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Analysis of Prospective Technologies of Food Production Wastewater Treatment

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ABSTRACT

The food industry is one of the industrial activities that uses a large amount of water and the high content of dissolved organic matter and nitrogen in production effluents is their characteristic feature. The treatment technology of such industrial effluents is a combination of different technologies and treatment methods blocks depending on the parameters of wastewater. The choice of efficient, environmentally friendly and energy efficient biotechnology of wastewater treatment will allow its successful application in most food industries. Treated effluents can be considered as a source of water for watering plants in the area to reduce the overall use of water in the process, and as a prospect of returning to the overall process for use, for example, for washing vegetables and fruits. The physico-chemical parameters of industrial waters of food industry enterprises were analyzed and their impact on the environment was monitored. On the basis of the perspective technologies review of the food industry wastewater treatment the technological scheme for effective treatment of industrial wastewater was offered.

Keywords: biogenic organisms, filtration fields, wastewater, energy efficient technologies, cannery, bakery.

INTRODUCTION

In recent decades, water pollution around the planet has become catastrophic. A significant role in the pollution of the hydrosphere is played by processing enterprises. As a result, surface waters are becoming increasingly polluted (Odnorih et al., 2020), the use of water from them for industrial, thermal, domestic and other needs necessitates more complex and costly treatment (Shestopalov et al., 2019; Hetta et al., 2019; Rykusova et al., 2019).

The main direction of the aquatic environment protection in industry is the transition of enterprises to work on a closed-loop water supply scheme, when the company after the treatment of its own wastewater reuses it in the technological cycle, and polluted and untreated wastewater does not enter reservoirs. Unfortunately, the level of wastewater treatment in Ukraine is very low. The existing treatment plants, which most companies have, remove only 10–40% of inorganic substances (40% nitrogen, 30% phosphorus, 20% potassium) and practically do not remove heavy metal salts. The consequences of water pollution can be dangerous to the health of people. Damage can be caused by such common pollutants as fluoro-, chloro-, and organophosphorus pollutants, nitrates, nitrites, nitro compounds, pesticides, herbicides, etc. (Shestopalov et al., 2019; Hetta et al., 2019; Rykusova et al., 2019).

Contamination of surface waters with organic substances from food production effluents poses a significant environmental risk. These substances, infiltrating into reservoirs, cause the development of decay processes in them, disturbance of natural balance of reservoirs, eutrophication, as well as negatively affect fauna and flora (Malyovanyy et al., 2016; Nykyforov et al., 2016). That is why the improvement and creation of conceptually new methods of wastewater treatment in the food industry is an urgent scientific task today.

The aim of the research was to assess the quality indicators of wastewater treatment of food industry enterprises on the example of the existing cannery and bakery, analysis of their impact on the environment and modeling of an effective technological scheme of their treatment.

Presentation of the main material

The food industry of Ukraine is one of the largest consumers of water needed for technological processes; therefore, it is a significant producer of wastewater. The annual consumption of enterprises in this industry is approximately 35.83 million m^3 of water. At the same time, almost 10.57 million m^3 of wastewater is generated, which significantly affects the environment of Ukraine due to the discharge of insufficiently treated or untreated wastewater into reservoirs (Shestopalov et al., 2019; Hetta et al., 2019; Rykusova et al., 2019). Utilization of technological waste of the food industry has its own features. Technological waste, having in its composition most of the same components as in the raw material, is a valuable raw material for further processing into food and feed additives and products; on the other hand, they activate the microflora and enzymes that lead to rapid deterioration (Stryzhak, 2020).

The wastewater from food industry enterprises is formed during the technological process, washing of raw materials, equipment, production facilities as well as after the use of water and steam in technological processes. The formed wastewater contains aggregatively stable colloids, which include animal and vegetable fats, proteins, starch, sugar as well as salts, carbohydrates, dyes, thickeners, and preservatives (Symanyna et al., 2016; Sydorskaia et al., 2016). In the food industry (for example, vegetable processing plants) after washing vegetables and fruits, wastewater is usually contaminated, which leads to an increase in water-insoluble impurities – sand and clay. Solid particles reduce the transparency of water, inhibiting the development of aquatic plants, clogging the gills of fish and other aquatic animals, deteriorating the taste of water, and even making it unfit for consumption. The wastewater from the food industry belongs to the category of highly concentrated and has unstable quality and quantity indices. Such effluents are complex polydisperse systems and contain contaminants that are different in nature depending on the type of production: fat, milk, scales, wool, blood, pieces of animal tissues, salts, insoluble mineral impurities, detergents and others. These waters are characterized by high indicators of BOD, COD, suspended solids, fats, etc. Discharge of wastewater into reservoirs quickly depletes oxygen reserves, causing the death of aquatic organisms (Shestopalov et al., 2019; Hetta et al., 2019; Rykusova et al., 2019). For example, the composition of wastewater from vegetable processing enterprises includes: soluble, insoluble and colloidal substances that are removed from the surface of products during their cleaning and washing; juices and syrups used in the processing of products, impurities, waste from raw materials, etc. are accidentally introduced. The size of these contaminants is significant, is 12-35% by weight of raw materials. From 20 to 50% of waste enters the sewer network together with wastewater.

