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EXPERIMENTAL RESEARCH OF INDUSTRIAL WATER PARAMETERS OF CANNING PLANT AND BAKERY. ANALYSIS OF TREATMENT TECHNOLOGIES

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Abstract. One of the industries that uses large amounts of water is the food industry. Industrial, domestic managers of the production process stand out with it and enter the environment surrounded by contaminated effluents. Their main feature is the high content of dissolved organic matter and nitrogen. You can also create wall water to create aggregate-resistant colloids, which include animal and vegetable fats, proteins, starch, sugar, as well as salts, carbohydrates, dyes, thickeners, preservatives. As a result of the technology of treatment of such industrial effluents, is a combination of different technologies and methods of treatment and the creation of several units depending on the parameters of wastewater.
The purpose of our work is:
1) Analysis of physical and chemical indicators of industrial waters of food industry enterprises, monitoring of their impact on the environment;
2) to outline perspective directions of technologies of industrial water purification and creation of closed water circulation systems.

Key words: food industry, bakery, waste, sewage, ecological safety, cannery.

1. Statement of problems in general and its connection with various scientific or practical tasks

One of the leading industries in the world including Ukraine, which is developing dynamically, is the food industry. In Ukraine, industrial food production is carried out by more than 22 thousand enterprises, which employ more than a million workers. According to various estimates, food production now accounts for 15–21 % of all industrial production in Ukraine. Significant domestic and foreign investments in Ukrainian food industry as well as the introduction of international experience have led to positive changes in the industry and significant improvement in product quality.

After analyzing the literature sources and the results of our own research, we have found that wastewater from food industry is characterized by high concentrations of organic contaminants and usually does not contain toxic impurities. Organic wastewater pollution includes components of raw materials of plant and animal origin and as all substances of biological nature they can be oxidized. Therefore, biological wastewater treatment technologies in the food industry can be used effectively (Kovalchuk, Kovalchuk, 2021).

Contamination of surface waters with organic substances from food production effluents poses a significant environmental risk. These substances, which are brought in water, cause the development of decay processes in it, disturb the natural balance of water, cause eutrophication and negatively affect fauna and flora.

In recent decades, water pollution around the planet has become catastrophic. A significant role in the pollution of the hydrosphere is played by the processing industry. As a result, the surface water sources become more contaminated, the use of water for industrial, thermal, domestic and other needs determines the necessity in complex and costly treatment (Shestopalov et al., 2019). So, the improvement and creation of conceptually new methods of food wastewater treatment is a relevant scientific and technological task today.

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Analysis of recent research and publications. Theoretical, practical and methodological issues related to the use of waste from the food industry and their social and economic consequences are in the field of scientific interests of many domestic and foreign scientists (Tymchak, 2016).

Analyzing the publications of O. Shestopalov, O. Getta, N. Rykusova on the study of wastewater treatment methods in the food industry, we can conclude that the complexity of treatment of such waters is due to the polydisperse composition of pollutants and a combination of organic, inorganic soluble and insoluble compounds that form stable colloids and dispersed systems. The publication also outlines promising areas for the creation of closed water circulation systems during product processing (Shestopalov et al., 2019).

Electrocoagulation process is increasingly used for wastewater treatment in the food industry.

Thus, in the study by Gizem Basaran Dindas, Yasemin Çaliskail, Emin Ender Çelebi, Mesnt TekhaG, Nihal BektaG, H. Cengiz Yatmaz highly concentrated wastewater from the food industry was treated with electro-Fenton (EF) and the process of electrocoagulation (EC) was sequentially applied for removing general organic carbon from sewage. H_2O_2 was added periodically during the EF process. The EC process was then continued to complete the sequential purification process. As a result, these tandem sequential machining processes have led to positive cleaning dynamics, reduction of turbidity and reduction of a number of indicators, applying optimal operating conditions (Basaran Dundas et al., 2018).

The formulation of the objectives of the article is to analyze the state of the existing wastewater treatment system of the food industry on the example of the existing cannery and bakery; analysis of the impact of food wastewater on the environment and search for modern methods of wastewater treatment.

Identification of the most promising areas of utilization and processing of food waste as a secondary raw material and the creation of closed water circulation systems.

