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ENVIRONMENTAL ASPECTS OF WASTEWATER TREATMENT FROM LIVESTOCK COMPLEXES AND POULTRY FARMS

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Modern wastewater treatment systems are based on a combination of mechanical, physicochemical, and biological processes. The central element of biological treatment is activated sludge – a complex biological system that ensures the degradation of organic pollutants. The relevance of this topic is driven by increasing anthropogenic pressure, the need to improve treatment efficiency, and the necessity of monitoring wastewater composition.

Wastewater from livestock complexes and poultry farms is among the most problematic types of agro-industrial effluents due to its complex physicochemical and biological composition. It is formed from animal excreta, feed residues, washing water, and technological effluents [3, 4].

According to recent studies, such wastewater is characterized by high concentrations of organic matter (high BOD and COD), significant content of suspended solids, elevated concentrations of nitrogen and phosphorus, as well as the presence of pathogenic microorganisms, antibiotics, and heavy metals [4, 5]. In particular, for swine wastewater, COD values can reach 2500–8900 mg/dm³ and BODs – 1100–6200 mg/dm³, which significantly exceeds the values typical for municipal wastewater [5].

The main environmental consequences include eutrophication of water bodies, contamination of soils and groundwater, and the spread of pathogens and antibiotic resistance [4].

Regarding the composition and biodegradation features of agricultural wastewater, an important characteristic is the BOD/COD ratio, which determines biodegradability and the efficiency of biological treatment [9]. Agricultural effluents are characterized by high variability in composition, a significant proportion of colloidal and refractory substances, and elevated levels of fats and proteins, which complicate aeration processes [8]. These factors negatively affect the stability of biological treatment facilities and bioreactors.

In this context, activated sludge at treatment plants is a key element of biological purification. The activated sludge process is one of the most widely used technologies for wastewater treatment, including agricultural effluents [2]. Its main advantages include high efficiency of organic matter removal (up to 80–90%), the ability to remove nutrients, and adaptability of microbial communities. However, when treating livestock wastewater, several problems arise: overloading with organic matter, toxic effects of ammonium and heavy metals, and disruption of the activated sludge biocenosis structure [1].

Wastewater treatment technologies for agro-industrial enterprises are complex and involve various methods. Preliminary treatment includes mechanical processes (screens, sedimentation) and physicochemical methods (coagulation, flotation), which reduce the load on biological systems [8]. Aerobic biological methods include activated sludge systems, biofilters, and aerobic granules, the latter demonstrating high efficiency in treating high-strength livestock wastewater [1]. Anaerobic bioreactors are widely used for treating concentrated organic wastewater with the possibility of biogas production [5].

Environmentally safe methods include constructed wetlands, phytoremediation, and the use of microalgae. Constructed wetlands effectively remove organic matter and nutrients from wastewater [6]. Microalgae ensure the removal of nitrogen and phosphorus while simultaneously producing biomass [7, 9]. Phytoremediation is a promising method for treating agricultural wastewater [3].

Modern approaches involve combining different treatment methods: mechanical, biological (anaerobic and aerobic), and polishing using natural systems. Such integrated systems ensure high treatment efficiency and enable resource recovery [4].

The main problems in the operation of wastewater treatment plants at agro-industrial enterprises include high concentrations of organic pollutants, significant variability in wastewater composition, the presence of toxic substances, and difficulties in sludge disposal [5]. These issues are particularly acute at large livestock complexes.

Our preliminary studies of agro-industrial wastewater based on key parameters have shown the following. In terms of mechanical composition,

wastewater typically contains coarse particles ($>100\ \mu\text{m}$), suspended solids, colloidal particles; suspended solids $\approx 150\text{--}400\ \text{mg}/\text{dm}^3$, total dissolved solids $\approx 500\text{--}1000\ \text{mg}/\text{dm}^3$. Chemically: BODs $\approx 150\text{--}300\ \text{mg}\ \text{O}_2/\text{dm}^3$, COD $\approx 300\text{--}600\ \text{mg}\ \text{O}_2/\text{dm}^3$, $\text{NH}_4^+ \approx 20\text{--}50\ \text{mg}/\text{dm}^3$, $\text{PO}_4^{3-} \approx 5\text{--}15\ \text{mg}/\text{dm}^3$, pH 6.5–8.5. Organic matter includes proteins, fats, carbohydrates, and surfactants. The biological component includes bacteria (heterotrophic, nitrifying), viruses, protozoa, and helminth eggs. Studies of activated sludge from several treatment plants showed concentrations of $2\text{--}5\ \text{g}/\text{dm}^3$ and a sludge index of $50\text{--}150\ \text{cm}^3/\text{g}$. The chemical composition consists of $\approx 60\text{--}80\%$ organic matter and $\approx 20\text{--}40\%$ mineral fraction, with main elements C, N, P and trace elements Fe, Zn, Cu.

It was found that the efficiency of wastewater treatment at agro-industrial enterprises is determined by the BOD/COD ratio, the structure of the activated sludge biocenosis, oxygen concentration, and sludge loading. The main problems include sludge bulking, the presence of toxic impurities in wastewater, and instability of the activated sludge biocenosis.

Thus, wastewater composition is complex and variable. The biological component determines the efficiency of treatment processes. Activated sludge is a key element of biological purification. Continuous monitoring of its physicochemical and biological parameters is required. One of the most challenging issues is the optimization of the activated sludge biocenosis. One possible solution is the use of granular activated sludge and controlled microbial consortia.

Therefore, the analysis of literature sources and our preliminary studies indicate that wastewater treatment at agro-industrial enterprises is a complex multifactorial problem requiring an integrated approach. The most effective solutions are integrated technologies combining biological, physicochemical, and natural treatment methods, ensuring not only pollution reduction but also resource recovery.

The obtained research results confirm that wastewater from agro-industrial enterprises, particularly livestock complexes and poultry farms, is characterized by a complex multicomponent structure, including high concentrations of organic matter, nutrients, and biologically active substances. Such composition poses significant risks to aquatic ecosystems, causing eutrophication, toxic impacts, and disruption of biological balance.

Traditional treatment methods based solely on classical approaches (mechanical and biological treatment using activated sludge) do not always provide stable efficiency for high-strength agricultural wastewater. This necessitates a transition to a new paradigm of water resource management based on the integration of scientific knowledge, technological innovation, and an ecosystem-based approach.

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