed material, but not more than 5 m/h;

-the duration of contact is at least 10 minutes.

Neutralization of alkaline wastewater with flue gases (fig. 42). The use of waste gases containing carbon dioxide, sulfur and nitrogen and other acid gases to neutralize wastewater makes it possible not only to neutralize wastewater, but also at the same time to carry out highly efficient purification of the gases themselves from harmful components. Neutralization is carried out in a column absorption apparatus.

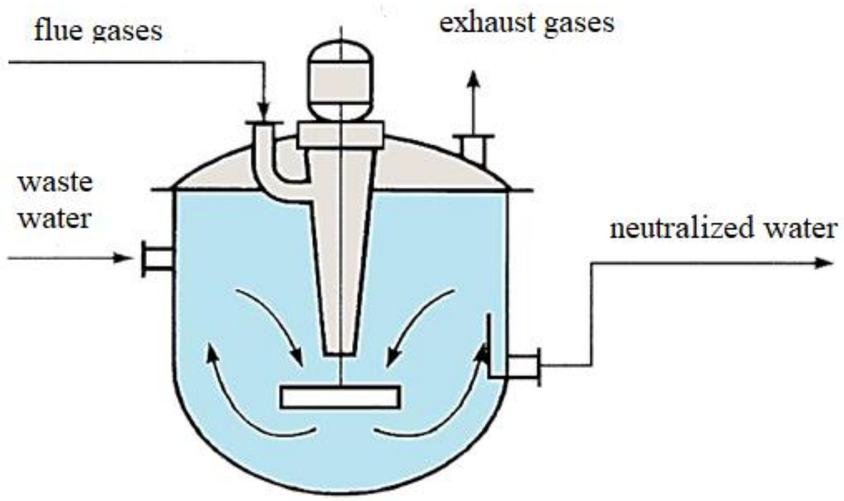


Fig. 42 Neutralizer of alkaline wastewater with flue gases

The choice of the neutralization method depends on many factors:

-the type and concentration of acids in industrial wastewater;

-the flow rate and mode of receipt of wastewater for neutralization;

-availability of reagents, local conditions, etc.

The processes of reagent neutralization of industrial wastewater are carried out at neutralization plants or stations, which include: sand traps, averaging tanks, warehouses of neutralizing reagents, solution tanks for the preparation of working solutions of reagents, dispensers of working solutions of reagents, wastewater mixers with reagents, reaction chambers (neutralizers), settling tanks for neutralized wastewater, sedimentation tanks (before mechanical dewatering of the resulting precipitation); structures for mechanical dewatering of precipitation, and in their absence – sludge sites, places for storing dehydrated precipitation, devices for chemical control of the neutralization process.

Oxidative method of wastewater treatment

Wastewater disinfection plants. The oxidative method is used in water treatment and for the neutralization of industrial wastewater containing toxic impurities (cyanides, phenols), as well as for the extraction of substances from wastewater that cannot or is impractical to extract by other methods.

The method is used in the following industries:

-mechanical engineering (in electroplating workshops);

-mining (at processing plants);

-petrochemical (at oil refineries and petrochemical plants);

-pulp and paper, etc.

Disinfection is the final stage of urban wastewater treatment. The release of even biologically treated wastewater into water bodies is inevitably associated with the threat of introducing pathogenic bacteria and viruses – pathogens of intestinal infections into them. It is known from the practice of wastewater treatment that during primary settling, the number of bacteria of the E. coli group decreases by 30-40%, and after secondary settling tanks – by 90-95%. Therefore, in order to completely free wastewater from pathogenic bacteria and viruses, it is necessary to use special disinfection methods.

For disinfection (disinfection) of wastewater, it is used:

- chlorination,

-ozonation,

-ultraviolet irradiation.

The reagents (oxidants) are chlorine, ozone, industrial oxygen and air oxygen. Disinfection of water with ultraviolet rays refers to physical (non-reactive) methods. In this case, bactericidal mercury-quartz lamps of high or low pressure are used.

Chlorination is the most common disinfection method and is highly effective against pathogenic bacteria. Chlorine gas and its derivatives (bleach, calcium and sodium hypochlorite, bleach, chlorine dioxide) are used as a disinfecting agent. Chlorination is also used to remove phenols, cyanides, hydrogen sulfide and other compounds from wastewater, to combat biological fouling of structures. Chlorine enters production in liquid form with a content of at least 99.5%.

Hypochlorous acid HCl has the same oxidizing ability as chlorine. However, its oxidizing properties are manifested only in an acidic environment. In addition, hypochlorous acid is an unstable product – it decomposes over time and in the light. Salts of hypochlorous acid have been widely used. Calcium hypochlorite Ca(ClO)2 is available in three grades with a concentration of active chlorine from 32 to 35%. The most stable salt of sodium hypochlorite is NaOCl · 5H2O.

Chlorine (IV) oxide ClO2 is a greenish-yellow gas, highly soluble in water, a strong oxidizer. When it interacts with water, chlorination reactions do not occur, which excludes the formation of organochlorine substances. Recently, extensive research has been carried out to clarify the conditions for replacing chlorine with chlorine oxide as an oxidizer. Advanced technologies using chlorine oxide have been introduced at a number of Russian plants.

The wastewater chlorination method has serious disadvantages, as well as hygienic and environmental limitations:

a) a long time of chlorine contact with water to achieve a disinfecting effect and high initial concentrations of active chlorine. Chlorine added to wastewater should be thoroughly mixed with it, and then be in contact with wastewater for at least 30 minutes, after which the amount of residual chlorine should be at least 1.5 mg/l. To achieve this value, the initial dose of active chlorine is, in accordance with the requirements of the SNiP, tens of mg / l.

To reduce Coli forms by 99.9%, the following doses of chlorine are required, mg/ l: after mechanical purification – 10; after chemical purification – 3-10; after complete and incomplete biological purification – 3 and 5, respectively; after filtration on sand filters – 2-5.

The chlorine gas chlorination plant has a chlorination plant, a mixer, and contact tanks;

a) the lack of necessary epidemic safety against viruses at a dose of residual chlorine of 1.5 mg/l;

b) high degree of chlorine toxicity. Chlorine is a highly toxic gas, and it is quite difficult to work with it;

c) high explosion hazard of liquid chlorine warehouses;

d) formation of organochlorine compounds in natural water in contact with chlorine in concentrations toxic to the biota of the water body and humans. Upon contact with water, chlorine is hydrolyzed to form hydrochloric acid. Biologically treated urban wastewater with a BOD level of 15-20 mg/l carries a sufficient amount of organic compounds of various classes capable of oxidation. With some organic substances that are present in the solution, chlorine can enter into chlorination reactions.

As a result, secondary organochlorine products are formed, which have a high degree of toxicity, mutagenicity and carcinogenicity, are able to accumulate in sediments, tissues of aquatic organisms and, ultimately, enter the human body. This makes it necessary to dechlorinate wastewater before releasing it into reservoirs. Therefore, recently there has been a tendency to abandon the disinfection of water with chlorine and the use of alternative methods.

Currently, chlorine is most widely used for wastewater disinfection, delivered to treatment plants in cylinders or in containers under high pressure in a liquid state. Disinfection is carried out at chlorination plants.

In order to understand how much chlorine needs to be dosed into water for its disinfection, it is necessary to separate the concepts:

- active,
- free,
-bound,
-residual chlorine.

Active chlorine is chlorine in the composition of a chemical compound capable of displacing iodine from the latter when its aqueous solution interacts with potassium iodide.

The active content in chlorine-containing preparations characterizes their bactericidal properties.

However, as it was found out earlier, the amount of active chlorine needed for disinfection of water should be determined not only by the number of pathogenic bacteria, but also by the total amount of oxidizing organic substances, microorganisms, as well as inorganic substances in chlorinated water. Therefore, the correct determination of the dose of active chlorine is extremely important: a lack of chlorine can lead to the fact that it will not have the necessary bactericidal effect, and its excess will lead to a deterioration in the organoleptic qualities of water. Therefore, the dose of active chlorine (chlorine consumption) should be determined depending on the individual properties of the treated water based on laboratory testing.

It is best if, when designing a chlorine disinfection plant, the estimated dose of active chlorine is taken based on the need to purify water during its maximum pollution, for example, during floods.

Residual chlorine is chlorine remaining in the water after the administered dose and after the oxidation of substances in the water.

It can be free and bound, i.e. it is represented by various forms of chlorine. It is the residual chlorine that is an indicator of the adequacy of the dose of chlorine taken. According to the requirements of SanPiN 2.1.4.1074-01, the concentration of residual chlorine in water before entering the network should be within 0.3 – 0.5 mg / l.

Free chlorine is a part of residual chlorine present in water in the form of hypochlorous acid, hypochlorite anions, or dissolved elemental chlorine.

Bound chlorine is a part of the residual chlorine present in water in the form of inorganic and organic chloramines.

The installation consists of the following elements: a chlorine supply warehouse, liquid chlorine evaporation units, chlorine gas dosing and chlorine water formation.

The capacity of the chlorination plant is determined based on the maximum wastewater consumption and chlorine dose. The daily amount and maximum hourly chlorine consumption are determined. It should be noted that the chlorine management of wastewater treatment plants should provide the possibility of increasing the calculated dose of chlorine, and, consequently, the consumption of chlorine, by 1.5 times.

The introduction of chlorine gas into wastewater is unacceptable, as this violates the safety conditions for the operation of installations. Liquid chlorine is pre-evaporated, turning it into gas, dissolved in water in a gaseous state and chlorine water is introduced into wastewater. The evaporation of 1 kg of liquid chlorine consumes 0.4 m^3 of water at a temperature of 30 ° C. From the evaporator, chlorine gas is directed to obtain chlorine water to a water-chlorine ejector, which creates a vacuum in the chlorine gas system, ensuring the safety of its operation.

Chlorine water is supplied from chlorinators through pipes for mixing with wastewater. Non-metallic pipes, such as high-strength polyethylene pipes, are recommended for transporting chlorine water. On the territory of treatment facilities, pipes are laid in separate channels or in pipe cases. A three-day supply of chlorine is placed in the chlorination room. Chlorine is evaporated directly in the container in which it is stored.

Next, the water enters the contact tanks. The calculation of reservoirs is similar to the calculation of settling tanks. They are calculated for the maximum inflow of wastewater. The number of tanks is accepted at least two, with a duration of chlorine contact with wastewater of 30 minutes. Vertical sedimentation tanks with gravity sediment removal or horizontal sedimentation tanks equipped with a pipe system with nozzles for flushing sediment with process water from the bottom of the sedimentation tank to the sedimentary part are accepted as contact tanks. During disinfection, fine and colloidal substances coagulate and precipitate, so the speed in the contact tanks should not be high. The amount of sludge depends on the degree and type of wastewater treatment.

Contact tanks must be designed without scrapers, which corrode when in contact with chlorine. The pre-agitated sediment is removed by gravity under hydrostatic pressure. The volume of the contact tanks is determined.

The chlorine supply warehouse is designed for a monthly (31 days) supply of chlorine. Determine the total amount of chlorine in the warehouse. The chlorine container capacity, diameter and length of the container are determined. A certain number of containers are accepted.

The chlorine supply warehouse is located on the territory of the treatment facilities in a separate building or in conjunction with the chlorination plant, but is separated from it by a capital wall and has independent entrances and entrances. The distance from the warehouse to the production premises is at least 30 m and the distance from public and residential buildings is 300 m. The chlorine plant and the chlorine warehouse are equipped with ventilation units with 12-fold air exchange.

During disinfection with liquid chlorine (chlorine water), the volume of sediment after mechanical cleaning is 0.08 l / (person / day), after complete biological purification in aerotanks – 0.03 l/(person / day), on biofilters – 0.05 l /(person / day). The moisture content of the sediment is 96%. Sediment removal from contact tanks is carried out under hydrostatic water pressure. The sediment is usually directed immediately to dehydration without fermentation and stabilization.

The amount of sediment deposited in contact tanks should be taken in liters per 1 m^3 of wastewater at a humidity of rok = 98% (SNiP 2.04.03-85): after mechanical cleaning a = 1.5; after biological cleaning in aerotanks and biofilters a = 0.5.

The sediment can be dewatered both after preliminary fermentation in methane tanks and directly in sediment dewatering facilities (silt sites).

Sorption wastewater treatment

Sorption processes of wastewater treatment. The absorbing substance is called a sorbent, and the absorbed substance is called a sorbate. In wastewater treatment technology, an adsorption process is mainly used on the developed solid surface of the sorbent. Adsorption of solutes is the result of the transition of a solute molecule from a solution to the surface of a solid sorbent under the action of a surface force field. In this case, two types of intermolecular interaction are observed: solute molecules with molecules (or atoms) of the sorbent surface, and solute molecules with water molecules in solution (hydration). The difference between these two forces of intermolecular interaction is the force with which the substance extracted from the solution is retained on the surface of the sorbent.

Sorption purification can be used in conjunction with biological purification as a preparation method and as an independent method. Sorption methods are very effective for extracting dissolved substances from wastewater with their subsequent regeneration and the use of treated wastewater in recycling water supply systems of industrial enterprises. Adsorption is used for deep purification of closed water supply waters and post-treatment of wastewater from organic substances.

Artificial and natural materials are used as sorbents – ash, coke fines, peat, silica gel, active clays, etc. The most effective are active (activated) coals of different brands. The main indicators of sorbents are porosity, pore structure, and chemical composition. The activity of sorbents is characterized by the amount of absorbed substance per unit volume or mass of the sorbent (kg/m^3, kg/kg).

Devices for sorption wastewater treatment are classified according to different criteria:

-according to the organization of the process – periodic and continuous operation;

-hydrodynamic mode – displacement, mixing and intermediate type devices;

-the state of the sorbent layer – with a stationary, moving, pulsating, stirring and circulating layer;

-organization of the contact of interacting phases – with continuous and stepwise contact;

-organization of the direction of movement of phases – with forward, countercurrent and mixed motion;

-structures – column and capacitive;

-the method of energy supply – without energy supply from the outside (gravitational movement of phases) and with energy supply from the outside (forced movement of the solid phase).