2. Presentation of the main material of the study

Ukraine's food industry is one of the largest consumers of water needed for technological processes, and therefore a significant producer of wastewater. The annual consumption of enterprises in this industry is approximately 35.83 million m3 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).

Utilization of technological waste of the food industry has its own features. Technological waste from processing at the relevant enterprises is accumulated in huge quantities. Having in its composition most of the same components as in the raw material, technological waste is, on the one hand, 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).

In the food industry (for example, vegetable processing plants) after washing vegetables and fruit, wastewater is usually contaminated, which leads to an increase in water-insoluble impurities such as 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 make it completely unfit for consumption.

Wastewater from the food industry belongs to the category of highly concentrated ones and has unstable quality and quantity indexes. 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 tissue, salts, insoluble mineral impurities, detergents and others. These waters are characterized by high levels of BSC, HSC, suspended solids, fats, etc. Discharge of wastewater into reservoirs quickly depletes oxygen reserves, which causes the death of aquatic organisms (Shestopalov et al., 2019).

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, preservatives (Simanina, Sidorskaja, 2016).

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, 12–35 % from weight of raw materials. From 20 to 50 % of waste enters the sewer network together with wastewater.

In circulating and wastewater, contaminants in vegetable processing plants are soil particles, fruit pulp and peel, mold and rot bacteria, and other wastes. During the treatment of the same raw material, wastewater can differ significantly.

Depending on the type of raw materials processed, the composition of wastewater varies significantly.

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, biological (biochemical). In addition, wastewater disinfection is used to destroy bacterial contamination.

The choice of 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, the requirements for the quality of treated water for reuse and recycling.

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. 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 ones, 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 treatment (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).

As is known, the criterion for oxidation of organic impurities in wastewater is the experimental determination of BOD. If this value is determined (that is, oxygen consumption has occurred), the impurities are biologically oxidizable. The degree of biooxidation of organic impurities is numerically estimated by the ratio BOD/ COD, that is, 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 of BOD/COD > 0.5, it is expedient to apply aerobic biological methods for neutralization of organic pollution.

Wastewater from the vast majority of food industry enterprises (except for the perfume and cosmetics industry, the salt industry, etc.) can be treated by 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 and pH fluctuations. The second condition is the need for two-stage schemes of biological treatment given the high concentrations of pollutants and different oxidation rates of their individual components.

Drainage regimes in the food industry are characterized by significant unevenness, which is mainly due to the availability of processed raw materials. 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 units, the volumes of which are comparable to the volumes of aeration tanks and emphasize the feasibility of using aeration tanks-mixers, which perform the function of averaging units for wastewater treatment in the food industry.

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 presence of fats in wastewater, which adversely affect the course of biochemical processes and are found in large quantities in the wastewater of the meat and fish processing industries. Preliminary flotation treatment allows to reduce significantly the content of coarse, emulsified and part of colloidal impurities, to increase the ratio of BOD/COD in wastewater (Table 1) 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 filtering through a polystyrene foam, 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 [1].

