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BIOTECHNOLOGY OF THE FOOD INDUSTRY WASTEWATER TREATMENT FROM NITROGEN COMPOUNDS

BIOTECHNOLOGIA USUWANIA ZWIĄZKÓW AZOTU ZE ŚCIEKÓW PRZEMYSŁU SPOŻYWCZEGO

Abstract: Wastewater of food industries contains high concentrations of nitrogen compounds, mainly in the form of ammonium nitrogen. Traditional technological lines are able to reduce ammonium nitrogen about 80÷90%, but the desired concentration of nitrates in treated water for the standards of water use are not provided. The respective disadvantages of traditional lines are: the use of expensive chemicals (methanol and ethanol), large size of devices and buildings, large oxygen demand to the nitrification process, and required recirculation piping at each stage of technological line. The effective anaerobic-aerobic treatment technology of nitrogen compounds for food industry wastewater is proposed. The laboratory installation consisting of 5 bioreactors in series was designed. Biotechnology based on consistently jointed anaerobic and aerobic bioreactors with carrier for microorganisms immobilization was suggested. Hydrobiological biocenosis composition was also analyzed during the study. Construction and process parameters of laboratory installation were presented. The proposed technology of wastewater treatment of organic and nitrogen compounds allows to reach the levels of 98% such contaminants removal.

Keywords: wastewater treatment, food industry wastewater, nitrogen compounds, anaerobic-aerobic treatment, microorganisms immobilization

Almost all industrial and domestic wastewater contain both organic and inorganic nitrogen. The problem of nitrogen compound removal was developed in connection with deterioration of water quality in rivers and lakes, as the result of eutrophication. It gives place to excess amount of biogenous substance in the surface water. In its turn, this causes intensified growth of algae's other water plant and macrophytes. These water flora reduce the amount of incoming light into the basin depth, consume the dissolved oxygen and lead to the destructions of fauna and total disappearance of fish. In addition, water supply system is generally not equipped to remove nitrogen. Thus nitrogen compounds may income to the consumer and cause various diseases (cardiovascular, metabolic, etc.), even if consumed in small quantities. The above facts explain the increased requirements to ensure removal of nutrients especially nitrogen compounds from wastewater.

Nitrification process in combination with subsequent denitrification is still considered as the most common method of biological wastewater treatment. This method allows to remove ammonium nitrogen at 80÷90%, but do not provide the desired concentration of nitrates in treated water for the standards of water use. There are a number of disadvantages: expensive chemicals (methanol and ethanol), large size of WWTP devices and buildings, large oxygen demand to the nitrification process, and required recirculation piping at each stage of technological line.

Over the last 15 years in wastewater treatment technology, several new processes of nitrogen compounds removal have been created: CANON (*Completely Autotrophic*

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Nitrogen removal Over Nitrite), OLAND (*Oxygen Limited Autotrophic Nitrification Denitrification*), SHARON-ANAMMOX (*Single reactor High activity Ammonia Removal Over Nitrite - ANaerobic AMMonium OXidation*), DEAMOX (*Denitrifying Ammonium Oxidation*) [1]. Among the most modern technological schemes that allow to remove nitrogen compounds A/O, A^2/O, An/O, Bardenpho, UCT, Biodenipho processes, Carousel scheme (simultaneous method), JHB, and others, can be marked [2]. External and internal recirculation of flow are used and is one of the main disadvantages of the above schemes and technological processes.

Anaerobic processes in traditional biological technology are recently used for anaerobic sludge stabilization (in clarifies, septic tanks, digestion tank). Today, the biological wastewater treatment with high level of nitrogen removal in anaerobic conditions is widely used worldwide and this trend is observed in practice. Anaerobic technologies have certain undeniable advantages in comparison with aerobic [3].