In the practice of wastewater treatment, adsorbers with a fixed and tightly moving absorber layer (sorption under dynamic conditions), devices with a fluidized adsorbent layer, as well as devices in which intensive mixing of the treated water with a powdery or pulverized sorbent is provided (sorption under static conditions) are often used.

The simplest design is a bulk filter column with a fixed sorbent layer through which the treated wastewater is filtered (Fig. 43).

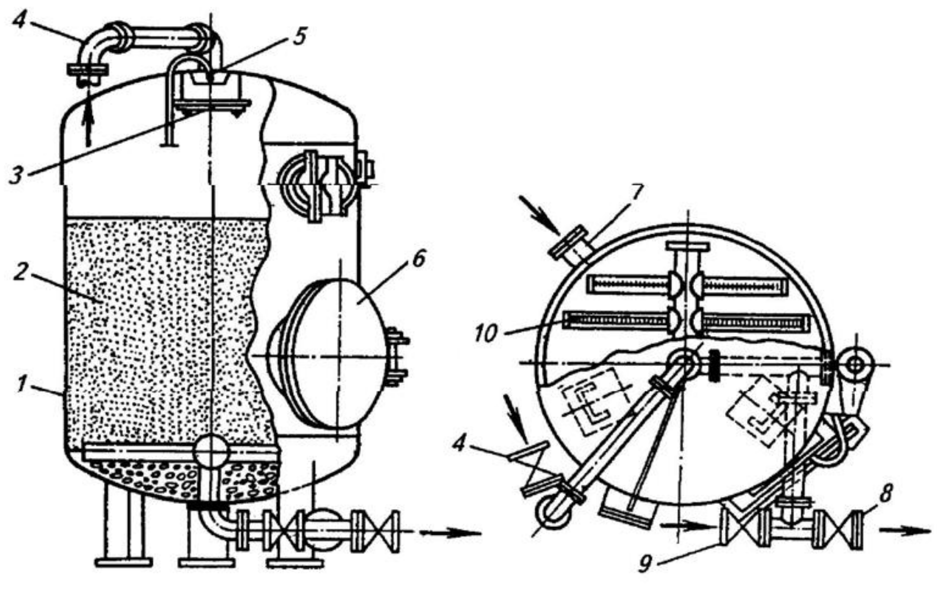


Fig 43 Sorption vertical parallel flow filter: 1 - housing; 2 – fixed layer of activated carbon; 3 – chipper; 4 – pipeline for the supply of treated wastewater; 5 – air vent pipe; 6 – hatch; 7 – pipeline for unloading activated carbon; 8 – pipeline for the discharge of purified water; 9 – loosening water supply pipeline; 10 – pipe distribution system

The filtration rate depends on the amount of substances dissolved in wastewater and can range from 1-2 to 5-6 m/h. The grain size of the sorbent is from 1.5–2 to 4-5 mm. The liquid moves from bottom to top. The content of suspended solids in the water entering the treatment should not exceed 5 mg/l.

Usually, a sorption plant consists of several parallel sections consisting of 3-5 filters arranged in series. When the saturation limit is reached, the first filter is switched off for regeneration, and the treated water is supplied to the next filter. After regeneration, the first filter is included in the cleaning scheme last. Currently, cylindrical single–tier adsorbers are used, into which activated carbon is loaded with a layer height of 2.5–2.7 m, the grain size of the sorbent is 0.25-1.9 mm.

Wastewater treatment by flotation

Flotation plants are used to remove oils, petroleum products, fats, resins, hydroxides, surfactants and other organic substances from wastewater, solid particles with a hydraulic size of less than 0.01 mm/s, polymers, fibrous materials, as well as for the separation of sludge mixtures.

Flotation plants are also used:

-to remove pollutants from wastewater before biological treatment;

-for separation of activated sludge in secondary settling tanks;

-for deep purification of biologically treated wastewater;

-during physico-chemical cleaning with the use of coagulants and flocculants;

-in the schemes of reuse of treated waters.

The process of wastewater treatment by flotation consists in the formation of "particle-bubble" complexes, the surfacing of these complexes and the removal of the formed foam layer from the surface of the treated liquid. The adhesion of the particle contained in it to the surface of the gas bubble is possible only when there is non-wetting or poor wetting of the particle with liquid.

To intensify the formation of bubble–particle aggregates, various reagents are added to the water: collectors, foaming agents, regulators that increase the hydrophobization of the particle surface, dispersion and stability of gas bubbles.

In the practice of wastewater treatment, various design schemes, techniques and methods of flotation have been developed. Significant differences in flotation methods are associated with saturation of the liquid with air bubbles of a certain size.

According to this principle, the following methods of flotation treatment of industrial wastewater can be distinguished:

-flotation with the release of air from the solution (vacuum, pressure and airlift flotation units);

-flotation with mechanical air dispersion (impeller, non-pressure and pneumatic flotation units);

-flotation with air supply through porous materials;
-electroflotation;
-biological and chemical flotation.

The various flotation methods differ in the design of the installations and the method of separating the liquid and floating phases.

Flotation plants can consist of one or two compartments (chambers). In single-chamber installations, in the same compartment, liquid saturation with air bubbles and the surfacing of floating pollutants occur simultaneously. In two-chamber installations consisting of a receiving and settling compartments, air bubbles and "bubble–particle" aggregates form in the first compartment, and sludge (foam) floats and liquid clarification occurs in the second.

Pressure, vacuum, non-pressure, electroflotation installations are used for wastewater treatment with a suspended solids content of over 100-150 mg/l (taking into account the solid phase formed by the addition of coagulants). With a lower content of suspensions, impeller, pneumatic and air dispersing installations can be used for fractionation of surfactants, petroleum products, etc. into foam and for foam separation. Coagulants and flocculants are used to increase the degree of retention of suspended solids.

Flotation with the release of air from the solution is used in the treatment of industrial wastewater containing very small particles of pollutants, since it allows you to obtain the smallest air bubbles. The essence of the method is to create an oversaturated solution of air in a waste liquid. The air released from such a solution forms microbubbles, which float the pollutants contained in the wastewater. The amount of air that must be released from the supersaturated solution and ensure the necessary flotation efficiency is usually 1-5% of the volume of treated wastewater.

The advantage of vacuum flotation (Fig. 44) is that the formation of gas bubbles, their adhesion to pollution particles and the surfacing of the formed "bubble-particle" aggregates occur in a calm environment and the probability of their destruction is minimized, energy consumption for saturation of the liquid with air is also minimal.

At the same time, the need to construct hermetically sealed tanks, the complexity of operating vacuum flotation plants, as well as the limited range of their application (the concentration of pollutants in wastewater should not exceed 250 mg/l) are disadvantages of the vacuum flotation method.

The waste liquid entering the flotation is pre-saturated with air for 1-2 minutes in the aeration chamber, from where it enters the deaerator to remove insoluble air. Further, under the action of rarefaction (0.02–0.03 MPa), wastewater enters the flotation chamber, in which the air dissolved at atmospheric pressure is released in the form of microbubbles and removes particles of pollutants into the foam layer. The duration of the wastewater stay in the flotation chamber is 20 minutes, and the load per 1 m^2 of surface area is about 200 m^3/day. The accumulated foam is removed by rotating scrapers into the foam collector. To drain the treated wastewater, the necessary level difference is provided in the flotation chamber and the receiving tank or pumps are installed.

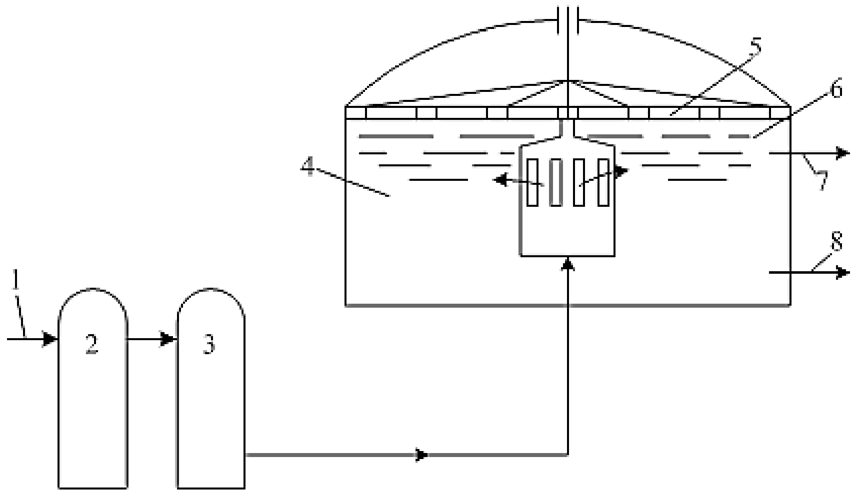


Fig. 44 Diagram of the vacuum flotation process with the release of air from the solution: 1 – wastewater supply; 2 – aerator; 3 – deaerator; 4 – flotation chamber; 5 – foam raking mechanism; 6 – foam collector; 7, 8 – discharge of foam and treated wastewater, respectively

Pressure flotation is most widely used in wastewater treatment processes, since it allows you to adjust the degree of supersaturation in accordance with the required efficiency of wastewater treatment at an initial concentration of pollutants up to 4-5 g/l or more.

The pressure flotation unit includes: collecting (receiving) tanks for collecting wastewater, pumps, ejectors or compressors, a pressure tank (saturator) for saturating water with air, a flotation chamber and equipment for collecting and removing foam with impurities. To increase the efficiency of purification, pre-coagulation of water is provided.

The installation is supplemented with mixers, flocculation chambers, etc.

Wastewater is pumped into the saturator. In the saturator, air is dissolved in an amount of 3-5% of the volume of purified water at a pressure of 0.3–0.5 MPa. Saturated with air, this water from the saturator is fed into a flotation chamber, which operates at atmospheric pressure, where dissolved air is released and the flotation process is carried out.

Thus, the formation of gas bubbles occurs due to a decrease in the solubility of air in water with a decrease in pressure. In this case, gas is released from the water directly on the particle. The floating mass is continuously removed by mechanisms for raking foam into foam collectors. When designing flotators for wastewater treatment with a flow rate of up to 100 m^3/h, rectangular chambers with a depth of 1-1.5 m are accepted, with a flow rate of more than 100 m^3/h – radial flotators (Fig. 45) with a depth of at least 3 m.

The depth of the flotation zone is assumed to be at least 1.5 m, and the duration of water stay in it is at least 5 minutes; the depth of the settling zone is at least 1.5 m, the period of water stay in it is 15 minutes. The main dimensions of typical settling tank flotators are shown in Table 4.

Wastewater saturated with air enters the flotation device from below through a rotating water distributor. The air bubbles released from the water float up along with the particles of pollution. The foam is raked into the tray by a rotating mechanism and removed. The treated water is drained from the bottom and poured through vertical channels into the discharge ring tray. The throughput capacity of one flotation device should not exceed 1000 m^3/h.

The depth of the flotation and settling zones is assigned at least 1.5 m, and the duration of water stay in them is at least 5 and 15 minutes, respectively. The area of the flotation chamber is taken based on the aeration intensity of 6-10 m^3/ (m2·h). Flotation time is 20 minutes.

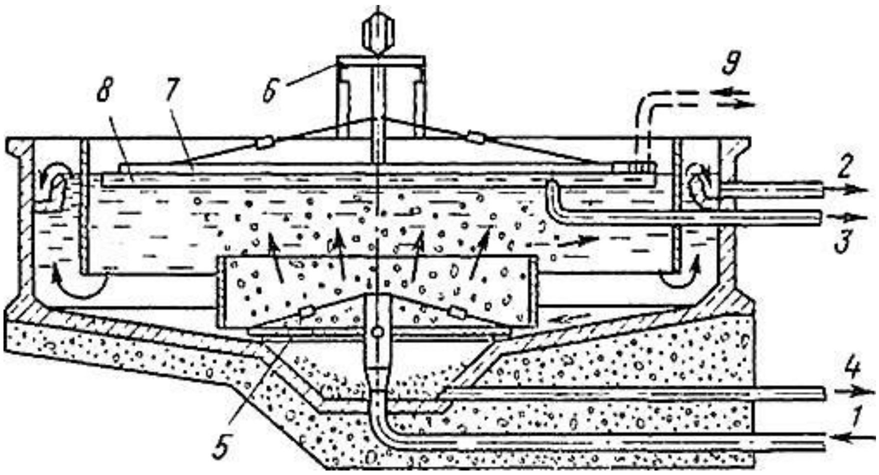


Fig 45 Radial flotation device: 1 – supply of condensate saturated with air; 2 – discharge of purified condensate; 3 – discharge of oil foam with water; 4 – discharge of sludge; 5 – switchgear; 6 – drive station – reducer for strokes; 7 – strokes; 8 – intake pipe for oil foam; 9 – steam supply for liquefaction and separation of oil from water in the intake pipe

Table 5 Main sizes of settling tank flotators with different capacities

Capacity, m^3/h	Flotation chamber		Overall dimensions	
	diameter, m	height, m	diameter, m	height, m
150	3	1,5	6	3
300	4,5	1,5	9	3
600	6	1,5	12	3
900	7,5	1,5	15	3

With airlift flotation, energy costs are 2-4 times less than with pressure flotation, but the design of the installation requires a significant difference in height between the feed tank with wastewater and the aerator, as well as between the aerator and the flotation chamber (the difference in marks is 20-35 m), which significantly narrows the scope of this method.

