Analysis of the features of activated sludge biocenosis in aeration tanks at wastewater treatment plants

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Abstract. Application of the method of microscopy and visual analysis of the composition of activated sludge in aeration tanks. The advantage and ease of use of the microscopy. Detection of violations in the biocenosis of activated sludge at early stages. Characteristics and diversity of microorganisms in activated sludge. Consequences of accidents at sewage treatment plant.

1. Introduction

In the modern world, the problem of environmental protection is acute. One of the many factors that affect pollution, is the quality of wastewater treatment. Waste water is supplied to treatment facilities from localities (household), industrial enterprises, and the agricultural sector, after which it is subjected to physical, chemical, and biological treatment. The most important role in the biological treatment of wastewater is played by microorganisms in the activated sludge. The degree of wastewater treatment before discharge into the reservoir depends on its quality. Any failures in the operation of the treatment plant systems can lead to accidents with subsequent deterioration of the environmental situation of the surrounding areas [1].

Periodically, reports appear in the media that feces and dead fish are found in reservoirs near treatment facilities. In this regard, investigations are being conducted to clarify the circumstances and detect the source of contamination. A similar case occurred in the Kursk region, in 2019 (figure 2). Residents reported a massive sea of fish in the Seim river, feces and an unpleasant smell. As it turned out, the accident was associated with the discharge of waste water wastewater from a textile enterprise exceeding the maximum permissible concentrations of toxic substances, which caused the death of activated sludge in the settling tanks and aeration tanks of treatment facilities [2].
The activated sludge ecosystem has a complex structure consisting of unicellular and multicellular microorganisms. Microbiological research of activated sludge shows that the dominance of one type species of organism over others may indicate problems in the composition of wastewater supplied to treatment facilities the treatment plant. Since some microorganisms are able to tolerate various extreme environmental conditions – the presence of heavy metals, petroleum products, surfactants, toxins, and others, the species diversity or death of one species of organisms may indicate a sharp discharge of harmful substances into wastewater. As a rule, as a result of such discharges, the only inhabitants of aeration tanks are bacteria. Unlike other macro- and micro-organisms, they are able to adapt to extreme environmental conditions and adapt to new food sources [3].

In order to adapt to the current prevailing living conditions, bacteria combine into flocules due to their villi located on the body, and the villi allow attracting other bacteria at considerable distances (figure 2). Only flocculation of bacteria ensures high activity of aerobes, microphiles and anaerobes at any point of the water space of the aeration tank, regardless of the water saturation with oxygen [4].

At first, the bacteria randomly attach to each other, forming young flocules. Over time, the maturation of flocules occurs – the process of redistributing the location of bacteria: anaerobic bacteria are fixed in the center, and aerobic bacteria are fixed outside. The best way to determine the quality of flocculation or the structure of activated sludge is by the sampling method, followed by microscopic analysis of activated sludge in a activated sludge in a bright field and obtaining photos or videos.

Figure 1. Photo of the Seim river after the accident in 2019 [2]
The following species of aquatic organisms of activated sludge are single-celled microorganisms (figure 3). They play an important role, as they regulate the number of bacteria in the activated sludge, make flocules less mobile, which eventually contributes to the deposition of activated sludge. Unlike bacteria, unicellular organisms do not participate in the destruction and consumption of pollutants in wastewater, but they have the ability to oxidize toxic substances, making them non-toxic. The first sign of a malfunction in the activated sludge or its poisoning is the absence or death of single-celled microorganisms [5].
The chain of activated sludge biocenosis is completed by multicellular, called "predators". They have the ability to consume almost all of the smaller inhabitants. The number of organisms primarily depends on the availability of suitable food and competition for it between species. The presence of multicellular organisms in the activated sludge indicates good operation of biological wastewater treatment facilities, proper operation of aeration tanks and sufficient aeration. With their appearance, the biocenosis is considered more developed, stable and less susceptible to destruction [6].

Multicellular inhabitants of activated sludge (figure 4):
- Rotifers represented in the activated sludge biocenosis by the genera Rotatyria, Philodina, Cathypna, Monostyla, and Notommata. Since a rotifer from living organisms can only be killed by rotiferophthora parasitic fungi, so other inhabitants of active silt activated sludge do not cause them much any special harm. However, for all their endurance, rotifers do not tolerate high concentrations of certain chemicals.
- Nematoda roundworms. In a well-functioning biomass of activated sludge, nematodes develop in small quantities, since they prefer stagnant zones. High abundance may indicate insufficient aeration or mixing of activated sludge. When the silt mass is digested by nematodes, the activated sludge flakes

![Figure 3. Some representatives of single-celled organisms in activated sludge](image)
are well mineralized and enlarged. However, too active exposure to nematodes can lead to excessive loosening of the structure of activated sludge.