Soil particles, pulp and fruit peel, mold and rot bacteria as well as other wastes are contaminants in the circulating and wastewater of vegetable processing plants. At the same time, the treatment of the same raw material wastewater can differ significantly. Depending on the type of raw material being processed, the composition of wastewater varies significantly. The choice of the wastewater treatment scheme of the enterprise depends on many factors: the amount of wastewater generated at the enterprises, the possibility and economic feasibility of removing impurities from wastewater, as well as the quality requirements of treated water for use in repeated and circulating water supply.

Wastewater treatment can be performed according to various schemes that provide high treatment efficiency. All methods of wastewater treatment currently used are divided into: mechanical, physicochemical, chemical, and biological (biochemical). In addition, wastewater disinfection is used to destroy bacterial contamination. A closed water supply system, for example, at vegetable and fruit processing enterprises, is a chemical and technological complex (shop) for the production of clean water within the enterprise. It is an integral and one of the main components of any waste-free production. The technological schemes of wastewater treatment in closed water supply systems are diverse and depend on many factors: the characteristics of wastewater, the company's ability to use treated water of a particular composition, the ability to dispose of concentrates at the company or nearby, and so on.

The technological scheme of industrial wastewater treatment of different composition includes the following units: averaging and accumulation of wastewater; mechanical cleaning from large residues; reagent (chemical, physicochemical, electrochemical, biotechnological) treatment of wastewater with the destruction of toxic and release in the form of a suspension of harmful (aggressive) impurities; aggregate formation (coagulation, flocculation) to intensify the process of removing the suspension from the drain; clarification (settling) of treated wastewater in high-speed (thin-layer) settling tanks; additional purification (if necessary) of clarified water on granular filters; water disinfection as well as dehydration of the released suspension of pollutants and disposal of the formed sediments (Shestopalov et al., 2019; Hetta et al., 2019; Rykusova et al., 2019).

As is known, the criterion for oxidation of organic impurities in wastewater is the experimental determination of BOD. If this value is determined (i.e. oxygen consumption occurred), the impurities are biologically oxidizable. The degree of biooxidation of organic impurities is numerically evaluated by the ratio BOD_{full}/COD, i.e. the ratio of the amount of organic impurities that are oxidized biologically to the total mass of organic impurities contained in wastewater. If the ratio BOD_{full}/COD> 0,5, it is expedient to apply aerobic biological methods for neutralization of organic pollution.

The wastewater of the vast majority of food industry enterprises (except for perfume and cosmetics production, salt industry, etc.) can be treated by using biological methods. Successful implementation of the process of biological wastewater treatment of food industry enterprises is possible only if two conditions are met. The first condition concerns the need to take into account the regime of wastewater inflow, the content of nutrients, suspended solids, fats, etc., pH fluctuations. The second condition is the need to use two-stage schemes of biological treatment due to the high concentrations of pollutants and different oxidation rates of their individual components.

The drainage regimes in the food industry are characterized by significant unevenness, which is mainly due to the availability of processed raw materials. The concentrations of wastewater pollution can change significantly during the transition of the enterprise to the processing of other raw materials. These circumstances require the installation of averaging, the volumes of which are comparable to the volumes of aeration tanks and emphasize the feasibility of using for wastewater treatment of food industry aeration tanks-mixers, which perform the function of averaging. In most cases, the content of nutrients in wastewater is also subject to adjustment, which is often insufficient for the normal implementation of the biological treatment process in aeration tanks.