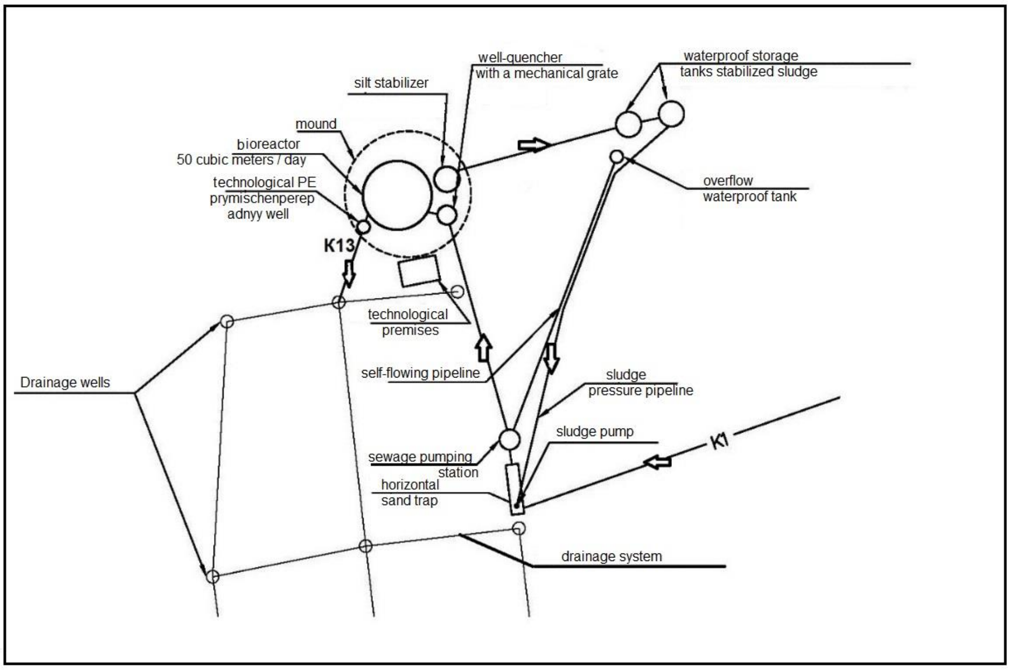

Fig. 1. The device system scheme of cannery sewage treatment

Let's analyze the wastewater treatment system of the cannery, shown in Fig.1

Wastewater treatment is as follows: domestic wastewater sewage station pressure pipeline K1 enters the well pressure damper with mechanical treatment (horizontal sand trap) where getting rid of coarse parts, the pipeline enters the local domestic treatment plants with a capacity of 50 m^3/day which consist 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. Stabilized activated sludge from treatment plants by pressure pipeline enters the waterproof containers for storage of stabilized sludge. Stabilized sludge is exported to the sludge sites of the utility company.

The total capacity of the cannery treatment facilities is 50 m^3/ day. The following stages of wastewater treatment are implemented: effective mechanical pre-treatment, averaging, biological treatment, secondary settling and stabilization of excess activated sludge with its subsequent storage in waterproof tanks.

Discharge of treated wastewater is carried out in the drainage network, which is a root irrigation system of 5–10 summer orchards. The treated water that has not been drained into the ground, with a volume of 4–7 m^3/day, is disinfected in the contact tank with sodium hypochlorite and is dumped into the river through a concrete head.

3. The results of the study

The implementation of food industry technology is accompanied by the formation of a significant amount of wastewater to which about a third of the processed raw materials passes and the concentration of pollutants in them is 10–100 times higher than in domestic one (Aujerman, 2003).

As the result of the production processes in the food industry wastewater is formed which is characterized as a concentrated multicomponent aqueous solution (suspension) with a high content of pollutants, respectively, their treatment in one way is not possible.

Experimental studies and analysis of wastewater were performed in the laboratory. Water samples were taken at the treatment facilities of existing food industry enterprises, namely a cannery and a bakery.

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. Sewage 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 the 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.

The result of the analysis of water parameters is shown in the summary table 1. As it can be seen from results of the research, not all parameters of sewage of both cannery and bakery correspond to the quality standard established by requirements. All water parameters, except pH, significantly exceed the MPC, especially for BOD_5, COD and ammonium nitrogen.

Table 1

Characteristics of wastewater

Date and point of sampling / Sewage quality indicators	19.06.2020 (entrance)	22.07.2020 (withdrawal)	22.07.2020 (entrance)	04.12.2020 (withdrawal)	Regulatory value Limit for discharge of pollutants
Bakery					
pH	7.12	6.95	7.05	7.15	**(max-min) 9-6.5**
BOD_5	19.6	49.6	47.5	36	**15**
Suspended substances	5.6	348	294.6	76	**15**
Chlorides	10.64	179.2	85.1	112	**350**
Sulfates	21.4	37	36.2	26.4	**500**
COD	48	124	96	78	**80**
Ammonium nitrogen	1.91	18.34	13.72	3.24	**2**
Nitrites	0.06	4.2	5.6	2.8	**3.3**
Nitrates	2.64	18.6	21.8	12.5	**45**
Phosphates	2.48	14.9	11.6	2.73	**3.5**
Total iron	0.26	0	0	0	**0.3**
Cannery					
	26.02.2020 (withdrawal)	18.03.2020 (withdrawal)	12.03.2021 (entrance)	12.03.2021 (withdrawal)	Regulatory value Limit for discharge of pollutants
pH	6.38	6.96	7.34	7.28	**(max-min) 9-6.5**
BOD_5	77.5	108.8	84	98	**6**
Suspended substances	189.2	352	156	198	**17**
Chlorides	223.4	252.6	170.16	191.43	**100**
Sulfates	35.39	31.56	23.87	25.51	**500**
COD	186	294	212	254	**35.7**
Ammonium nitrogen	2.45	6.8	4.6	9.8	**2.5**
Nitrites	1.32	2.72	0.09	0.11	**3.3**
Nitrates	9.42	16.34	5.34	6.52	**45**
Phosphates	15.87	16.92	34.72	27.28	**2.35**
Total iron	0.52	0.84	0.15	0.2	**0.3**

