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INNOVATIVE BIOTECHNOLOGY APPROACHES FOR EFFICIENT WASTEWATER TREATMENT

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The increasing intensity of water pollution in Ukraine each year requires immediate measures to reduce the impact of anthropogenic pollution on aquatic ecosystems. The implementation of innovative biotechnological strategies will lead to increased efficiency in wastewater treatment processes and a reduction in negative environmental impact. Furthermore, ensuring access to clean water for consumers becomes an increasingly critical task. The development of biotechnologies for wastewater treatment involves not only reducing wastewater pollution but also ensuring access to safe drinking water for the population. The growing attention to water quality standards and environmental norms necessitates the continual improvement and implementation of innovations in the field of wastewater treatment. The development and implementation of innovative biotechnological strategies in wastewater treatment are a key element of sustainable development and the conservation of natural resources.

One of the strategies focuses on addressing the increasing pollution of natural waterbodies by compounds of nutrients that come from insufficiently treated wastewater as a communal, as well as industrial origin, leads to an increase of eutrophication processes in water sources. The results are: the rapid development of aquatic plants and algae, water pollution, reduction of oxygen concentration in water, deterioration of the waterbodies state, strengthening of saprogenic processes, reduction of the hydrobionts species diversity, etc.

Municipal and industrial wastewater treatment requires different approaches due to the qualitative and quantitative composition of wastewater. However, the use of biological methods prevails in both cases [1-3]. Also, the issue of wastewater treatment quality is not only relevant in Ukraine, but also globally [4,5]. Technologies such as membrane bioreactors (MBR) and moving bed biofilm reactors (MBBR) are used worldwide due to their compactness and high efficiency, but their high cost hinders the widespread use of these methods. The main features and applications of these processes are the simultaneous removal of organic matter, nitrogen and phosphorus. Given the importance of removing nitrogen compounds from wastewater, the latest advances in this area, including new nitrogen removal processes (e.g. Anammox), are also considered [6].

A biological wastewater treatment technology that will allow to achieve the discharge standards to water bodies and at the same time will not be expensive, both in construction and operation, is the goal of this study. The recommended and implemented wastewater treatment technology for example of the meat plant [7] provides high treatment efficiency: up to 98% for COD, up to 99% for ammonium nitrogen, up to 96% for nitrates, and up to 98% for phosphates. Concentrations of pollutants in treated water after the introduction of technologies at treatment plants do not exceed the maximum allowable discharge into a natural reservoir.

Therefore, the use of immobilized microorganisms for biological treatment of industrial wastewater can significantly increase the efficiency of treatment of organic compounds, nutrients - nitrogen and phosphorus compounds. This is due to the growth on the surface of carriers - nylon fibers, biomass of destructive microorganisms in both anaerobic and aerobic conditions for the gradual breakdown of complex organic compounds to form minerals and gases. The method of biological treatment with immobilized microorganisms is characterized by simplicity, reliability, low energy costs, which determine its viability and cost-effectiveness.

Another strategy could be to ensure the continuity of operation and effective restoration of biological wastewater treatment plants. In situations of military aggression and crisis, new approaches to the operation of wastewater treatment plants in both cities and industrial enterprises may be required. Shutdowns of treatment plants may also be caused by seasonality of operation, due to the availability of raw materials only during certain periods of the year (e.g., skins in the spring-summer-autumn period at tanneries, or vegetables in the summer-autumn period at canneries, or periodic operation of resorts, etc.) The problem is exacerbated by military operations (destruction of energy facilities, interruption of electricity supply, and thus suspension of biological treatment facilities, death of activated sludge microorganisms, loss of part of the activated sludge due to wastewater discharge, etc.) If the inflow of contaminated wastewater has stopped, but the treatment plant continues to operate, this leads to the death of microorganisms in the aerotanks (biofilters), and the re-launch and recovery of the facilities will require a significant amount of time and cost to reproduce activated sludge (biofilm). In addition, the minimal amount of biomass is usually not able to oxidise pollution after restarting, which leads to a decrease in the quality of treated wastewater discharged into water bodies. Therefore, to restore biomass performance, activated sludge from other efficiently operating treatment plants is often used, which leads to significant technical and economic costs (to ensure a dose of activated sludge of 3 g/dm^3 for a 1000 m^3 aeration tank, at least 3 tonnes of activated sludge is required).

The aim of the study is to establish the possibility of recovering the performance of biological wastewater treatment plants after a long shutdown without additional activated sludge input.

The goal of a control strategy is to maintain optimal operating conditions to ensure that the desired microbial communities are maintained and have the necessary metabolic characteristics to ensure optimal biological oxidation. Even during transient periods of operation, such as system shutdowns and start-ups, strategies that maintain biomass are considered crucial to restore effective biological wastewater treatment during system start-up. To solve the problem of maintaining the adapted composition of activated sludge during plant shutdown, the use of artificial media for biomass immobilisation was investigated. During the two years of operation of the semi-production plant for biological wastewater treatment using immobilised microorganisms at the malt plant, two shutdowns were carried out in October-November and start-ups were carried out after the winter period. The air temperature drop during the winter period reached -10 to -32°C. During the shutdown period, the plant was freed from wastewater and circulation pumps, but the immobilised biomass carriers were left open in the bioreactors (for air drying). The plant was restarted for 35 and 48 days, respectively, until the treated wastewater was produced in accordance with the requirements for discharge into the river.

The hydrobiological analysis of microorganisms confirmed their ability to periodically work with the restoration of vital activity under conditions of being in a dry state during the shutdown of the treatment plant and even after testing at low temperatures (-30 - -32°C). Among the hydrobionts, there were sarcoderma, variously shaped and abdominal ciliates, circular ciliates, and rotifers, which indicates the presence of organisms of different trophic levels. The treatment plants with immobilised microorganisms are capable of intermittent operation, and the formed and preserved biocenosis is resistant to recovery and quick start-up even at rather low winter temperatures. The objectives of further research will be to establish the technological modes of operation of facilities with immobilised microorganisms during the period of shutdown, shutdown and restart and to optimise processes during this period to minimise its duration and save material and financial costs.

The presented strategies are not a complete list of new approaches to biotechnology for wastewater treatment, but they provide a clear understanding of the benefits of such technologies that will contribute to the conservation of water resources and ensure sustainable development of society. In the future, it is planned to further study the carriers of immobilised microorganisms and, accordingly, the processes and biological agents that ensure wastewater treatment at batch facilities in accordance with the Ukrainian regulations for discharge into water bodies or the municipal sewerage network.

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