- Small-scale aelosomaworms that feed mainly on activated sludge bacteria. They have a clearly marked anterior section, as well as the structure of the digestive and reproductive systems. Under the influence of their digestion, activated sludge flakes are well mineralized and compacted, so they have a positive effect on the working properties of activated sludge.

- Gastropod worms or gastrotricha Gastrotricha is rare, but occurs in active silt activated sludge with prolonged aeration. They feed on bacteria, protozoa and detritus using oral cilia or by sucking in a pharynx that works as a pump. Reproduction of gastrotrichs is an indicator of under-loaded silts sludge, high mineralization, and deep cleaning.

- Tardigrades. Their food consists of protozoa, rotifers and nematodes, that is, they represent a higher stage of evolution of predators of the active silt activated sludge biocenosis. Under unfavorable conditions, they can fall into suspended animation while inside the capsule, and only come out of it when they are finished. Therefore, the presence of slow-moving plants is an indicator of a high degree of purification and nitrification of treated wastewater.

Dangerous substances for multicellular microorganisms in the composition of activated sludge are: formaldehydes, alkalis, chlorides, nitrates. A very wide range of chemical, synthetic, and organic substances gets into wastewater from settlements and industrial enterprises, which in turn, when mixed, can give a variety of chemical reactions, releasing toxic substances that exceed the maximum permissible concentrations of dangerous compounds.
Activated sludge has an important feature—it is self-cleaning ability and sufficient resistance to chemicals contained in wastewater, since the biocenosis of hydrobionts is formed on the basis of available nutrients, and microorganisms adapt to the specific composition of wastewater treatment plants. Sometimes in the waste water wastewater are substances that are toxic to organisms in the sludge. Sometimes substances that are toxic to sludge organisms get into wastewater. The concentration of substances familiar to the organisms of silt sludge increases tenfold with salvo emissions of enterprises. In these cases, hydrobionts of activated sludge can’t cope with the increased load of toxic substances, their partial death or complete destruction of the activated sludge biocenosis occurs. As a result, the wastewater treatment process either worsens or stops altogether [3]. Physical phenomena occur, such as "swelling" or "foaming" of activated sludge.

The concepts of "foaming" and "swelling" of silt sludge means that the active silt activated sludge contains filamentous bacteria that impair its ability to settle [7].

Moreover, the higher the density and length of filamentous bacteria, the worse the cleaning is. There are 29 species of filamentous bacteria (Sphaerotilus Natans, Thiothrix, Beggiatoa, Microthrix Parvicella, etc.), each of which has a different effect on the quality of wastewater treatment. The main reasons for the appearance and development of filamentous bacteria in activated sludge: low oxygen

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**Figure 4.** Some representatives of multicellular organisms in activated sludge

Rotifer Philodina  Oligochaete and roundworm  Multicellular organisms of activated sludge  Gastropod worm Gastrotricha  Tardigrada
concentration (some substances can cause oxygen deficiency in the sludge mixture), weak load in the reactor, rotting waste water, the presence of sulfur compounds, lack of biogenic elements (nitrogen and phosphorus). Slight foaming and swelling at the initial stages is considered normal in aeration tanks (figure 5). To stop these processes, it is enough to change the speed of sludge circulation or introduce a small amount of reagents.

![Image of aeration tanks](image1)

**Figure 5.** The aeration tanks: Gomel, Borovichi, Bryansk

The principle of operation of any aeration tank is based on a sufficient supply of oxygen – aeration in a mixture of wastewater (figure 5). However, it is necessary to control not only the power and time of aeration, but also the composition of wastewater and the amount of activated sludge, as well as its condition and composition of the biocenosis. In the process of biological treatment of activated sludge may become toxic. To maintain a sufficient amount in the aeration tanks, the activated sludge discharged from the secondary settling tanks is divided into two streams: excess sludge directed to dewatering to the precipitation mixture and return sludge discharged back to the aeration tank. In fact, return sludge is just as toxic as excess sludge [8].

![Diagram of aeration process](image2)

**Figure 6.** Principle of operation of the aeration tank
The reaction of activated sludge biocenosis to volleys of toxic substances has not been fully studied. The composition of wastewater emissions is unstable both in composition therefore it is necessary to monitor and manage the wastewater treatment process at an optimal level. The main task is to determine the permissible and critical load [9]. In order for the composition of the emissions to be within the permissible concentrations of toxic substances, it is necessary to pre-treat the wastewater at the industrial enterprises themselves, as well as to check the composition of the already treated water before discharge into the sewer network. The creation of program control and process management mechanical and biological treatment of municipal wastewater to remove nitrogen and phosphorus, preparation of projections, the quality of treated water, collection and treatment operational parameters for the aeration tanks, primary and secondary clarifiers possible only if the analysis of the work of these structures in operational conditions [8].

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