Thus, in accordance with the final results of wastewater analysis, the maximum allowable norms of ammonium nitrogen, BOD5 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 several times (Table 1).

At the same time, it should be noted that according to the latest results of wastewater analysis from the bakery, we can see an improvement in the degree of wastewater treatment, which indicates that the treatment system works and practically reaches its quality. Unfortunately, this cannot be said about the results of another company, the cannery, where the positive dynamics is not so clear.

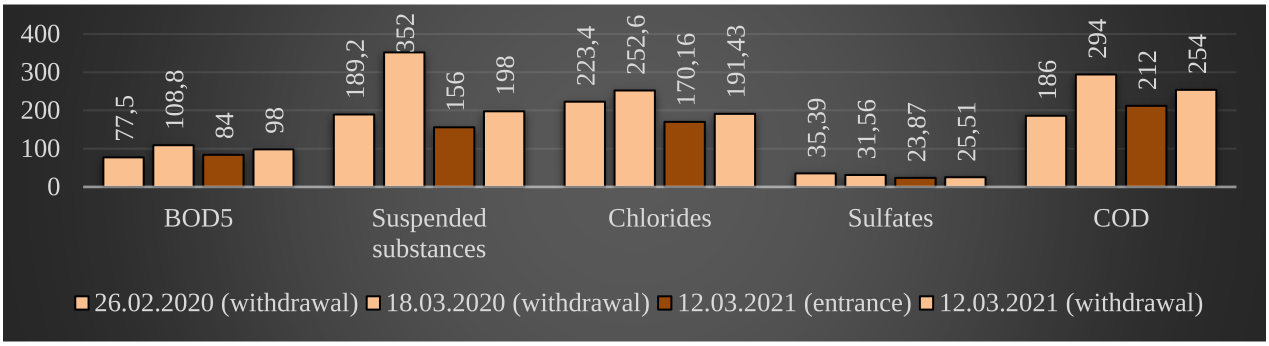

Fig. 2. Dynamics of the content of pollutants in wastewater at the entrance and the withdrawal of the existing treatment facilities of the cannery by BOD, COD suspended solids, chlorides and sulfates

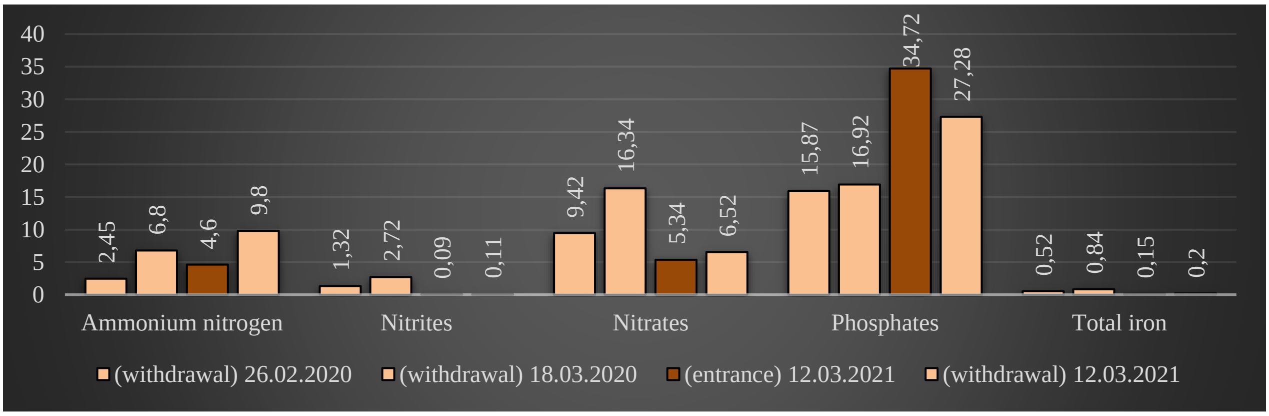

Fig. 3. Dynamics of the content of pollutants in wastewater at the entrance and the withdrawal of the existing treatment facilities of the cannery by ammonium nitrogen, nitrites, nitrates, phosphates and total iron