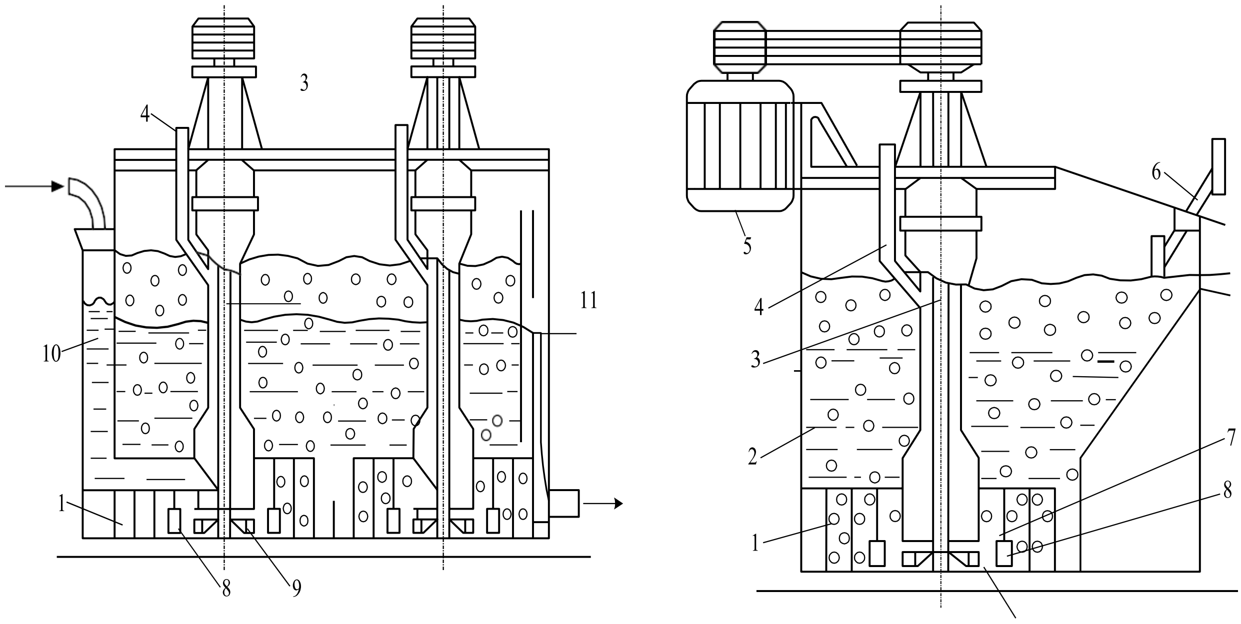
The flotation process with mechanical air dispersion (impeller flotation) occurs as follows. When the air jet moves in the water, an intense vortex motion is created in the latter, under the influence of which the air jet breaks up into separate bubbles. Vigorous mixing of wastewater in flotation impeller installations creates a large number of small vortex flows in it, which makes it possible to obtain bubbles of a certain size.

An impeller is a propeller or a system of blades operating in a circumferentially closed housing.

The use of impeller installations is advisable for wastewater treatment with a high concentration of undissolved contaminants (more than 2-3 g/l) and containing oil, petroleum products, fats. Impeller flotation is widely used for the processes of enrichment of raw materials and wastewater treatment from substances that easily turn into foam. The disadvantage of this type of flotation is the inability to use coagulants, since during turbulent mixing of water, the coagulant flakes are destroyed.

Figure 46 shows a diagram of a two-chamber direct-flow flotation plant. Waste water from the intake pocket flows to the impeller, into which air is sucked through the tube. Above the impeller there is a stator in the form of a disk with holes for internal water circulation. The water and air mixed in the impeller are ejected through the stator. The gratings located around the stator contribute to a finer dispersion of air in the water. The air bubbles settle over the grate. Foam containing floatable particles is removed with a paddle foam pick-up device. From the first chamber, water enters the second of the same design, where additional wastewater treatment takes place.

Flotation with air supply through porous materials is characterized by the simplicity of the hardware design of the process and relatively low energy consumption. Air is supplied to the flotation chamber through finely porous filter plates, pipes, nozzles laid at the bottom of the chamber. The size of the holes should be 4-20 microns, air pressure 0.1–0.2 MPa, flotation duration 20-30 minutes, air flow is determined experimentally. The working level of the treated wastewater before flotation is 1.5–2 m. The disadvantage of this method is the possibility of overgrowth and clogging of pores, as well as the difficulty of selecting finely porous materials that provide the exit of small, close-sized air bubbles.



a *b*

Fig 46 Two–chamber direct–flow flotation unit: a – transverse section: 1 – bumpers; 2 – flotation chamber; 3 – impeller shaft; 4 – air tube; 5 – electric motor; 6 – foam collector; 7 – holes in the stator for internal water circulation; 8 - stator; b - longitudinal section: 9 – impeller; 10, 11 – intake and exhaust pockets, respectively

Pneumatic flotation plants are used in the treatment of wastewater containing dissolved impurities that are aggressive to mechanisms (pumps, impellers, etc.) having moving parts. The crushing of air bubbles is achieved by admitting air into the flotation chamber through nozzles that are located on air distribution tubes laid on the bottom of the flotation chamber at a distance of 0.25–0.3 m from each other. The diameter of the nozzle holes is 1-1.2 mm; the working pressure in front of them is 0.3–0.5 MPa; the jet exit velocity from the nozzles is 100-200 m/s. The depth of the flotation device is 3-4 m.

Biological and chemical flotation is used to seal sewage sludge. In the process of wastewater flotation, foam is formed, which has a different structure, usually a film-structural one. Such foam contains a significant amount of water, especially in the lower layers, and its stability and mobility vary depending on the quantity and nature of the floated materials. The process of compaction of the surfaced sludge is most intense in the first 2 hours, then it slows down, and after 4 hours it practically stops.

The process of compaction and destruction of the foam layer can be intensified with the help of spray cans or by heating. In most cases, the disposal of foam condensate is economically impractical.

4.5 Biological methods of wastewater treatment. The equipment used

After mechanical treatment, some suspended solids, dissolved organic substances and a large number of micro organisms remain in the water. The biological method is based on the use of the vital activity of aerobic microorganisms, for which organic substances of wastewater (in a dissolved and colloidal state) are a source of nutrition. In the presence of free oxygen in wastewater, microorganisms oxidize (mineralize) organic substances.

The main purpose of biological treatment of urban wastewater is the decomposition and mineralization of organic substances in a colloidal and dissolved state. These substances cannot be removed from drains mechanically. Wastewater is released from organic substances in two phases.

The first is the sorption phase. It is based on the physico-chemical processes of adsorption of organic substances and colloids by the surface of a microbial cell. The second phase is the sequential oxidation of dissolved and adsorbed organic substances, which is based on the assimilation of organic substances by microorganisms. From a hygienic point of view, complete mineralization of all organic impurities of wastewater is not considered necessary.

The task of biological treatment of urban wastewater is to mineralize organic substances to such an extent that wastewater could be discharged into a water body without violating its sanitary regime.

The decomposition of organic compounds of different classes occurs in a certain sequence and at different rates. The decomposition of carbohydrates to carbon dioxide and water is extremely fast, only a few hours. Fats are oxidized more slowly. The breakdown of protein substances entering wastewater, mostly in the form of urea, is most difficult and takes a long time. Urea is hydrolyzed by bacteria to ammonium carbonate. In the next step, ammonium salts are oxidized to nitrites, then the nitrites are converted to nitrates.

The nitrification process is associated with the consumption of a large amount of oxygen, which is taken into account when organizing biological purification. Nitrification is an exothermic process, which greatly facilitates the operation of wastewater treatment plants in winter. Nitrification should be considered not only as the mineralization of nitrogenous organic compounds, but also as the accumulation of bound oxygen in water. In case of oxygen deficiency in a water body, the bound oxygen of nitrates can be mobilized during the denitrification process.

Biological wastewater treatment can take place in natural and artificial conditions. Soil methods are used for cleaning in natural conditions. This method, known since ancient times, is used mainly for the treatment of domestic and urban wastewater, and not purely industrial. Irrigation fields, filtration fields and biological ponds (bioprudes) are used for wastewater treatment.

Biofilters and aerotanks are used for wastewater treatment in artificially created conditions.

Facilities for biological wastewater treatment in artificially created conditions

Biofilters

A biofilter is a structure in which wastewater is filtered through a feed material coated with a biological film (biofilm) formed by colonies of microorganisms. Biofilters are designed in the form of round or rectangular tanks with solid walls and a double bottom: the upper bottom is a grate, the lower one is solid.

The biofilter consists of the following parts (Fig. 47):

-filter loading placed in a tank of round or rectangular shape in plan (biofilter body);

-a water distribution device for uniform irrigation of the loading surface with wastewater;

-drainage device for removing filtered liquid;

-an air distribution device for the intake of air into the biofilter.

Wastewater clarified in primary settling tanks enters distribution devices, from which it is periodically released onto the surface of the biofilter. The filtered water enters the drainage system and then flows down the solid bottom of the biofilter to the discharge trays.

In biofilters, biodegradable organic substances of wastewater are sorbed and oxidized under aerobic conditions by a population of heterotrophic facultative bacteria forming a biofilm on the surface of the loading material (nozzles). Passing through the biofilter loading, the contaminated water leaves undissolved impurities in it that have not settled in the primary settling tanks, as well as colloidal and organic substances sorbed by the biofilm.

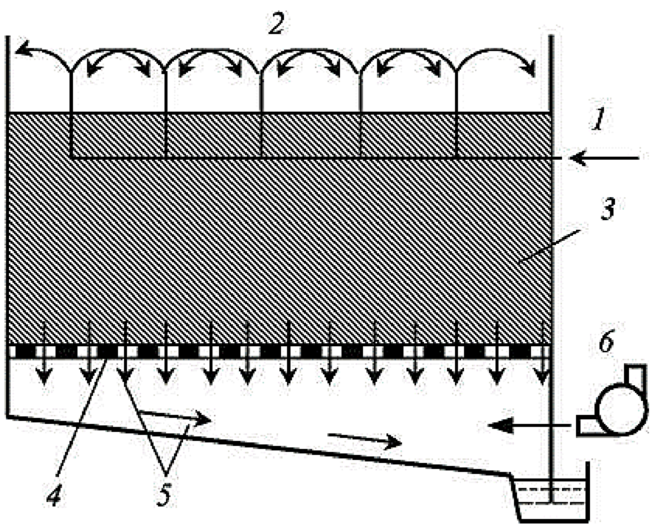


Fig 47 Section of the biofilter: 1 – wastewater supply; 2 – water distribution device; 3 – filter loading; 4 – drainage device; 5 – purified wastewater; 6 – air distribution device

To irrigate the nozzle, contaminated water is periodically or continuously supplied to the upper part of the structure through fixed sprinklers (sprinklers) or reactive rotating water distributors.

The scheme of the sprinkler water distribution network is shown in Fig. 48. The active part of the biofilm extends to a depth of 70-100 microns. The necessary oxygen can be supplied to the loading column by natural and artificial ventilation.

Microorganisms use part of the organic matter to increase their biomass. Anaerobic conditions are created in the film layers adjacent to the nozzle, and partial cell death occurs. Under the influence of hydraulic load, such parts of the film are detached from the substrate and carried out with water. The spent and dead biofilm is washed off with wastewater and removed from the body of the biofilter, after which it is separated from the purified water in secondary settling tanks.

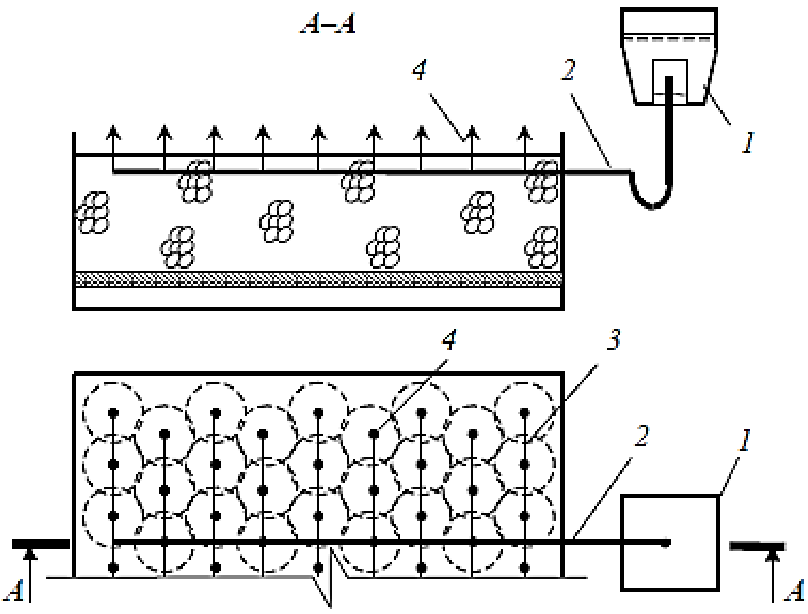


Figure 48 Diagram of the sprinkler water distribution network: 1 – dosing tank; 2 – main pipe; 3 – spreading pipes; 4 – sprinklers

Biofilters are classified according to various criteria:

according to the degree of purification:

-for full,

-incomplete biological purification;

according to the method of air supply:

-with artificial aeration (air filters),

-with natural air supply;

according to the operating mode:

-with waste water recirculation (that is, with the return of part of the purified liquid to the biofilter), without waste water recirculation;

according to the technological scheme:
-single-stage,
two-stage;

by bandwidth:
-drip,
-highly loaded;

according to the type and features of the loading material:
-biofilters with volumetric (gravel, slag, expanded clay, crushed stone, etc.),
-planar (plastics, fabrics, asbestos cement, ceramics, metal, etc.) loading.

Biofilters with bulk loading vary in loading height:
-drip have a height of 1-2 m and a capacity of 0.9–9 $m^3/(m^2 \cdot day)$,
-highly loaded – height 2-4 m and carrying capacity 9-40 $m^3/(m^2 \cdot day)$,
-tower – height 8-16 m.

Drip biofilters are used at stations with a capacity of no more than 1 000 m^3/day, and high–load ones - up to 50 000 m^3/day.