Typically, the average efficiency of wastewater clarification in primary settling tanks is about 50%, and with the use of preaeration and biocoagulation can increase up to 75%. Thus, to ensure the supply of wastewater to aeration tanks with a concentration of suspended solids not exceeding 150 mg/l, the concentration of suspended solids in treated wastewater should not exceed 300-600 mg/l. For most food industry enterprises, the actual concentrations of suspended wastewater significantly exceed these limits, which emphasizes the feasibility of using pressure flotation for their pre-treatment.

The importance of flotation is especially important in the case of the fats presence in wastewater, which adversely affect the course of biochemical processes and are contained in large quantities in the wastewater of the meat processing and fish processing industries. Preliminary flotation treatment can significantly reduce the content of coarse, emulsified and part of the colloidal impurities, increase the ratio of wastewater in the wastewater BOD_{full}/COD and thus improve the efficiency of biological wastewater treatment.

If it is necessary to discharge treated wastewater into natural reservoirs, their additional treatment can be carried out by filtration through foam polystyrene loading, which has a high dirt content and is easily washed. In the second stage of biological treatment, membrane bioreactors can be used, which ensure the achievement of quality indicators of treated wastewater sufficient for their discharge into natural reservoirs (Kovalchuk et al., 2010; Sameliuk et al., 2010).

RESULTS AND DISCUSSION

The analysis of wastewater treatment systems of a cannery was conducted. Wastewater treatment is as follows: domestic wastewater sewer station pressure pipeline K1 enters the well pressure extinguisher with mechanical treatment (horizontal sand trap) removing coarse parts, the pipeline enters the local 50 m^3/day, consisting of an above-ground polypropylene tank. Then, the treated wastewater after domestic and mechanical treatment facilities by pressureless pipeline K13 enters the self-flowing drainage system, which consists of drainage wells and drainage pipelines, and stabilized activated sludge from treatment plants by pressure pipeline enters the watertight storage tank. Stabilized sludge is exported to the sludge sites of the utility company (Havryshko et al., 2021; Popovych et al., 2021). The use of spent activated sludge in the composition of substrates for biological reclamation of disturbed lands (Tymchuk et al., 2020; Tymchuk et al., 2021) is promising, which allows minimizing the area of sludge sites where its accumulation takes place.

According to the principle of making treatment facilities with a total capacity of 50 m^3/day, the cannery implements the following stages of wastewater treatment: effective mechanical pretreatment, averaging, biological treatment, secondary settling, stabilization of excess activated sludge with subsequent storage in watertight tanks.

The wastewater generated as a result of production processes in the food industry is characterized as a concentrated multicomponent aqueous solution (suspension) with a high content of pollutants; their treatment in one way is not possible.

The implementation of food industry technology is accompanied by the formation of a significant amount of wastewater, which passes about a third of the processed raw materials, and the concentration of pollutants in them is 10–100 times higher than in household (Havryshko et al., 2021; Popovych et al., 2021).

The analysis of the composition of wastewater was conducted at the existing enterprises of the food industry located in western Ukraine. The total capacity of treatment facilities is 50 m^3/day and 5 m^3/day at the cannery and bakery, respectively. At both enterprises, wastewater undergoes complete biological treatment on the principle of typical ones.

Wastewater had a constant flow during each day with an average flow per day. The peak day was observed every 7-14 days during the work of enterprises overtime. Wastewater was discharged through a pipe, and later it was connected to the distribution box of treatment plants. Water sampling from the cannery was carried out for 2 months and a control one after a year. Sampling of wastewater from the bakery was analyzed for 6 months. According to standard methods, the main indicators of water were determined and the compliance with the MPC was analyzed.

According to the results of the analysis of water parameters research given in the publication (Havryshko et al., 2021; Popovych et al., 2021) diagrams of dynamics of pollutants in wastewater were constructed. It should be noted that not all parameters of wastewater, both originating from cannery and bakery, meet the quality standard and established requirements. All water parameters, except pH, significantly exceed the MPC, especially for BOD_5, COD and ammonium nitrogen. Thus, in accordance with the final results of wastewater analysis, the maximum allowable norms of ammonium nitrogen, BOD_5 and COD were exceeded. Their concentrations at both plants were 9.8 mg/dm^3, 98 mg/dm^3 and 254 mg/dm^3 at the cannery and 3.24 mg/dm^3, 36 mg/dm^3 and 78 mg/dm^3 at the bakery, respectively, which exceeds the permissible norms by several times. At the same time, it should be noted that according to the latest results of the analysis of wastewater from the bakery, an improvement in wastewater treatment can be seen, which indicates that the treatment system works and practically reaches its quality, which unfortunately cannot be said about the results from another enterprise, the cannery, where the positive dynamics is not so clear.