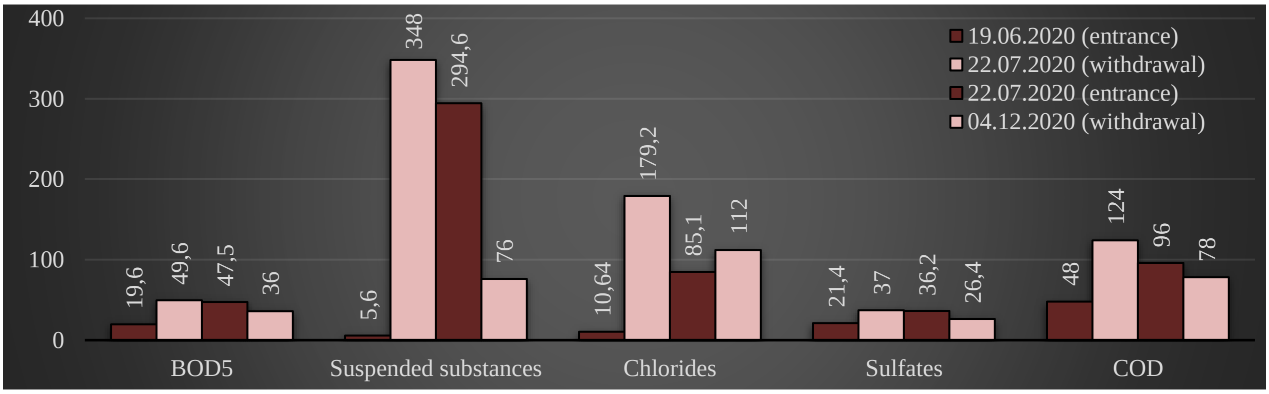

Fig. 4. Dynamics of the content of pollutants in wastewater at the entrance and the withdrawal of the existing treatment facilities of the bakery by BOD, COD, suspended solids, chlorides and sulfates

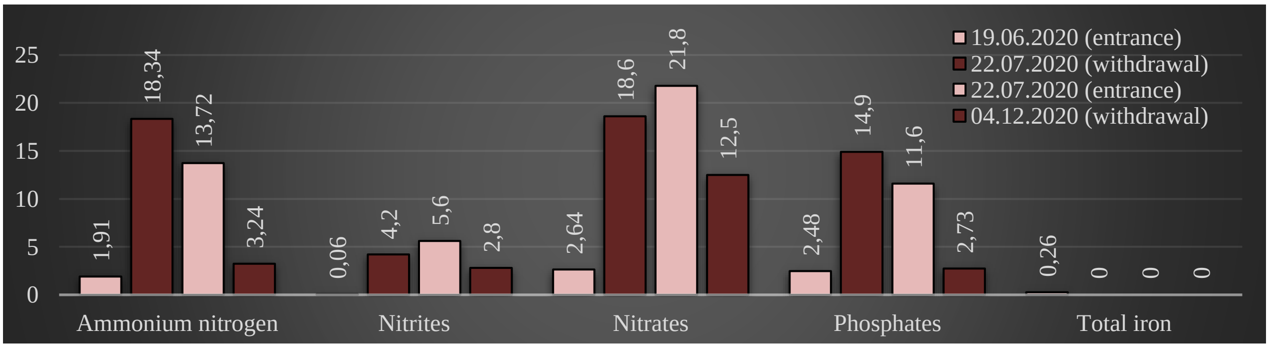

Fig. 5. Dynamics of the content of pollutants in wastewater at the entrance and the withdrawal of the existing treatment facilities of the bakery by ammonium nitrogen, nitrites, nitrates, phosphates and total iron

Also, in the wastewater of the cannery, as the 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 high-quality wastewater composition.