In drip biofilters, natural aeration is provided through windows located evenly along the entire perimeter of the walls of the biofilter within the interstitial space. They are placed in buildings in the form of separate sections, which can be round or rectangular in plan. Waste water recirculation on drip biofilters is used when the value of the waste water BPC_P is over 220 mg/l. Treated wastewater can have a BPC_P of up to 15 mg/l. The disadvantages of drip biofilters are low productivity and frequent siltation of the surface of the loading material, which usually occur due to exceeding the permissible pollution load.

The design differences of highly loaded biofilters (aerofilters) are the high height of the loading layer, the large size of its fractions and the special design of the bottom and drainage, which provides the possibility of artificial purging of the loading material with air. They are designed with artificial aeration. An air fan is supplied to the enclosed interior space. Highly loaded biofilters are used for complete and incomplete biological purification and placed outdoors. The loading has a working height of 2-4 m, the size of the loading material ranges from 40 to 70 mm. The permissible value of the BPC_P of wastewater without recycling is 300 mg/l. The number of biofilters should be from 2 to 8, all working.

Tower biofilters have a height of 8-16 m and are used for wastewater treatment plants with a capacity of up to 50,000 m^3/day with favorable terrain and with a BPC_P of treated wastewater up to 20-25 mg/l. The grain size of the loading is 60-80 mm. They are used abroad, but have not been widely used in domestic practice.

Biofilters with planar loading (fig. 49) are divided into the following types:
-with rigid filling (ceramic, plastic or metal bulk elements);

-rigid block loading (corrugated or flat sheets or spatial elements);

-with a soft or roll loading made of metal or plastic nets, synthetic fabrics that are mounted on frames or stacked in rolls;

-submersible biofilters consisting of a package of discs mounted on a horizontal axis of rotation.

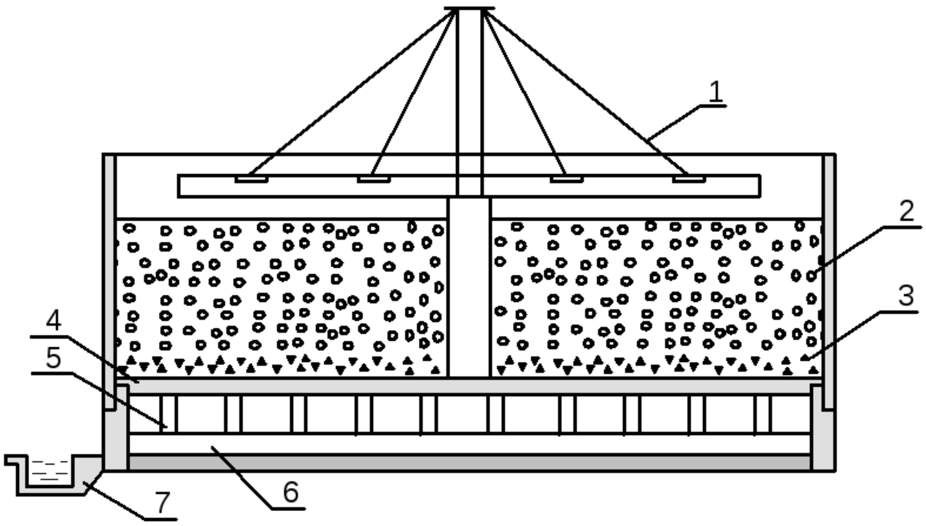


Fig. 49 Diagram of a biofilter with plastic loading: 1 – sprinkler; 2 – pipeline for water supply for purification; 3 – plastic loading; 4 – discharge of treated runoff; 5 – air inlet, 6-pallet, 7 –sewage pit

Biofilters with planar loading have the following advantages: they are compact, have low energy consumption, reliable in operation, are not subject to siltation, and have a high industriality of construction. Block, backfill and roll materials made of plastics, metal, asbestos cement, ceramics, glass, wood, fabrics, etc. are used as loading.

Biofilters with plastic loading have a porosity of 93-96% and a specific surface area of 90-110 m^2/m^3. Blocks made of polyvinyl chloride, polystyrene, polyethylene, polypropylene, polyamide, smooth or perforated plastic pipes with a diameter of 50-100 mm or filling elements in the form of scraps of pipes with a length of 50-150 mm, a diameter of 30-75 mm with perforated, corrugated or smooth walls are accepted as loading. Biofilters have a round, rectangular and octagonal shape in plan. The height of the loading layer is 3-8 m, the loading density is 10-250 kg/m^3, the specific surface area is 60-250 m^2/m^3. The hydraulic load per 1 m^3 of biofilter volume per day is 6-18 m^3.

Options for loading the biofilter – fig. 50.

In the construction project, it is necessary to provide a distribution device for uniform irrigation of wastewater over the entire surface of biofilters. Sprinkler irrigation and irrigation using mobile sprinklers have become the most widespread.

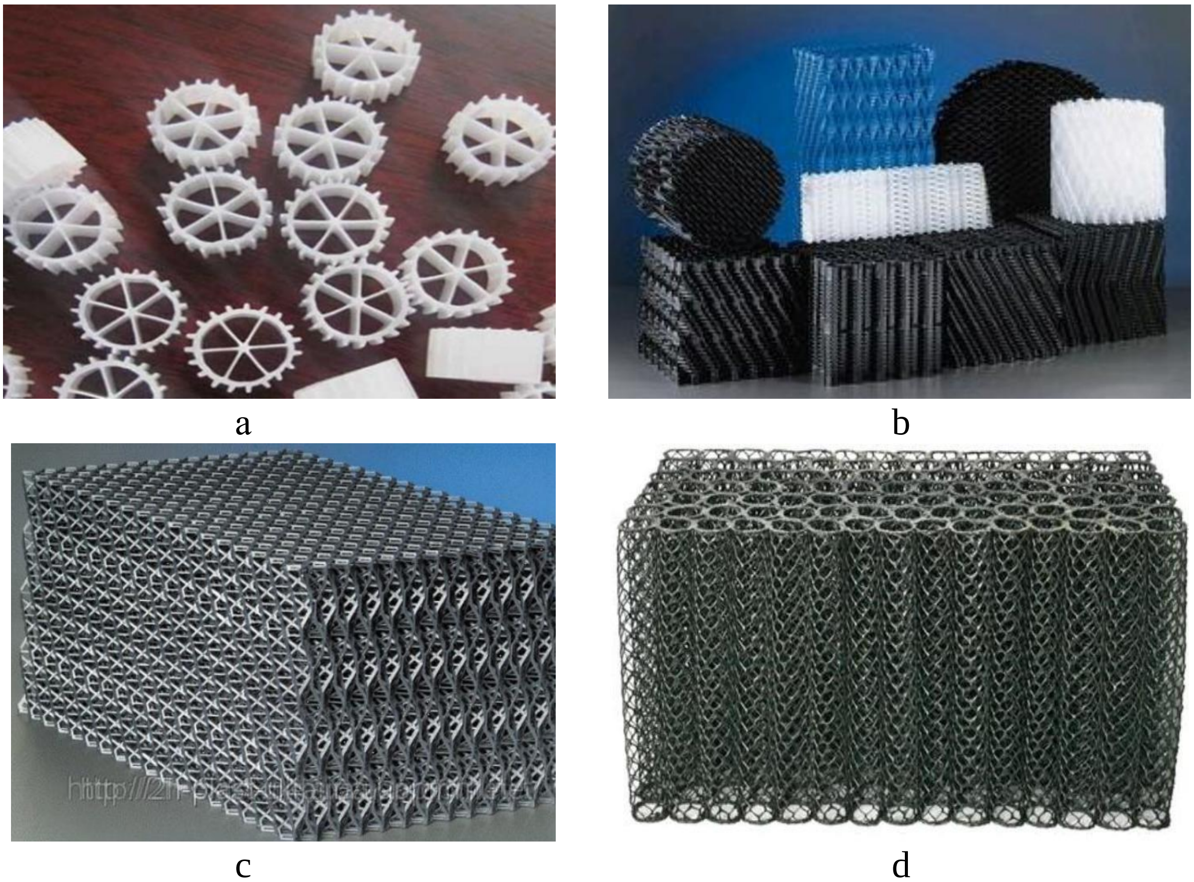


Fig. 50 Options for loading biofilters:
a, b – rigid filling; c, d – rigid block

Aerotanks

Aerotanks are used for biological treatment of urban and industrial wastewater. The concentration of suspended solids in the water supplied to the aeration tanks (after the primary settling tanks) should not exceed 150 mg/l.

An aerotank is a flowing structure with free–floating activated sludge. The structures are made in the form of long reinforced concrete rectangular tanks with a depth of 3-6 m, a width of 6-10 m, and a length of up to 100 m. Aerotanks consist of several sections (corridors) separated by partitions. Active sludge is formed in them – a combination of microorganisms and solid particles. Active sludge includes bacteria, protozoa, fungi, algae, capable of sorbing organic pollutants on its surface and oxidizing them in the presence of oxygen. The schematic diagram of the aeration tank is shown in Fig. 51.

After clarification in the primary settling tanks, the waste liquid enters the aeration tank and mixes with the circulating activated sludge. A mixture of wastewater and activated sludge along the entire length of the aeration tank is purged with air coming from the compressor station. Aerobic microorganisms absorb organic substances from wastewater and oxidize them in the presence of oxygen. From the aeration tank, a mixture of wastewater with activated sludge is sent to a secondary settling tank, where the activated sludge settles.

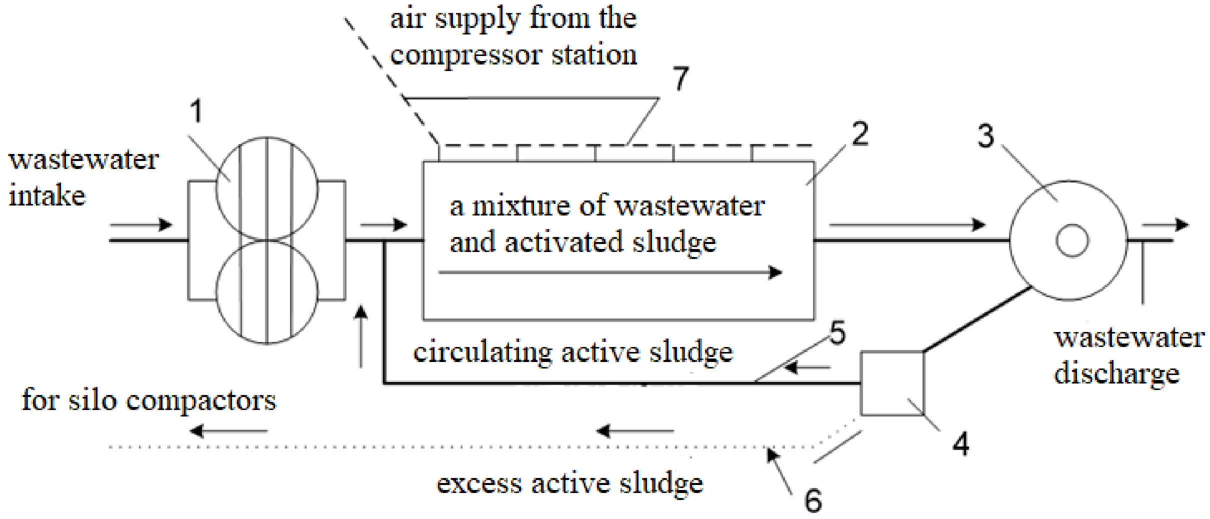


Fig.51 Schematic diagram of the aeration tank operation: 1 – primary sump; 2 – aeration tank; 3 – secondary sump; 4 – pumping station; 5 – circulating active sludge; 6 – excess active sludge; 7 – air supply to the aeration tank

As a result of the growth of microorganisms, the mass of sludge in the aeration tank is continuously increasing. Therefore, the pumping station pumps excess activated sludge from the secondary sump into the silt compactors, and the circulating activated sludge back into the aeration tank. Secondary settling tanks are used to separate purified water from activated sludge. Their design practically does not differ from the design of primary settling tanks (they can be horizontal, vertical and radial).

Two processes take place in biological wastewater treatment: sorption of contaminants by activated sludge and their intracellular oxidation by microorganisms. The sorption rate significantly exceeds the rate of biooxidation, therefore, after the end of the sorption process and achieving the required BOD purification effect, the sludge separated in the sump is sent to a regenerator (aeration tank section) in order to biooxify residual wastewater contaminants. Regenerators are arranged to ensure the stable operation of aerotanks. The sorbing activity of activated sludge is restored in them. The sludge in the regenerators is constantly aerated. A part of the aeration tank corridors is usually allocated for regenerators.

To provide oxygen to microorganisms, as well as to maintain sludge in a suspended state, continuous artificial aeration of a mixture of wastewater and activated sludge is used. Thus, the active biomass is suspended in the aeration tank.

There are the following technological schemes for wastewater treatment in aerotanks. In a single-stage scheme without regeneration (fig. 52, a), activated sludge is supplied in a concentrated manner together with wastewater to the entrance to the aeration tank. The resulting sludge mixture under aeration conditions flows to the outlet of the aeration tank and is then fed to a secondary sump, where it is divided into purified water and activated sludge. The active sludge is further divided into excess and circulating, the latter returns to the aeration tank. A feature of this scheme is to reduce the load on activated sludge along the length of the aeration tank and reduce the oxygen demand of activated sludge along the length. According to the hydraulic mode, the aerotank is a displacer.