Moreover, in the wastewater of the cannery, as a result of changes in raw materials in the production process and the use of other detergents, the maximum permissible levels of phosphates and chlorides were recorded 10 and 2 times, respectively, which confirms that all stages of the production process have an impact on the qualitative composition of wastewater.

On the basis of on the obtained values and taking into account the established experimental ratio of BOD/COD, it may be appropriate to improve the stage of biological treatment of industrial waters, to obtain the quality indicators that meet the standards. In particular, chemical oxygen demand (COD) and oxidation by potassium permanganate indicate the presence of substances and their concentration when treated with strong oxidants. The value of the COD parameter is most evident in the determination of wastewater contamination before biochemical oxidation by estimating the ratio of BOD/COD = 0.7-0.8, and for biochemically treated it is 0.4-0.1.

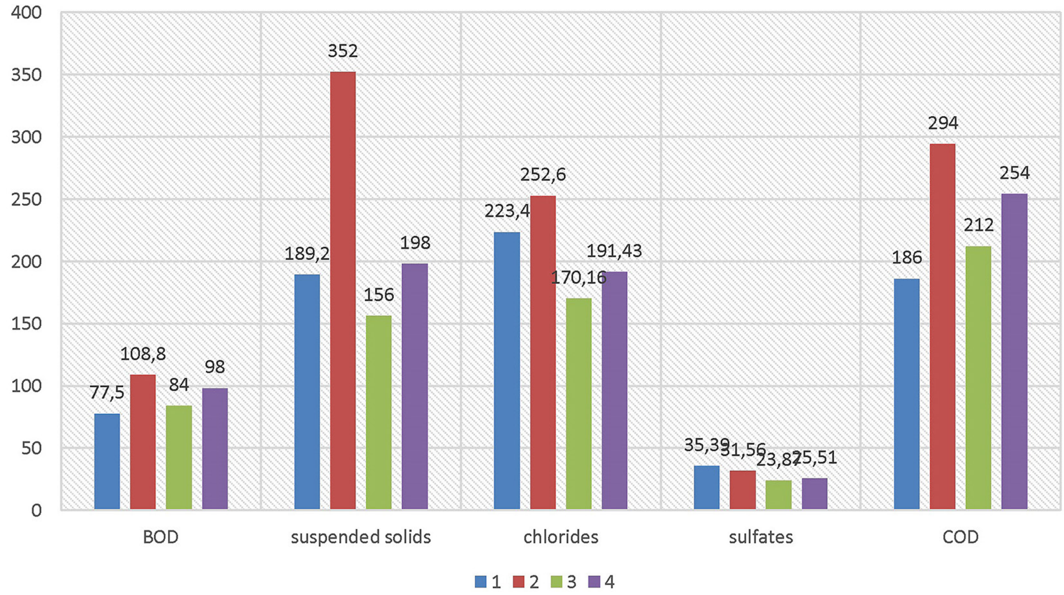

Figure 1. Dynamics of the content of pollutants in wastewater at the inlet and outlet of the existing treatment facilities of the cannery by BOD, COD, suspended solids, chlorides and sulfates; 1 – input, 2 – input, 3 – output, 4 – input