Based on the obtained values and analyzing the ratio of BOD/COD, it is possible to offer the enterprises to improve the stages of biological treatment of industrial water to obtain quality indicators that meet the standards.

In particular, chemical oxygen demand (COD), oxidation by potassium permanganate indicates 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.

After analyzing the dynamics of changes in pollutants in the wastewater of the bakery and cannery, we can conclude that the biological treatment systems at these enterprises do not function satisfactorily and clearly need improvement. In particular, if in the wastewater from the bakery substances in excess of the norms remained only three indicators of wastewater quality out of six that were at the beginning of the study, in the case of the cannery, their number has not changed. Thus, if in the wastewater of the bakery the excess of certain 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, 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 treatment of contaminated water. This is a natural process that reproduces in artificial conditions and allows you to get rid of organic impurities without the use of complex and costly technologies. However, to increase the efficiency of the technology, biological wastewater treatment is used in combination with other 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.

4. Conclusions

Wastewater from the food industry is highly concentrated in terms of organic impurities, suspended solids, may have unfavorable for biological treatment content of nutrients and pH values, but the analysis of the degree of biooxidation of organic impurities in relation to BOD_5 / COD showed that wastewater from the vast majority of food industry can be purified by biological methods.

For wastewater treatment which contains a high content of organic, suspended solids, nutrients, oils and fats you need to use a combined treatment technology: physical, biological and phytotherapy.

The value of COD decreases to 99.71 %, BOD to 99.76 %, Nitrogen to 98.90 %, oil and fat content to 99.75 % of the initial characteristics of wastewater.

Modern biological methods which include anaerobic (methane) fermentation allow not only to treat wastewater but also to obtain high-quality fertilizers and electricity from biogas combustion.

The considered biotechnology of wastewater treatment, which is successfully used in most food industries, can also be considered as a source of water for watering plants in the area to reduce overall water use in the process and return to the general process, for example to use for washing vegetables and fruit.

References

Aujerman, L. Ja. (2003). *Tehnologija hlebopekarnogo proizvodstva: uchebnik. 9- e izd.; pererab. i dop.* SPb: Professija.

Basar Dindas, G., Çaliskai, Y., Ender Çelebi, E., Tekbaş, M., Nihal Bekta, & Cengiz Yatmaz, H. (2018). Sequential Treatment of Food Industry Wastewater by Electro- Fenton and Electrocoagulation Processes. *Int. J. Electrochem. Sci.*, 13 12349 – 12359. doi: 10.20964/2018.12.82

Kovalchuk, V. A., & Kovalchuk, O. V. (2021). Biotekhnolohiia ochystky stichnykh vod pidpryiemstv kharchovoi promyslovosti. Retrieved from http://eprints.kname.edu.ua/31310/1/14.pdf

Shestopalov, O. V., Hetta, O. S., & Rykusova, N. I. (2019). Suchasni metody ochyshchennia stichnykh vod kharchovoi promyslovosti. *Ekolohichni nauky*, *2*(25), 20-27.

Tymchak, V. S. (2016). Otsinka ekoloho-ekonomichnoi efektyvnosti vykorystannia vidkhodiv kharchovoi promyslovosti. *Ekonomika APK*, 10, 102–109.

Stryzhak, D. O. (2020*). Ochystka vidkhodiv vyrobnytstva vid pisliaspyrtovoi ridkoi bardy: Suchasni dosiahnennia pryrodnychykh nauk : materialy Vseukr. stud. nauk.-prakt. konf.* Poltava, 254–255

Simanina P., & Sidorskaja S. (2016). *Stochnye vody pishhevoj promyshlennosti. Sbornik materialov 72-j Studencheskoj nauchno-tehnicheskoj konferencii*, 20-28 aprelja 2016. Belorusskij nacional'nyj tehnicheskij universitet, Fakul'tet gornogo dela i inzhenernoj jekologii. Sekcija «Jekologija». Minsk, 178–183.

Vahanov, I. I., Maievska, I. V., Popovych, M. M. (2013). *Inzhenerna heolohiia ta okhorona navkolyshnoho seredovyshcha* .Retrieved from https://web.posibnyky.vntu.edu.ua/iebmd/vaganov_inzhenerna_geologiya/13.3.1.htm