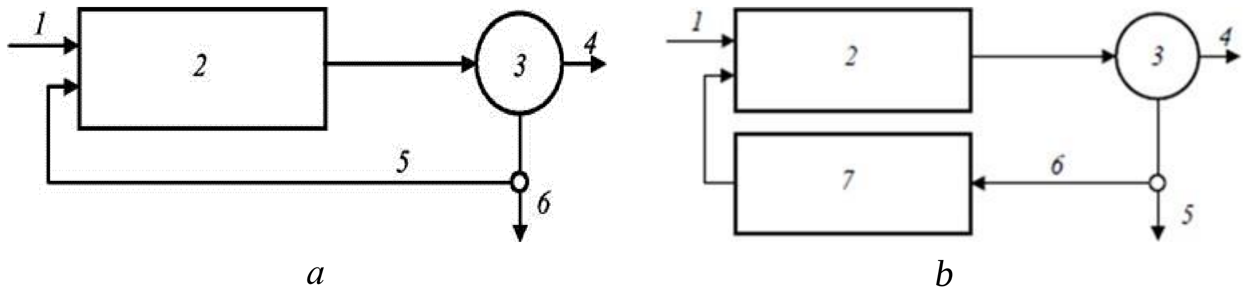


Fig 52 Technological schemes of wastewater treatment in aerotanks: a – single–stage purification scheme in aerotanks: 1 – waste water; 2 – aerotank; 3 – secondary sump; 4 – purified water; 5 and 6 – circulating and excess activated sludge; b – single-stage purification scheme in aerotanks with regeneration: 7 - sludge regenerator

A single-stage scheme with activated sludge regeneration (Fig. 52, b). Here, two stages of biological purification are implemented separately: the absorption of pollutants by activated sludge from wastewater, which occurs directly in the aeration tank, and the oxidation of these pollutants, which occurs in the regenerator. In the regenerator, the activated sludge is aerated without waste liquid. In the aeration tank, wastewater is aerated for about 1.5– 2.5 hours, in the regenerator – several times more.

A two-stage scheme without regeneration (Fig. 53) is advisable with a high concentration of organic substances in wastewater, as well as in the presence of substances in it whose oxidation rate differs sharply. In the aerotanks of each stage, active sludge develops, which is most adapted to these conditions. A variation of this scheme is a scheme with regenerators at each stage.

According to the hydraulic scheme of operation, aerotanks are divided into three types (Fig. 54):

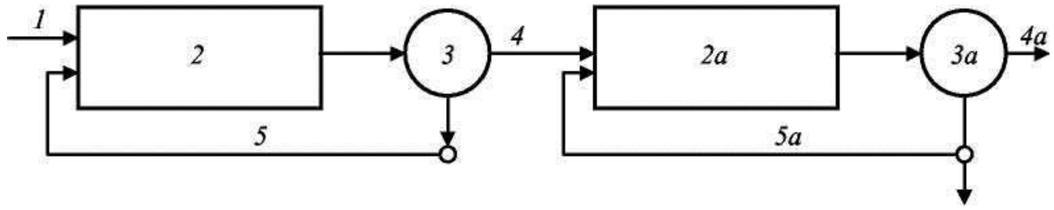


Fig. 53 Two-stage cleaning scheme in aerotanks without regeneration: 2 and 2a – aerotanks of I and II stages; 3 and 3a – secondary settling tank of I and II stages; 4 and 4a – purified water after I and II stages; 5 and 5a – circulating active sludge of I and II stages; 6a – excess active sludge of II stage

-air tanks- displacers – structures with concentrated intake of water and activated sludge in them and with a decreasing load on activated sludge along the structure (scheme I). This type of aeration tank allows for high quality cleaning, but is sensitive to sudden fluctuations in flow and composition of effluents;

-aerotanks-mixers with water and activated sludge supply evenly along one of the long sides of the aerotank (scheme II). The same load on the activated sludge is observed throughout the entire volume of the aeration tank. The advantage of the aeration tank mixer is the smoothing of volley loads on the activated sludge;

-aerotanks with a sewage inlet dispersed along the structure (scheme III). This species occupies an intermediate position between the two previous ones. The load on activated sludge varies cyclically along the length of the structure.

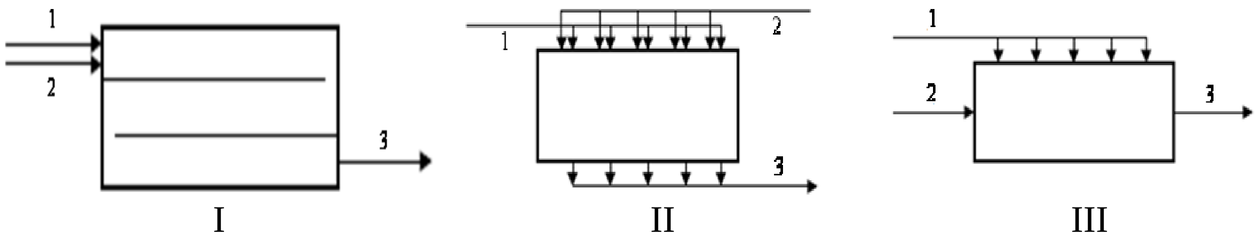


Fig. 54 Types of aerotanks: 1 – waste water; 2 – activated sludge; 3 – sludge mixture

Aerotanks-displacers without regenerators are recommended for cleaning urban and industrial wastewater close to them in composition with a BPCp of no more than 150 mg/l, with a BPCp of up to 300 mg/l, aerotanks-displacers with regenerators are used.

It is advisable to use aerotank mixers for the treatment of industrial wastewater with relatively small fluctuations in their composition and the presence of mainly organic substances in the water. In case of significant fluctuations in the composition and consumption of industrial effluents, it is necessary to use aerotank mixers with regenerators.

An aerotank with a dispersed wastewater supply is used to purify mixtures of domestic and industrial wastewater.

The most important structural element of the aeration tank is the aeration system. There are pneumatic, mechanical, combined (mixed) and jet (ejector) aeration systems.

With a pneumatic system, water aeration is carried out by supplying air under the surface of the water.

Depending on the type of aerator used, there are:

-fine bubble aeration with air bubbles of 1-4 mm in size. In this case, ceramic, fabric and plastic aerators are used;

-medium bubble aeration, the size of the bubbles is 5-10 mm. For this purpose, perforated pipes, slit aerators, etc. are used;

-large-bubble aeration with a bubble size of more than 10 mm. Pipes and nozzles open from the bottom are used.

In Russia, the most common type of fine bubble aerator is a filter plate made of porous vitreous material. These plates are embedded in reinforced concrete channels in the bottom of the aeration tank along its long side. The tank is equipped with air ducts, from which air is supplied through risers to filter channels closed by filters. Through such plates, fine bubble aeration of the mixture occurs in the aeration tank. The filter plate is made of chamotte (refractory clay, kaolin), which is connected by a mixture of liquid glass with fine fireclay dust. The size of the plates is 300×300 mm, the thickness of the plates is 35-40 mm. The average pore size of domestic filters is 100 microns.

The design of a typical four-corridor air tank displacer is shown in Fig. 55 and 56 (respectively, the plan and section).

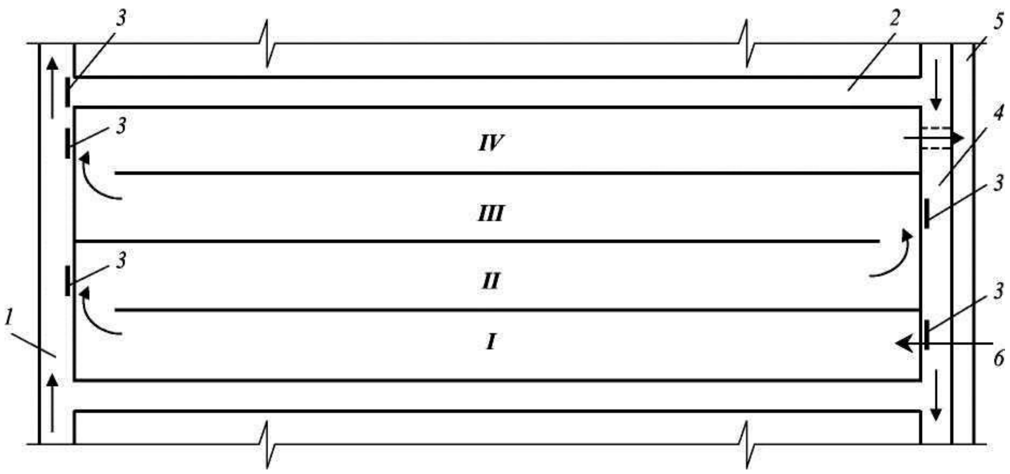


Fig. 55 Plan of a typical four–corridor aeration tank: 1 – upper distribution channel; 2 – middle channel; 3 – shield gate (gate); 4 – lower distribution channel; 5 – channel for collecting purified water; 6 – circulating active sludge; I...IV - corridors of the aeration tank

Figure 56 additionally shows the device of a filter channel with filter plates. When working without regeneration, wastewater passes through all four corridors, with 25% regeneration of activated sludge, corridor I works as a regenerator, and wastewater is supplied from the upper channel to corridor II. With 50% regeneration, corridors I and II are allocated for it, with 75% regeneration– corridors I, II and III.

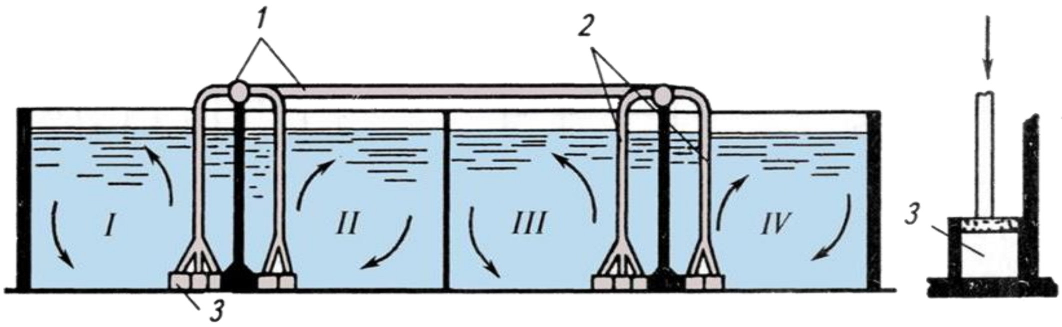


Fig. 56 Section of a typical four–corridor aerotank: 1 – air ducts; 2 – risers; 3 - filter channel

The disadvantage of filter plates is their clogging and biofilm overgrowth. The use of porous pipes avoids these difficulties. In addition, it is convenient to remove pipes from the water for repair in whole sections. Perforated pipes belonging to medium-bubble aerators are laid horizontally at the bottom of the aerotank. The pipes have holes with a diameter of 3-4 mm.

The disadvantage of leaky pipes is rust clogging. For large-bubble aeration, pipes with a diameter of 50 mm with open ends are used, lowered vertically down to a depth of 0.5 m from the bottom of the aeration tank.

Depending on the pressure generated at the outlet, aerators of low (up to 10 kPa), normal (10-50 kPa) and high (over 50 kPa) pressure are distinguished. The various types of aerators are shown in Fig. 57.

The principle of operation of mechanical aerators is to draw air directly from the atmosphere by rotating parts of the aerator (rotor) and mix it with the entire contents of the aerotank.

All mechanical aerators are classified:

-according to the principle of operation: impeller (cavitation) and surface;

-the planes of the rotor axis of rotation: with a horizontal and vertical axis;

-rotor designs: conical, disc, cylindrical, wheeled, turbine and screw.

Wastewater from the main sewage pumping station enters the receiving chamber of the treatment facilities. Next, the drains pass through grates and aerated sand traps. The waste from the grates is collected in a storage bunker, decontaminated and transported by road to a landfill for the disposal of solid household waste. Sand from the sand traps is removed by means of hydraulic elevators to the sand platforms for dewatering.

After the sand traps, wastewater enters the primary settling tanks, where suspended solids are removed. The raw sediment from the primary sedimentation tanks is raked with silt scrapers and pumped to the silt pads.

Then the clarified effluents undergo biological treatment in aerotanks. Secondary settling tanks are designed to separate biologically purified wastewater in aerotanks from activated sludge. The purified water after disinfection with liquid chlorine is discharged into a water body. The return (circulating) activated sludge is supplied by circulation pumps to the beginning of the aeration tank regenerator corridor, where it is restored, oxygenated and oxidized to hard-to-oxidize organic matter.