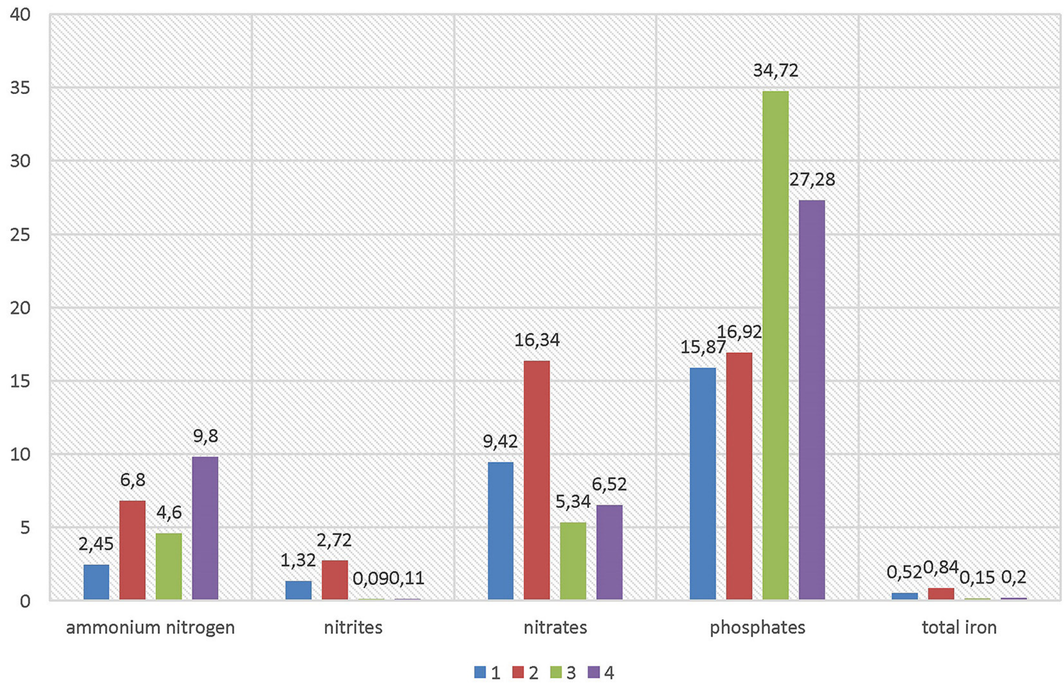

Figure 2. Dynamics of the content of pollutants in wastewater at the inlet and outlet of the existing treatment facilities of the cannery with ammonium nitrogen, nitrites, nitrates, phosphates and total iron; 1 – input, 2 – input, 3 – output, 4 – input

After analyzing the dynamics of changes in pollutants in the wastewater of the bakery and cannery, it can be concluded that the biological treatment systems at these enterprises do not function satisfactorily and clearly need improvement. In particular, in the wastewater from the bakery, the only three indicators of the quality of wastewater out of six exceeded the norms; in the case of the cannery, their number has not changed. In the wastewater of the bakery, the excess of individual pollutants, such as ammonium nitrogen, BOD_5 and suspended solids was 1.6 times, more than 2.5 times and more than 5 times, respectively; in the wastewater from the cannery the excess is twice as high, namely: 16.3 times for BOD_5, 11 times for suspended solids,

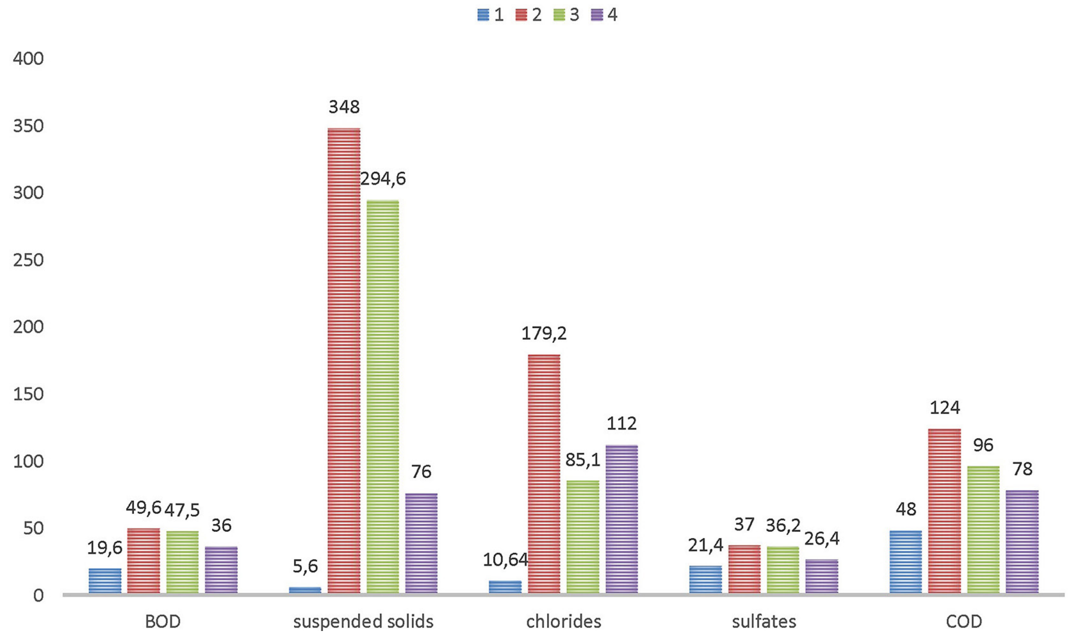

Figure 3. Dynamics of the content of pollutants in wastewater at the inlet and outlet of the existing treatment facilities of the bakery by BOD, COD, suspended solids, chlorides and sulfates; 1 – input (19.06.2020), 2 – output (22.07.2020), 3 – input (22.07.2020), 4 – output (04.12.2020)