After the biological wastewater treatment in anaerobic condition necessarily to aerobic advanced treatment occur. However, it requires a much lower cost than the only aerobic wastewater treatment. The low rates of growth and slow metabolism of the microorganisms removing nitrogen compounds lead to increase the activated sludge age to achieve their proper concentration in bioreactor. This problem can be solved by using of anaerobic and aerobic bioreactors with microorganisms immobilization. System with immobilized microorganisms does not require for wastewater recirculation. Immobilization of microorganisms cells allows for complex multistage process, causes better protection of cells from the action of extreme factors, and creates a high concentration of cells in the reactor. In addition, immobilized microorganisms are often less sensitive to toxic substrates.

The objective of our researches is to intensify the process of biological wastewater treatment, including food industry, of nitrogen compounds by technological line with immobilized microorganisms.

Materials and methods

For the food industry wastewater treatment, the anaerobic-aerobic biotechnology was applied. The laboratory installation was composed of five bioreactors. The anaerobic and aerobic reactors have 1 dm^3 of effective volume, respectively. Carrier height was 0.17÷0.235 m, diameter of fiber - 3 mm, number of fiber in one carrier 142÷98 units. The wastewater from milk plant and malt factory was chosen for the research. Investigation was carried out separately on different plants, similar in composition and work.

The concentration of pollution in milk plant wastewater is characterized by: *Chemical Oxygen Demand* (COD) 1000÷5000 g m^{-3}, *Biochemical Oxygen Demand* (BOD_5) 700÷3700 g m^{-3}, total nitrogen 20÷170 g m^{-3}. Model solution was prepared for a milk plants sewage simulation. Concentration of ammonium nitrogen was 45÷58 g m^{-3}, pH 6.5÷6.8. Wastewater of malt factory was generated in the process of soaking and germination malts and contain: COD 1760÷4000 g m^{-3}, BOD_5 1400÷2000 g m^{-3}, total nitrogen 30÷80 g m^{-3}, suspended solids concentration of 350÷600 g m^{-3}, pH 6.0÷7.5. The solution used for researches was consist of wastewater from malt factory of Slavuta, Ukraine. The concentration of ammonium nitrogen about 25÷40 g m^{-3}, suspended solids: 510÷580 g m^{-3}, pH 6.0÷6.3.

As a precursor for increase the biomass in bioreactors was used activated sludge from Slavuta municipal wastewater treatment plant. The carriers made of artificial fibers of the VIYA (Eyelash) type were used for microorganisms immobilization. After starting the experiment, on the "VIYA" the amount of microbial biomass in the anaerobic and aerobic bioreactors was gradually increase. The process of increasing biomass has reached the maximum level at 45 day [4].

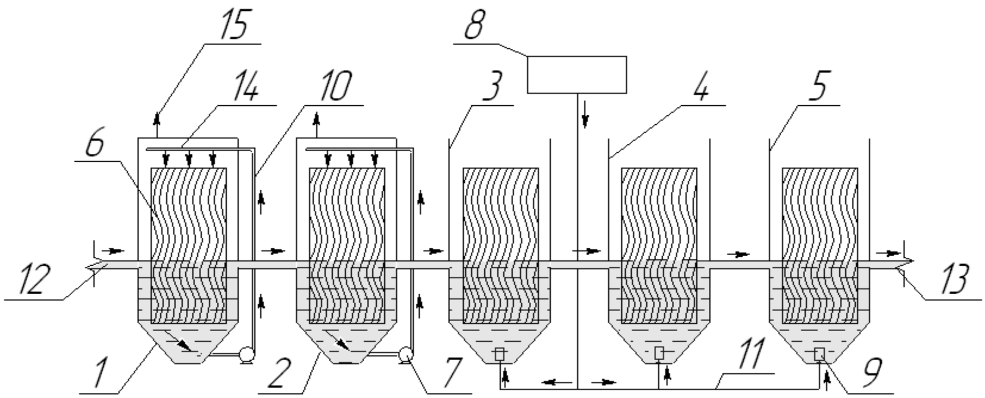

Fig. 1. Scheme of laboratory installation: 1, 2 - anaerobic bioreactors, 3, 4, 5 - aerobic bioreactors, 6 - fibrous carrier "VIYA", 7 - pump, 8 - compressor, 9 - aerator, 10 - irrigation piping, 11 - air line, 12 - supply pipeline wastewater; 13 - pipeline for the treated water, 14 - perforated pipe, 15 - a device for collecting gas