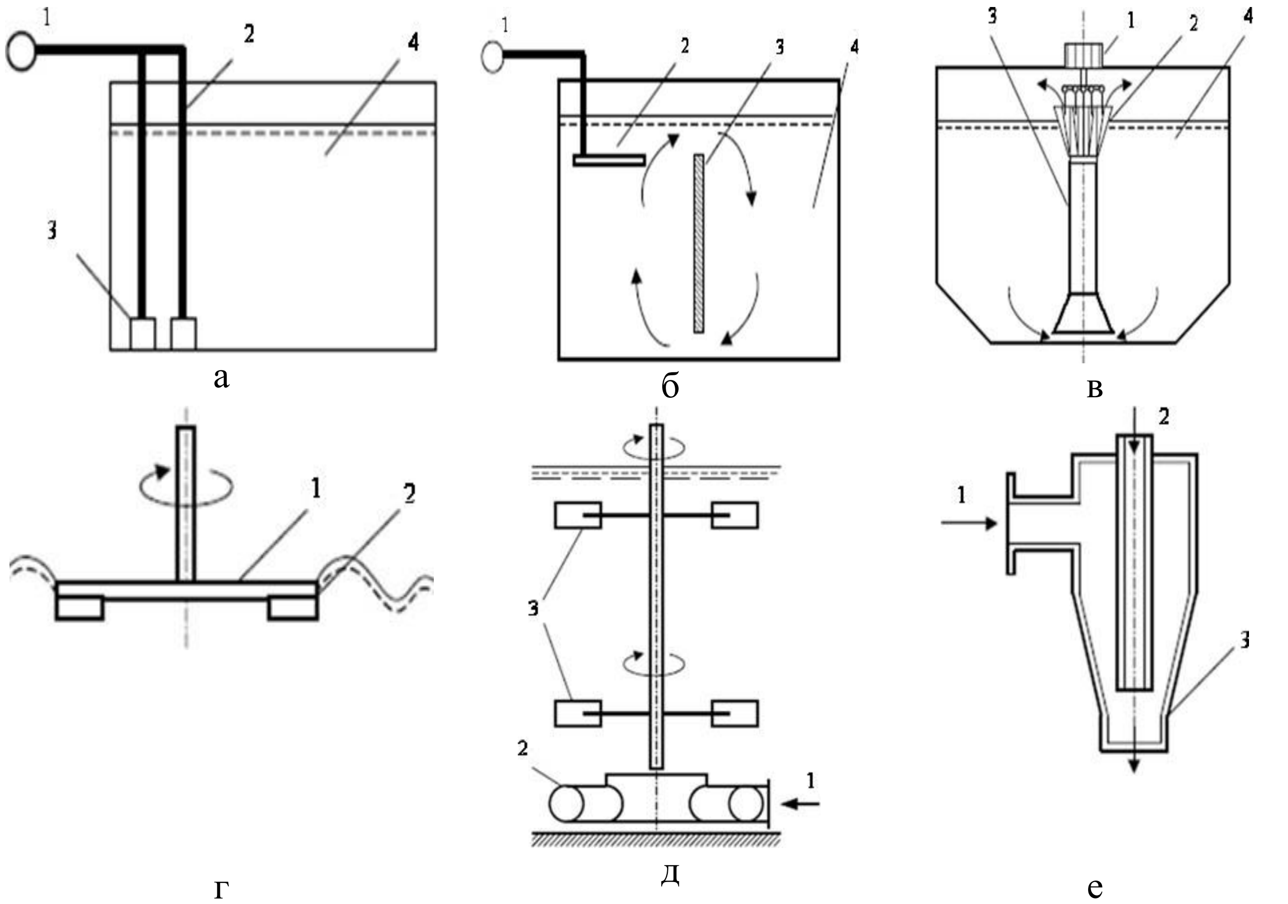


Fig. 57 Types of aerators: a – filter aerator: 1 – duct; 2 – riser; 3 – filter channel; 4 – aeration tank corridor; b – INCA system aerator: 1 – duct; 2 – grille; 3 – partition; 4 – aeration tank corridor; c – Simplex aerator: 1 – electric motor; 2 – cone with blades; 3 – hollow pipe; 4 – aeration tank corridor; g – disc aerator: 1 – disc; 2 – blades; d – pneumomechanical aerator type PM: 1 – air supply; 2 – annular air distributor; 3 – turbines with blades; e – jet aerator: 1 – waste water; 2 – air supply; 3 – compressed section

The silt compactor is designed to seal excess activated sludge, which is formed as a result of a constant increase in activated sludge in aerotanks. The compacted sludge is collected by scrapers of the silt scraper into the central pit, from where it is pumped to the silt pads by pumps located in the pumping station of the silt compactors. Silt sites are facilities for dewatering sewage sludge and compacted excess activated sludge. Clarified water from the silt pads is collected in an annular tray and pumped (automatically) to the head of the structures.

4.6 Thermal methods of wastewater treatment. The equipment used

Wastewater from different enterprises contains various mineral salts, as well as organic substances, among which there may be valuable components. As a rule, the content of impurities in them is low, and their direct extraction is irrational from an economic point of view. Therefore, wastewater undergoes a preliminary stage of concentration.

This method is mainly used for the neutralization of mineral wastewater. It allows the extraction of salts from wastewater to obtain conditionally pure water suitable for recycled water supply. The process of separation of minerals and water can be carried out in two stages (Fig. 58): concentration and separation of dry substances. In many cases, the second stage is replaced by the burial of concentrated solutions.

Wastewater concentration

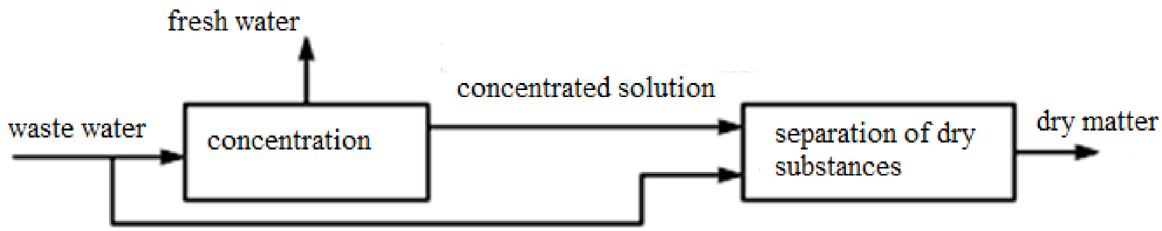


Fig. 58 Stages of separation of minerals and water

Concentrated wastewater treatment can be carried out in evaporative, freezing and crystallohydrate installations of continuous and periodic action. The classification of thermal concentration plants is shown in the diagram (Fig. 59).

The method of evaporation in special (evaporative) plants has become the most widespread. The resulting distillate of water is suitable for secondary use. The concentrate of impurities is subjected to burial or goes for further processing with the release of valuable components.

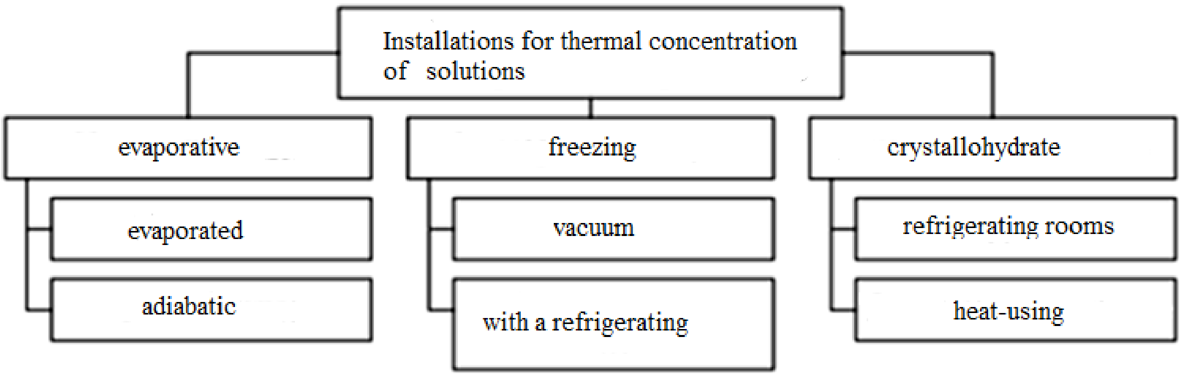


Fig. 59 Classification of thermal concentration plants

During evaporation, a large amount of thermal energy is consumed, so the issue of heat recovery is given special importance

Thermal neutralization of gas emissions can be carried out both by purely thermal methods and thermochemically.

Thermal methods of processing gas emissions, the basis of which is a change in the thermal state of interacting media, include heating, cooling and condensation of gaseous media. The driving force of these processes is the temperature difference (thermal potentials) of the interacting media.

Thermochemical neutralization, which proceeds with a change in the physical properties and chemical composition of the initial pollutants in gases, is characterized by the transformation of these substances into relatively harmless ones. These processes include homogeneous and heterogeneous catalysis processes, as well as direct combustion of organic impurities in gases.

The driving force of chemical processes is the difference in chemical (thermodynamic) potentials. Chemical transformations in such processes are developed under the influence of changes in the external conditions (temperature) in which the process is implemented.

Thermochemical methods of direct and catalytic combustion are used to neutralize industrial gas emissions. The direct combustion method is used to neutralize industrial gases containing easily oxidizing organic impurities, such as hydrocarbon vapors. The combustion products of hydrocarbons are carbon dioxide and water, and organic sulfides are sulfur dioxide and water.

A system containing toxic substances can be neutralized by heat treatment if the reactions occurring in it lead to the formation of less toxic components.

The process of cleaning gases in surface condensers

Condensation treatment of waste gases is usually included in the technological cycle if the process is accompanied by significant losses of intermediate or final products. Often, by condensation, solvent vapors are captured and returned to the technological process, which are removed from the surface of products after applying functional, protective and coloring layers.

Sometimes condensation is used to extract valuable (expensive) or especially dangerous substances from the gas stream. With economically and technically acceptable parameters of the working medium, vapors of low-boiling compounds (usually used as solvents) with concentrations of at least 5-10 g/m3 can be condensed. Condensation of more dilute pollutants is a technically difficult task and requires significant costs.

The degree of capture (extraction depth) of the pollutant depends on the degree of cooling and compression of the gas emissions. In production conditions, the temperature and pressure are assumed such that the energy consumption for condensation is a small fraction of the total cost of the technology. Therefore, the degree of extraction of even expensive products is prescribed low, usually in the range of 70 ... 80%. For the same reason, it is unacceptable to use condensation as an independent means of sanitary cleaning (i.e. with a depth of extraction up to sanitary standards).

At the same time, condensation treatment can be successfully applied in multi-stage emission purification schemes.

There are three areas in the field of gas purification where condensation is not only useful, but also necessary:

-pre-deposition of the bulk of the pollutant vapors in front of the adsorbers with a high degree of emission pollution;

-partial extraction of vapors containing compounds of phosphorus, arsenic, heavy metals, halogens before thermal decontamination of a mixture of pollutants;

-condensation of pollutants after chemical treatment in order to convert them into easily condensable compounds, for example, after chemisorption devices.

Condensation can be used to treat systems containing vapors of substances at temperatures close enough to their dew point. This method is most effective in the case of hydrocarbons and other organic compounds having sufficiently high boiling points under normal conditions and present in the gas phase in relatively high concentrations. To remove pollutants that have a sufficiently low vapor pressure at normal temperatures, water- and air-cooled condensers can be used. For more volatile solvents, two-stage condensation is possible using water cooling in the first stage and low-temperature cooling in the second. The maximum reduction in the content of inert or non-condensing gases in the treated mixture makes it easier to carry out the concentration process and increase its economic efficiency, since it makes it possible to eliminate the need for cooling to very low temperatures corresponding to the dew point.

If the gas needs to be cooled to a temperature 40...50 K below the dew point in order to achieve the required removal of pollutants, then fog formation may begin during condensation in the mass of the gas stream. The particle sizes of this mist are usually 1.0 microns or even smaller, which makes it difficult to capture.

Fog is formed when the heat transfer rate significantly exceeds the mass transfer rate and the bulk of the gas is cooled to a temperature well below the dew point of the condensed vapor. Condensation centers then arise in the steam and the process of condensation of droplets in the bulk of the gas stream begins even before the steam reaches the cold surface. In condensers with direct contact, fog is rarely formed, since the mass of gas is very close to cold heat-conducting surfaces (droplets or films of liquid).

The formation of fog in surface condensers can be predicted by calculating the rates of heat and mass transfer during the passage of gas through the condenser. If the mass of the gas stream becomes supersaturated at a given temperature, then the formation of fog is likely. Condensation with direct contact should be used to prevent fog.

Another method is to cause fog formation in advance and remove it using an appropriate device (electrofilter, Venturi scrubber, appropriate filters).

Condensation can be used for pretreatment of gases, in which valuable solvents are released and the amount of pollutants is reduced before the subsequent processing stage. Partial condensation can be used in cases where the treated gas is not discharged, but is returned to the process or used in the afterburning process. Pretreatment by condensation is advisable in cases where the gas stream needs to be cooled before the main treatment, for example, during adsorption.

There are two types of condensation:

-surface (or simply condensation), in which the condensing vapors and the cooling agent are separated by a wall and vapor condensation occurs on the inner or outer surface of the cold wall;

-condensation by mixing, in which the condensing vapors come into direct contact with the cooling agent.

If vapors of liquids insoluble in the cooling agent (water) or steam that is an unused waste product of a particular process are subjected to condensation, cooling and condensation of these vapors can be carried out by direct mixing with the cooling agent (water).

The efficiency of the mixing capacitors is directly dependent on the contact surface of the cooling agent and steam, therefore, the contact surface is increased by spraying the cooling agent using various devices.

Types and designs of capacitors.

According to the method of interaction of the cooling and cooled medium, capacitors are divided into:

- contact information,
- superficial.

In contact condensers, the cooled gases and the coolant are mixed, and in surface condensers they are separated by a solid wall.

Contact devices are similar in design and calculation methods to absorption devices.

Condensation by mixing is carried out in mixing condensers.

Depending on the method of flow devices, there are:

-wet,

-dry mixing capacitors.

In wet condensers, the cooling agent, condensate and non-condensing gases (air) are removed from the lower part of the apparatus together using a wet-air pump, in dry condensers, the cooling agent and condensate are removed from the lower part of the apparatus, and the air is sucked out by a vacuum pump from the upper part.

In addition, there are direct-flow mixing condensers in which the cooling agent and steam move in the same direction (from top to bottom), and countercurrent ones in which steam and cooling agent move in opposite directions (agent from top to bottom, and steam from bottom to top).

Surface condensers are similar in design to other types of surface heat exchangers - heaters, refrigerators, evaporators (Fig. 60).

Shell-and-tube condensers with many pipes can be arranged vertically or horizontally. Condensed gases are usually directed into their inter-tube space, and the coolant is sent into the tube space.