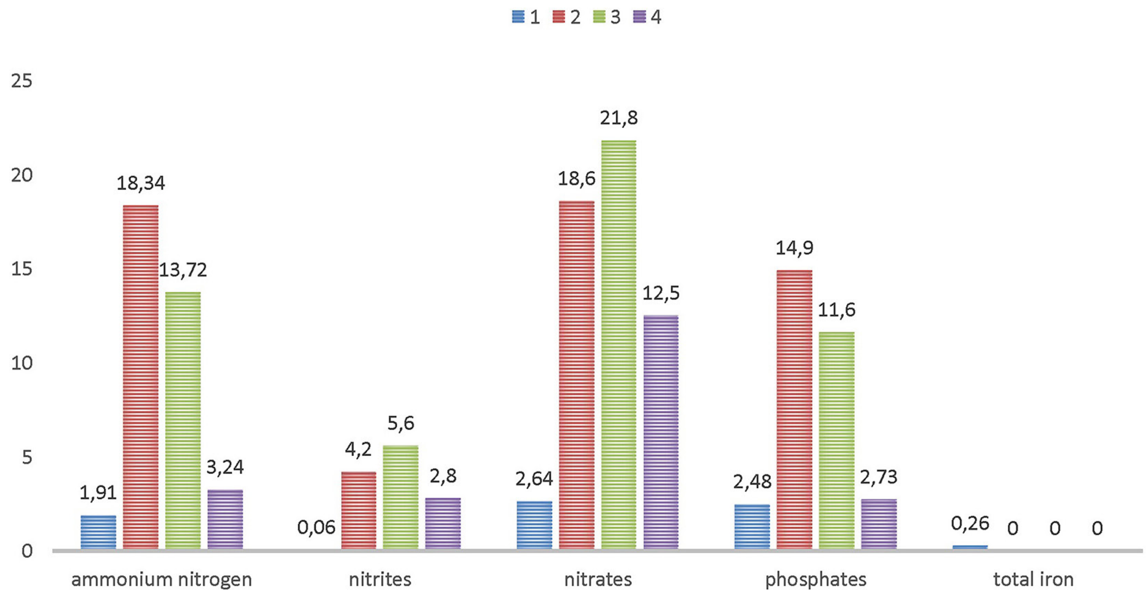

Figure 4. Dynamics of the content of pollutants in wastewater at the inlet and outlet of the existing treatment facilities of the bakery for ammonium nitrogen, nitrites, nitrates, phosphates and total iron; 1 – input (19.06.2020), 2 – output (22.07.2020), 3 – input (22.07.2020), 4 – output (04.12.2020)

3.1 times for ammonium nitrogen, 7 times for COD, 1.9 times for chlorides and 11.6 times for phosphates. At the same time, if we compare the initial indicators of wastewater quality with the latest results of the study, both from the bakery and the cannery, there is a positive trend in the quality of their treatment, although minimal, as excess pollutants are present but their nominal value has decreased.

The use of microorganisms in the process of biological treatment of industrial water today is a widely used method of purification of polluted water. It is a natural process that reproduces under artificial conditions and allows removing organic impurities without the use of complex and high-cost technologies. However, to increase the efficiency of the technology, biological wastewater treatment is used in combination with other