Operation of the laboratory installation may be described as follows (numbers in brackets are connected with scheme presented at Figure 1): Wastewater pass by anaerobic section (1). Then wastewater passes through fibrous carrier “VIYA” (6) and contacts with immobilized microorganisms on it. Irrigation is conducted by the circulating pump (7). Process in anaerobic bioreactor (1) proceeds with allocation of gases, collected by the device for gathering of gas (15), and development of anaerobic bacteria which are kept on fibers of the carrier (6). The water treated thus gets in following anaerobic bioreactor (2) where occur a similar process differed only by specific structure of microorganisms biocenosis, which change under the influence of spatial microorganisms succession. Then wastewater flows consistently by aerobic bioreactors (3, 4, 5) in which from the compressor (8) connected with an air pipe (11) air is pressed in regular intervals to be distributed in the form of small air bubble through aerators (9). In all aerobic bioreactors fibrous carriers (6) on which the microorganisms with specific structure shaped by process condition of sewage treatment also are located. The pipeline (13) takes the cleared wastewater out of installation.

The number of variants was considered for the choice of the most effective carrier material for microorganisms immobilization. The artificial fibers “VIYA” selected to role of carrier, has a following advantages: the large specific surface for biocenose fastening and insolubility in water. It is also characterized by high durability and firmness to microbe destruction and is not harmful to microorganisms [5].

Results and discussion

Using the first two stages of installation connected with anaerobic process (first and second bioreactors) allows the removal of organic pollutants. Stirring was conducted with circulating pump. In anaerobic bioreactors, treatment process takes place without oxygen and with the selection of gases, which collect specific device.

The third bioreactor of wastewater treatment occurs with air supply, but the conditions in the reactor are anoxic (shortage of oxygen). After passing the wastewater through anaerobic bioreactor, the concentration of organic matter significantly reduced, and that causes the first stage of nitrification. In deeper layer of fiber carrier, with no oxygen, but enough organic matter, denitrification can also occur. In this bioreactor, ANAMMOX-process is possible at high concentrations of ammonium compounds (> 0.2 g m^{-3}) and low concentrations of organic carbon [6].

The fourth and fifth bioreactor is saturated by air from the compressor that provides aerobic conditions. There is a second stage of nitrification. Immobilized microorganisms conduct the biological oxidation of pollutants which clean wastewater from all forms of nitrogen, with minimum amount of excess sludge which is characterized by good dewatering and low humidity.

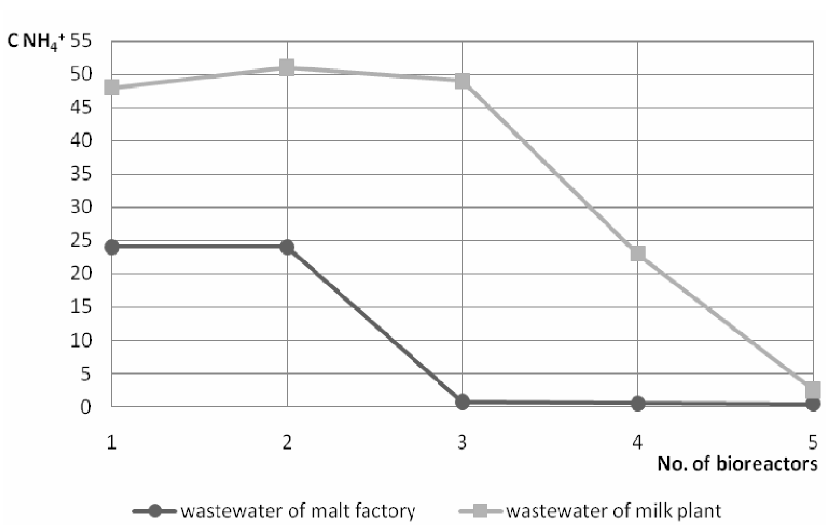

Fig. 2. Changes in the concentration of ammonium nitrogen of food industry wastewater after passing by five following bioreactors