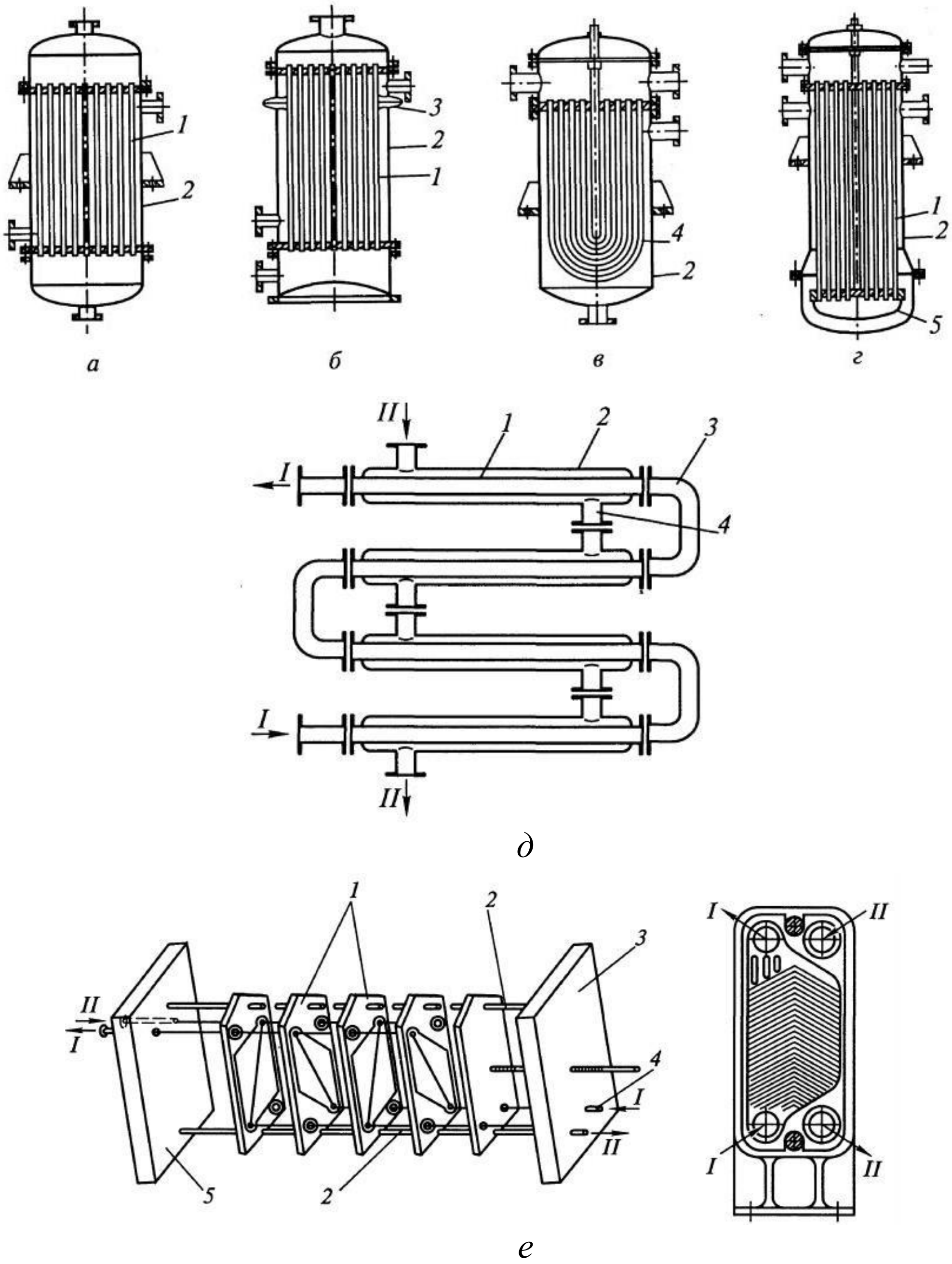


Fig. 60 Designs of heat exchangers-condensers: a - with rigid fastening of pipes in pipe grids; b - with a lens compensator on the body; c - with U-shaped pipes; d - with a lower floating head; d - heat exchange of the "pipe in a pipe" type: 1, 2 - pipes; 3- "roll"; 4 - branch pipe; I, II - heat carriers; e - plate heat exchanger: 1 - plates; 2 - beam; 3, 5 - movable and fixed plates; 4 - pipe; I, II - heat carriers

Multi-tube capacitors are more complex in design and have two varieties:
-type H with a fixed grid (fig. 60, a) is designed for conditions that do not require compensation of temperature stresses;
-type K (fig. 60, b) has a lens compensator on the casing.

Floating-head capacitors are even more advanced, but structurally quite complex (Fig. 60, d). Heat exchangers with U- and W-shaped tubes (Fig. 60, c) have good compensation characteristics and are simpler in design, but they are not used as capacitors.

For devices of type H, depending on the material, diameter and pressure, a maximum temperature difference of 20 between the cooling and cooled media is allowed...60 °C. With a greater temperature difference, K-type or floating-head devices are used. The maximum pressure for type K capacitors is 1.6 MPa, and for floating-head capacitors up to 1 MPa in the tube and 12.5 MPa in the inter-tube space. All elements of shell-and-tube capacitors (pipes, partitions, casing, etc.) can be made of carbon or alloy steels. The simplest are "pipe-in-pipe" type capacitors (fig. 60, e), which are manufactured according to standards or individual projects.

Plate capacitors are easier to manufacture, have lower resistances and are less metal-intensive. Batch plate heat exchangers are made of thin metal sheets in the form of multilayer collapsible, semi-collapsible or non-collapsible packages. In collapsible structures (Fig. 60, e), plates 1 are assembled between movable 3 and fixed 5 plates on coupling devices with sealing by means of large and small gaskets made of heat-resistant rubber. In semi-collapsible or non-collapsible structures, the plates are partially or completely welded together. Collapsible structures are used at operating pressures up to 1 MPa within the temperature range of -20...180 °C, welded - at pressures up to 4 MPa.

Purification of gas emissions in catalytic reactors

Thermal oxidation of gaseous pollutants can occur in the gas phase (in volume) or at the interface (on the surface). The gas-phase process is carried out by direct fire treatment (flame burning) of gas emissions at temperatures exceeding the ignition temperature of the combustible components of the emissions.

Catalysts are used to organize the oxidation process at the interface.

Catalysts are substances that accelerate chemical reactions, actively participate in them, but in the end they themselves are not consumed.

Reactions under the action of catalysts are called catalytic.

Inhibitors are substances that slow down the rate of a chemical reaction.

The phenomenon of acceleration of a chemical reaction is called catalysis, and deceleration is called inhibition.

In the process under consideration, catalysts are condensed substances capable of accelerating the oxidation of a particular pollutant at temperatures below the ignition temperature due to the activity of surface particles. Catalytic methods of gas purification are based on heterogeneous catalysis and serve to convert impurities into harmless or easily removed compounds from the gas.

The peculiarity of the processes of catalytic purification of gases is that they occur at low concentrations of impurities to be removed. The main advantage of the method is that it provides a high degree of purification, and the disadvantage is the formation of new substances that must be removed from the gas by adsorption or absorption.

The peculiarity of the processes of catalytic purification of gases is that they occur at low concentrations of impurities to be removed. The main advantage of the method is that it provides a high degree of purification, and the disadvantage is the formation of new substances that must be removed from the gas by adsorption or absorption.

Thermocatalysis is unacceptable for the treatment of gases (vapors) of high-molecular and high-boiling compounds, which, poorly evaporating from the catalyst, are coked, i.e. they fill the active surface with soot products of incomplete oxidation.

The temperature level of the thermocatalytic oxidation process is in the 350 range...500 ° C, which requires appropriate fuel costs.

Heterogeneous catalysis processes take place on the surface of catalyst solids. Catalysts must have certain properties: activity, porous structure, resistance to poisons, mechanical strength, selectivity, heat resistance, low hydraulic resistance, have a small cost.

Metals or metal oxides are usually used as catalysts. The best catalysts are developed on the basis of noble metals, and among others, the most active catalysts are from oxides of cobalt, chromium, iron, manganese, nickel, etc. However, they have lower activity than noble metal catalysts, as well as low chemical and thermal resistance.

Usually, activating components are applied to neutral heat-resistant media (porcelain or chamotte in the form of tablets, balls, granules; nichrome wire mesh). Catalysts are selected individually for each specific case, taking into account their cost, physico-chemical properties and concentrations of pollutants, emissions, the presence of catalyst poisons, and other conditions. There are no universal catalysts.

Catalytic oxidation is used to remove sulfur dioxide from flue gases, and catalytic reduction is used to neutralize gases from nitrogen oxides. Oxidation is carried out on a vanadium catalyst at 450 ... 480 ° C. After oxidation, the gases are sent for absorption.

Catalytic reduction of nitrogen oxides is performed to elemental nitrogen in the presence of a gas reducing agent. Methane, coke oven and natural gas, carbon monoxide, hydrogen, and ammonia are used as reducing agents. The catalysts are platinum metals, palladium, ruthenium, platinum, rhodium or alloys containing nickel, chromium, copper, zinc, vanadium, cerium, etc. The degree of purification reaches 96%.

The use of each catalyst has certain temperature limitations. Exceeding the temperature leads to its destruction. Overheating of the catalyst most often occurs due to the instability of the content of oxidized components of waste gases, the concentrations of which usually change several times during the technological cycle from zero to a maximum, sometimes reaching several tens of grams per cubic meter of emissions.

To protect against overheating, it is necessary to equip decontamination plants with automatic control of the supply of energy (usually gas fuel), depending on the concentration of the pollutant. The automation system is based on the specifics of specific technological processes and is developed individually.

Structurally, thermocatalysis plants usually consist of a furnace with gas burners and a reactor in which catalytic nozzles are placed (Fig. 61 and Fig. 62).

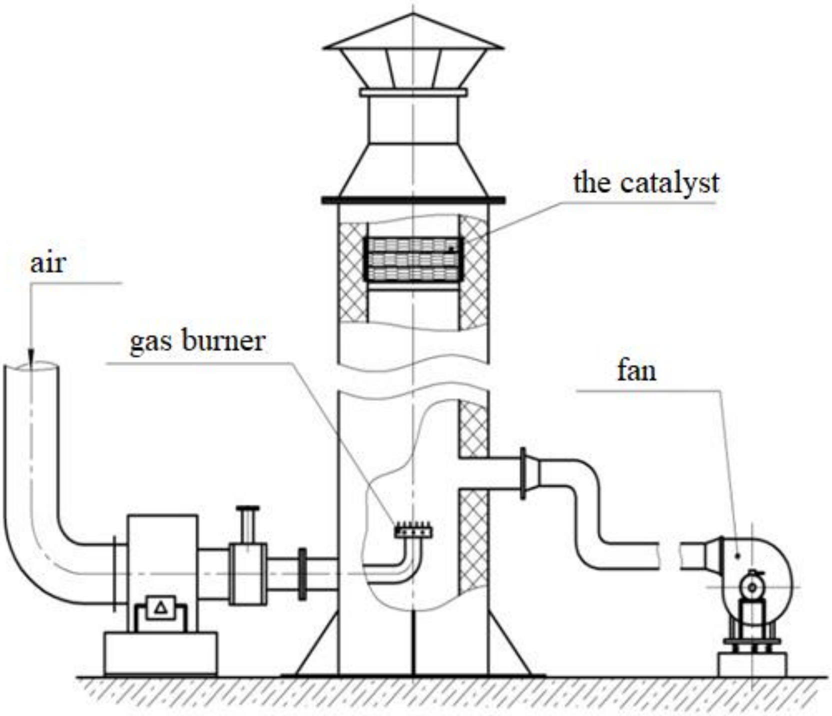


Fig. 61 Installation of catalytic neutralization of gases: 1 – catalyst; 2 – contact apparatus; 3 – furnace

The design of a thermocatalytic neutralization plant is reduced to the selection of designs and sizes of furnace and burner devices, the type of catalyst and the method of its placement in the reactor. Hydraulic calculations of air ducts, gas pipelines, chimneys are also performed, fans and smoke pumps are selected.

The amount of fuel gas is determined by the temperature of the thermocatalytic neutralization process, which is found experimentally or according to current analogues. The size of the reactor depends on the number of processed emissions and the volume of the catalyst mass.

The last parameter can be determined only experimentally or according to information about existing analogues that actually provide the required degree of purification. Information of this kind can be considered reliable if it is obtained by a specialist upon direct acquaintance with the current installation.

The supply of the treated gases is usually set in the form of a flow rate, m^3 / h, per 1 m^3 of catalyst mass. This characteristic is called the processing speed and is used to compare the throughput of reactors. With increasing processing speed, the degree of conversion of the initial pollutants decreases. Their transformations will not reach the final stage with harmless products - CO2 and H2O, but will stop at any of the intermediate stages of oxidation with the formation of compounds possibly more dangerous than the initial ones.

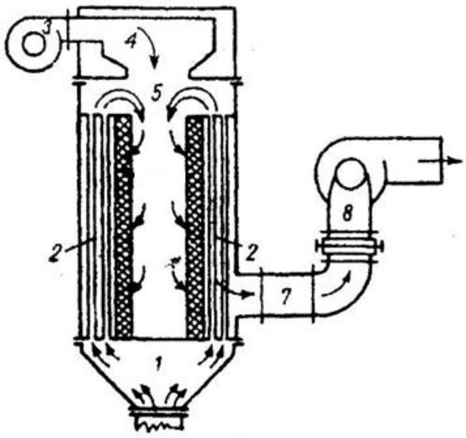


Fig. 62 Diagram of the installation of catalytic combustion of gas waste from the production of lacquers: 1 – distributor; 2 – heat exchanger; 3 – fan; 4 – combustion chamber; 5 – mixing chamber; 6 – catalyst; 7 – flue gas; 8 – adjusting gate

Installations for thermal decontamination of gas emissions

The gas-phase thermal oxidation process is carried out by direct fire treatment (flame burning) of gas emissions at temperatures exceeding the ignition temperature of the combustible components of the emissions.

By fire treatment, as well as by thermocatalytic oxidation, it is fundamentally possible to neutralize only substances whose molecules do not contain any other elements except hydrogen H2 carbon C and oxygen O. By burning, it is possible to neutralize these substances in gaseous, liquid and solid states.

Pollutants containing any elements other than H, C and O - sulfur S, phosphorus P, halogens, metals, etc., cannot be submitted to thermal oxidation treatment, since the combustion products will contain highly toxic compounds. In real conditions and during the combustion of purely organic compounds, it is not possible to ensure absolutely complete oxidation of the initial components to practically harmless carbon dioxide CO2 and water vapor H2O. Carbon monoxide CO and other products of chemical underburning (incomplete oxidation) are always present in flue gases. In addition, at elevated temperatures, the oxidation reaction of nitrogen, which enters the combustion zone with fuel and air, is noticeably accelerated. Gorenje Some nitrogen oxides have harmful effects on the human body and the environment.