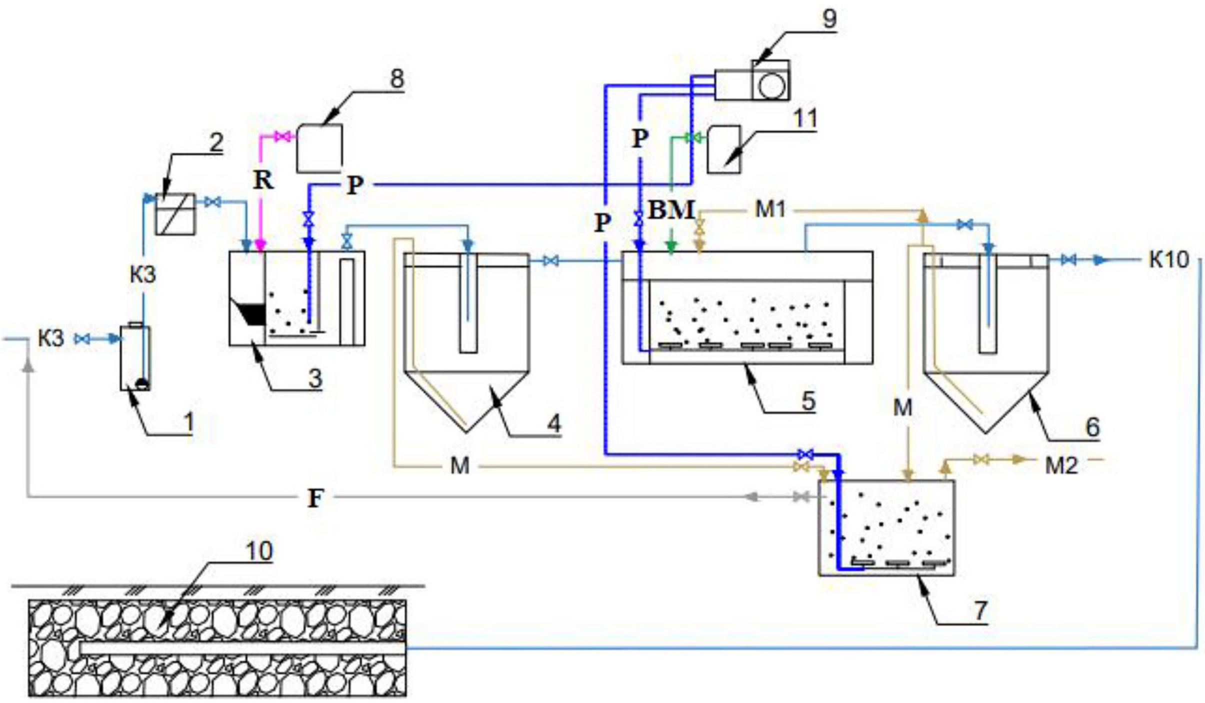

Figure 5. The scheme of industrial wastewater treatment of the food industry is proposed, where: 1 – sewage pumping station (SPS); 2 – mechanical lattices; 3 – aerated averaging; 4 – primary settling tank; 5 – aeration tank; 6 – secondary settling tank; 7 – aerobic stabilizer; 8 – reagent preparation unit; 9 – the compressor (blowers); 10 – filtration fields; 11 – preparation and dosing of biogenic microorganisms; K3 –wastewater entering treatment; R – technological pipeline for supplying reagents; P – air ducts; BM – technological pipeline for supply of nutrients; M – technological pipeline of activated sludge supply; M1 – technological pipeline for circulating sludge supply; M2 – technological pipeline for the supply of activated sludge for dehydration; F - fugate; K10 – technological pipeline for discharge of treated wastewater

methods of removing liquid from contaminants. Therefore, in this case, it is advisable to consider the possibility of using filtration fields as a stage of post-treatment, as well as to select microorganisms to improve the stage of biological treatment.

For effective wastewater treatment of enterprises, the authors propose a scheme of treatment facilities, which is presented in (Fig. 5).

The cleaning technology shown in the diagram includes the following methods: filtering through mechanical grids (2); averaging and mixing with flocculant reagents supplied by the dosing pump from the reagent preparation unit (8) in the aerated averaging unit (3); settling in the vertical settling tanks primary (4) and secondary (6) after the aeration tank; biochemical treatment in an aeration tank (5); additional treatment and discharge of return water into groundwater is carried out through filtration fields (10). In order to stabilize the sludge formed on the facilities (4) and (5), a sludge stabilizer (7) is used, from which the supernatant is returned to the head of the treatment facilities (1), and the excess sludge is fed to dehydration. Air to the buildings (3), (5) and (7) is supplied by means of a compressor (9) and air ducts. For efficient operation of the aeration tank, dosing of biogenic organisms is carried out (11).

The scheme proposed by the authors differs from the known schemes in that the use of energy-efficient equipment and stimulation (acceleration) of treatment processes allowed optimizing the technological process of treatment and as a result significantly reduce the load on natural resources and energy.