The efficiency of ammonium nitrogen removal from dairy wastewater and malt wastewater, which is 98.5% and 98% respectively (Fig. 2) was achieved. Sampling of sewage for investigation was conducted at the inflow to each bioreactor.

Summary and conclusions

Based on the conducted experiment with the implementation of anaerobic-aerobic technology with immobilized microorganisms it is possible to make the following conclusions:

- Due to immobilization of microorganisms connected which their concentration in small volumes of a construction the reduction of bioreactor capacity is possible.
- Increase in concentration of a biomass allows to reduce duration of wastewater treatment.
- Constant and high concentration of biomass as well as lack of their recirculation between bioreaction chamber and absence of aeration in two chambers allow to reduce quantity of the used electric power.
- The sediment received from the last bioreactor is in small amount, dewaters well and is characterized by low humidity (90%).
- The presented technology allows to reach high level (98%) of wastewater treatment from organic matters and nitrogen compounds. It can be applied to food-processing industry wastewaters.

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BIOTECHNOLOGIA USUWANIA ZWIĄZKÓW AZOTU ZE ŚCIEKÓW PRZEMYSŁU SPOŻYWCZEGO

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Abstrakt: Ścieki z przemysłu spożywczego mają wysokie stężenia związków azotu, w tym głównie azotu amonowego. Tradycyjne linie technologiczne umożliwiają obniżenie stężeń azotu amonowego o około 80 do 90%. Jednakże uzyskiwane stopnie usunięcia związków azotu z oczyszczanych ścieków przemysłu spożywczego nie spełniają standardów pozwalających na ich bezpośrednie odprowadzenie do wód odbiornika bądź też powtórne wykorzystanie. Ponadto przy zastosowaniu tradycyjnych schematów technologicznych pojawia się szereg niedogodności. Do ważniejszych z nich można zaliczyć konieczność okresowego zastosowania kosztownych związków chemicznych (np. metanolu lub etanolu) oraz duże rozmiary urządzeń i objętości komór oczyszczania. Wymagane znaczne strumienie powietrza niezbędne w prowadzeniu procesu nitryfikacji, a także konieczność wykorzystania pomp i przewodów recyrkulacyjnych w odpowiednich punktach linii technologicznej powodują wzrost kosztów energii elektrycznej. W celu uniknięcia wspomnianych niedogodności zaprojektowano przedstawioną w ramach niniejszej pracy beztlenowo-tlenową technologię biologicznego oczyszczania ścieków z przemysłu spożywczego. Opracowana instalacja laboratoryjna składa się z pięciu połączonych szeregowo bioreaktorów. Poprzez wykonanie poszczególnych sekcji bioreaktorów uzyskano możliwość oczyszczania ścieków w systemie przepływowym bez konieczności recyrkulacji pomiędzy sekcjami. Mikroorganizmy osadu czynnego wykorzystywane podczas biologicznego oczyszczania ścieków mogą także zasiedlać zamontowane w tym celu wypełnienie z nośników w postaci włókien, co służy zwiększeniu koncentracji biomasy w bioreaktorze. W ramach prowadzonego eksperymentu badano parametry procesowe instalacji laboratoryjnej oraz skład biocenozy saprobów zasiedlających bioreaktory. W wyniku prowadzonych procesów oczyszczania udało się osiągnąć obniżenie stężenia związków azotu na poziomie 98%.

Słowa kluczowe: oczyszczanie ścieków, ścieki przemysłu spożywczego, związki azotu, oczyszczanie tlenowo-beztlenowe, immobilizacja mikroorganizmów