The possibilities of the thermooxidation method of neutralization are also limited by the amount of waste gases and the content of combustible components in them. If the concentration of the combustible components of the emissions does not reach the lower ignition limit ("fuel-poor" emissions), then their fire treatment requires additional fuel consumption to warm up the emissions to the self-ignition temperature, which for hydrocarbon vapors and oxygen derivatives of hydrocarbons is about 500...750 °C.

When choosing methods of neutralization, the approximate amount of waste gases "poor" in fuel, which can be subjected to thermal oxidation treatment with acceptable fuel consumption, can be taken no higher than 1.5...2 m^3/s.

For large emission sources with low pollutant content, a combined two-stage purification with preliminary concentration of combustible components to the lower ignition limit is a more optimal solution. Subsequent fire treatment of such emissions becomes economically acceptable. The effect of combustible components on combustion parameters becomes noticeable at concentrations above 50 -100 mg/m^3.

Gases are burned in installations with an open torch or in furnaces of various designs. Direct combustion is carried out at 700...800 ° C using gaseous or liquid fuels. For combustion, an excess of oxygen is required by 10... 15% more than the stoichiometric amount. If the heat of combustion of hydrocarbons is sufficient for the heat of reaction to exceed 1.9 MJ/m^3, the gases are also flared. To ensure that the flame of the torch is not smoky, water is added in the form of steam. In this case, the reaction of water vapor with hydrocarbons occurs, accompanied by the formation of hydrogen and carbon monoxide.

If the concentration of combustible gases is low and the heat generated is not enough for the combustion reaction, then the gases are preheated. To ignite the main burner, a standby burner running on natural gas is provided in all installations.

There are several types of flare installations. They can be factory–wide, where similar gas emissions from a variety of industries are burned - for example, they can be hydrocarbons.

Flare installations can also be special, which are located as part of separate technological productions or installations.

There are also different designs for flare installations - these are installations, Fig. 63:

- open,
- closed type.

An open flare system is a rectilinear passage of gas through a barrel that is placed vertically and its height is no more than four meters.

Closed systems, which are often called ground torches, thermal oxidation torches, are well suited for densely populated areas.

They are made in a mobile form, horizontal, very rarely high-rise, on tripods. That is why they are called a ground flare installation.

a b

Fig. 63 Flare installations

Closed-type flare installations are used for smoke-free disposal of emergency, permanent, periodic discharges. Since oil refineries are often located near populated areas, closed flare systems are usually used.

This is due to their advantages:
- no smoke, visible flame, steam and odor;
- low noise level;
- controlled and small emissions;
- there is no heat plume;
- simple control system, easy access;
- easy maintenance;
- no thermal radiation;
- reliable and, most importantly, safe disposal of any waste.

Special safety measures must be taken when burning hydrocarbons in ground-based flare installations.

In this case, the flare burner is installed in a bowl about 2 m high and the composition of the gas contained in it is constantly monitored to prevent the leakage of hydrocarbons into the environment.

To eliminate the danger of ignition of gases and vapors released from safety valves and technological installations, as well as harmful effects on personnel of thermal radiation of the flame, a free zone is provided around flare installations. Usually, a zone with a radius of at least 50 m is required for ground flare installations, and for high–altitude installations with a radius of 30-40 m.

A closed installation can have two options for heat recovery – either preheating the waste stream for subsequent combustion, or a boiler for the formation of water vapor.

The flare installation consists of the following elements:
- barrel;
- the headpiece;
- automation system;
- stairs;
- service platforms;
- gas expander;
- a tank with a pumping pump, with a set of fittings and automation equipment.

According to the location of the flare burner, flare installations are divided into:
- high-rise,
- ground-based.

And also:
-vertical and horizontal, fig. 64

In high-altitude flare installations, the flare burner is located in the upper part of the flare tube; combustion products enter the atmosphere immediately.

In ground installations, the burner is located a short distance from the ground, and the combustion products are discharged into the atmosphere through a chimney.

High-altitude flare installations can be divided into:
-medium (4-25 m),
-high (more than 25 m).

a b

Fig. 64 Flare installations by location

In some flare installations, the flare height is 80-120 m.

Flare installations are used at oil and gas industry facilities:

- low pressure – for maintenance of workshops and installations operating under pressure up to 0.2 MPa;

- high pressure – for maintenance of workshops and installations operating under pressure above 0.2 MPa.

Flare gases from low and high pressure systems can (if possible) be collected in a gas tank for further targeted use (at a chemical enterprise).

A gas tank is a tank for storing gaseous substances, such as natural gas, biogas, liquefied petroleum gas, air, etc.

There are gas tanks of variable and constant volume, as well as stationary and mobile ones.

The following requirements are imposed on flare installations:

-completeness of combustion, excluding the formation of aldehydes, acids, smoke, soot and other harmful intermediates;

-stability of the torch when changing the flow rate and composition of the discharged gases;

-safe ignition, noiselessness and no bright glow.

In practice, various flare systems are used:

- a system with the discharge of gases into a flare pipe, fig. 65.

-a system for high-pressure gases with the selection of flare gases for processing or for combustion in boiler plants, Fig. 66.

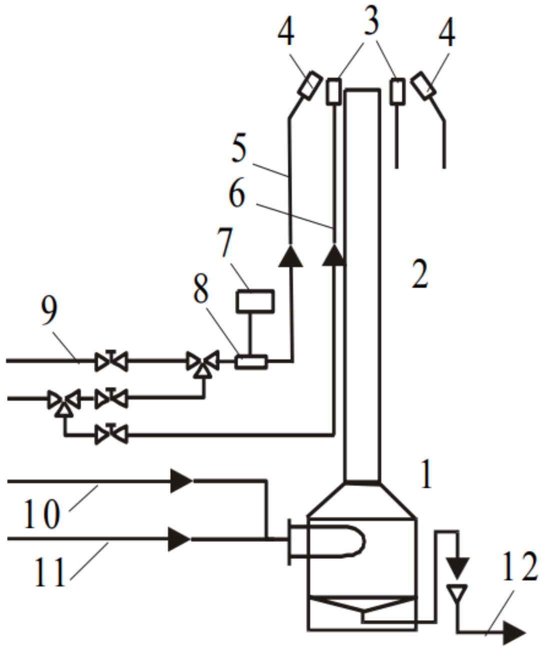


Fig. 65 The gas discharge system into the flare pipe: 1-separator, 2- flare pipe, 3-standby burner, 4- ignition burner. I - discharge (flare) gas, II- nitrogen for purging, III- fuel gas, IV- air, V- condensate.

The discharged gases pass through the separator before entering the flare pipe. Condensate from the separator is returned to production or disposed of in another way or drained into the sewer.

The flare tube is equipped with on-duty and ignition burners. Such a system is used when gases are not disposed of (or are not subject to disposal) or when the pressure at technological installations is not sufficient to supply the discharge (flare) gas to the gas tank.

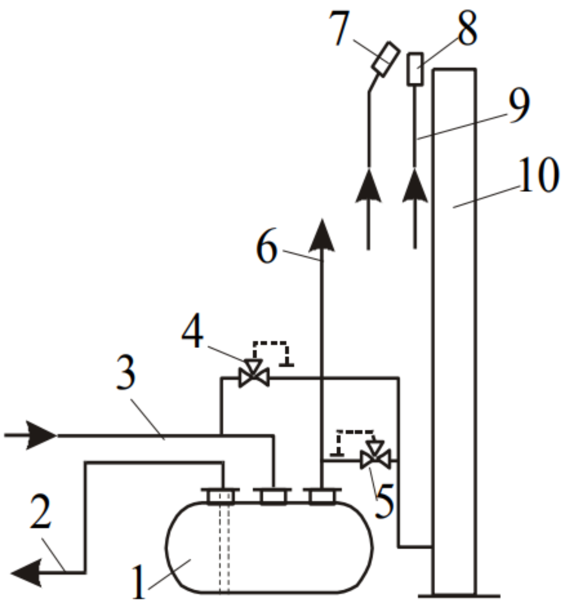


Fig 66 System for high-pressure gases with the selection of flare gases for processing or for combustion in boiler plants: 1-separator, 10- flare pipe, 8-standby burner, 7- ignition burner, 4- control valve. I-waste gas, II- gas to the consumer, III-condensate

In the second type of systems, gases enter the separator, where they are separated from the condensate. The bulk of the gas is sent to the consumer, and the excess is discharged into the flare pipe through a control valve.

Exposure to thermal radiation from flares is extremely dangerous for humans, animals and the entire environment. Vegetation is dying within a radius of 50-100 m from the torch.

The safety of operation of flare installations depends on the correct choice of operating parameters: the diameter of the torch barrel, which should ensure a stable flame under conditions of variable composition and consumption load; the height of the trunk and the distance around the trunk at which thermal radiation will be safe.

Thermal oxidation neutralization of concentrated gases is carried out in installations, which usually consist of furnace and burner devices with flues for the removal of combustion products and heat exchangers.

The design of the neutralizer must ensure the neutralization of the toxic product. To do this, its residence time in the neutralizer is 0.1 ... 1.0 C. The combustion temperature is 100 ... 150 ° C higher than the self-ignition temperature.

The designs of furnace devices for heat treatment furnaces can be divided into chamber, cyclone, shaft and drum. The most common are vertical and horizontal chamber structures (fig. 67), as well as cyclonic horizontal structures.

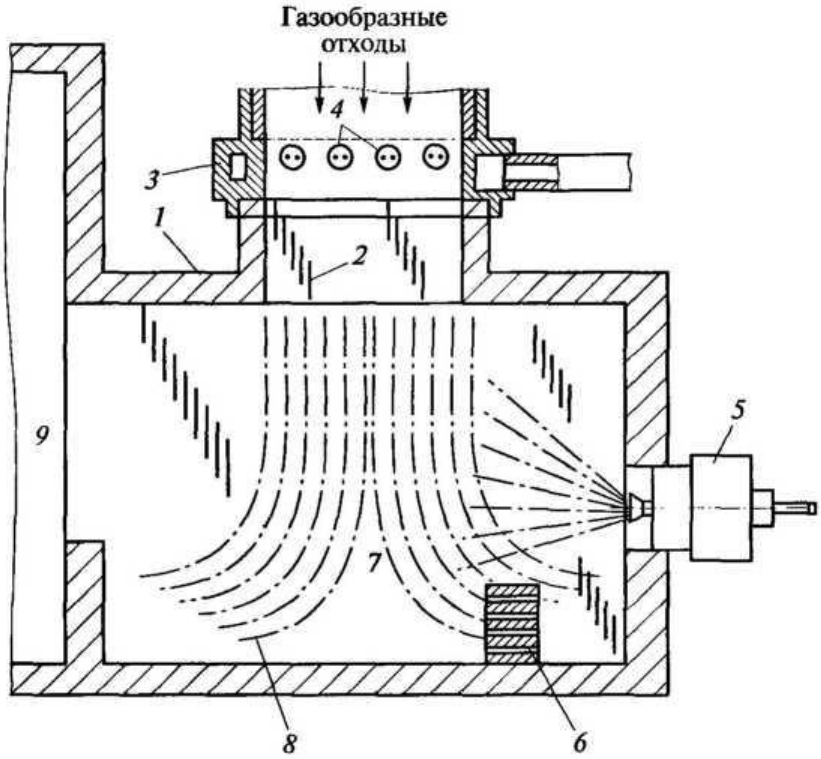


Fig 67 Furnace for burning gaseous waste: 1 – furnace body; 2 - hole; 3 – collector; 4 – gaseous waste; 5 – distribution pipes; 6 – front wall; 7 - burner; 8 – perforated wall; 9 - under; 10 - chamber; 11 – chamber for disposal heat

In cyclone furnaces, the rotational and translational movement of gorenje products is organized, which ensures a longer residence time of the treated gases than in chamber furnaces of the same dimensions. The latter are usually designed as one- or two-way flue gases. They can be rectangular or circular in cross-section. Vertical rectangular structures have a worse filling of the furnace volume with flue gases compared to horizontal round-section furnaces.

In chamber furnaces, it is possible to install additional vaults that increase the temperature in the reaction zone, which cannot be performed in cyclone furnaces. Ultimately, the design and dimensions of the furnace device are such as to ensure the required residence time of waste gases in the high temperature zone.

The type of burner device for thermal decontamination plants and the waste gas supply scheme are selected depending on their composition.

Gas emissions with a high oxygen content, which can be used as blast air, are most advantageously supplied to the air paths of blast gas burners.

Fuel-rich gas emissions with low (or no) oxygen content can be fed directly into the gas and air paths of blast burners.

Injection type burners are practically unsuitable for these purposes due to the instability of the emission composition. At the same time, injection burners running on fuel gas of stable composition are used as pilot (combustion-supporting) devices. gorenjeutsionnye gorenjeutsionnye gorenjeutsionnye gorenjeutsionnye gorenjes. The high temperature in the combustion zone of such burners ensures thermal oxidation of the pollutant with fluctuations in the composition of the treated gases. Gorenje In addition, they do not require the cost of electricity to supply gorenje air.

The completeness of thermal oxidation of organic pollutants depends on the process temperature, the residence time of the pollutant particles and oxygen in the high temperature zone, the thermal stress of the furnace volume, the physico-chemical properties of pollutants, the parameters of the state and composition of waste gases, as well as many other factors.

CONCLUSION

Environmental pollution is a serious problem. As the population grows and production develops, the environmental consequences become more significant.

Engineering environmental protection is one of the conditions for improving safety and quality of life.

Currently, the scientific interests of scientists and technologists are aimed at the development of low-waste and resource-saving technologies (whose tasks include the creation of production with a minimum amount of waste, the harmful effects of which do not exceed the permissible sanitary and hygienic standards), as well as the economical use of natural resources.

Greening production is a complex and time-consuming process. Its basis is the improvement of technologies, the development and modernization of wastewater treatment plants, waste minimization, which requires scientific research, practical implementation and training of competent personnel.

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