CONCLUSIONS

Treatment of wastewater containing high levels of organic, suspended solids, nutrients, oils and fats should be carried out using a combined treatment technology. Since the wastewater of the food industry is highly concentrated in the content of organic impurities, suspended solids, may be unfavorable for biological treatment of the content of nutrients and pH values; however, the analysis of the biooxidation degree of organic impurities in the ratio of BOD_5/COD showed that the wastewater of the vast majority of food industry enterprises can be treated by using biological methods. The proposed scheme for the treatment of such effluents was developed using modern biological methods, which include anaerobic (methane) fermentation, which allows not only treating wastewater, but also obtaining high quality fertilizers and electricity from biogas combustion.

REFERENCES

1. Auerman L.Y. 2003. Technology of bakery: textbook. 9th ed., revised and supplemented. SPB: Profession.
2. Gizem Basaran Dundas Yasemin Çaliskai, Emin Ender Çelebi, Mesnt Tekha G., Nihal Bekta G., H. Cengiz Yatmaz. 2018. Sequential treatment of food industry wastewater by electro-fenton and electrocoagulation processes. Electrochem. Sci., 13.
3. Havryshko M., Popovych O., Yaremko H. 2020. Ecological aspects of modernization of alcohol industry enterprises at the present stage of development. Environmental Problems, 5(3), 179–184. https://doi.org/10.23939/ep2020.03.179.
4. Havryshko M., Popovych O., Yaremko H. 2021. Experimental research of industrial water parameters of canning plant and bakery. Analysis of treatment technologies. Environmental Problems, 6(2), 117–124. https://doi.org/10.23939/ep2021.02.117.
5. Kovalchuk V.A., Kovalchuk O.V., Sameliuk V.I 2010. Biotechnology of food industry wastewater treatment. Water, Ecology, Society. http://eprints.kname.edu.ua/31310/1/14.pdfe
6. Malovanyy M., Nikiforov V., Kharlamova O., Synelnikov O. 2016. Production of renewable energy resources via complex treatment of cyanobacteria biomass. Chemistry & Chemical Technology, 10(2), 251–254. https://doi.org/10.23939/chcht10.02.251.
7. Nykyforov V., Malovanyy M., Kozlovska T., Novokhatko O., Digtiar S. 2016. The biotechnological ways of blue-greenal gaecomplex processing. Eastern-European Journal of Enterprise Technologies, 5(10), 11–18. https://doi.org/10.15587/1729-4061.2016.79789.
8. Odnorih Z., Manko R., Malovanyy M., Soloviy K. 2020. Results of surface water quality monitoring of the Western Bug river basin in Lviv region. Journal of Ecological Engineering, 21(3), 18–26. https://doi.org/10.12911/22998993/118303.
9. Shestopalov O.V., Hetta O.S., Rykusova N.I. 2019. Modern methods of food industry wastewater treatment. Ecological Sciences, 2(25), 20–27. https://doi.org/10.32846/2306-9716-2019-2-25-4.
10. Simanina P., Sidorskaya S. 2016. Wastewater of food industry. Collection of Materials of 72nd Student Scientific and Technical Conference, 20-28 April, 2016. Belorussian National Technical University, Faculty of Mining and Engineer Ecology. Section "Ecology". Minsk, 178–183. https://rep.bntu.by/handle/data/27398.
11. Stryzhak D.O. 2020. Production wastewater treatment from after alcohol liquid bard. Modern Achievements of Natural Sciences. Materials from all Ukrainian Scientific and Practical Conference. Poltava, 254–255.
12. Tymchak V.S. 2016. Assessment of ecological and economic Eefficiency of food industry waste usage. Economy of Agro-Industrial Complex, 10, 102–109.
13. Tymchuk I., Malovanyy M., Shkvirko O., Chornomaz N., Popovych O., Grechanik R., Symak D. 2021. Review of the global experience in reclamation of disturbed lands. Journal of Ecological Engineering, 22(1), 24–30. https://doi.org/10.12912/27197050/132097.
14. Tymchuk I., Shkvirko O., Sakalova H., Malovanyy M., Dabizhuk T., Shevchuk O., Matviichuk O., Vasylinych T. 2020. Wastewater a source of nutrients for crops growth and development. Journal of Ecological Engineering, 21(5), 88–96. https://doi.org/10.12911/22998993/122188.
15. Vahanov I., Mayevska I., Popovych M. 2013. Engineering geology and environment protection. https://web.posibnyky.vntu.edu.ua/iebmd/vaganov_inzhenerna_geologiya/13.3.1.htm.