

ECOLOGICAL ASPECTS OF MODERNIZATION OF ALCOHOL INDUSTRY
ENTERPRISES AT THE PRESENT STAGE OF DEVELOPMENT

Marianna Havryshko, Olena Popovych, Halyna Yaremko

*Lviv Polytechnic National University,
12, S. Bandery Str., Lviv, 79013, Ukraine
marianna.i.havryshko@lpnu.ua, lpolenaeko@yahoo.com, halynayaremko@gmail.com*

<https://doi.org/10.23939/ep2020.03.179>

Received: 10.08.2020

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Abstract. At the present stage of development, the entire world industry has faced the problem of rational use of renewable natural resources, in particular the most efficient ways of wastewater treatment and the use of accumulated waste in the production process as secondary raw material.

In particular, the alcohol industry, as one of the components of food, medical, chemical and various industries, leads to the formation of a huge amount of waste, including wastewater. The food industry, like any other industry, has a negative impact on the environment. Water bodies are the most affected by the food industry. Almost the first place in terms of water consumption per unit of production is the production of alcohol. Consumption of large amounts of water leads to the formation of wastewater, which is highly polluted and adversely affects the environment.

Due to the high chemical and biological consumption of oxygen, specific colour and odor, suspended solids, low pH value, the purification of such waste in the filtration fields, and discharge into water bodies is not possible. The purpose of our work is:

- 1) the analysis of the alcohol industry potential in Ukraine in recent years, and methods of waste disposal as a potential source for the development of bioenergy.
- 2) environmental aspects of the alcohol industry modernization at the present stage of development and implementation of modern wastewater treatment technologies.

Key words: food industry, alcohol industry, waste, sewage, ecological safety, bioenergy, bioethanol, state regulation

1. Problem statement and its connection with important scientific or practical tasks.

At the present stage of the food industry development in Ukraine, the alcohol industry is one of the leading industries that is evolving dynamically. At the same time, this branch of the food industry is the source of the negative impact on the environment. According to the degree of interaction intensity of the

alcohol industry with the environment, the first place among the objects of nature is occupied by water resources, which are used in most technological processes to obtain products as the main or auxiliary raw materials. In terms of water consumption per unit of output, the alcohol industry is one of the first places.

Enterprises producing ethyl alcohol, rectified grape ethyl alcohol, and rectified fruit ethyl alcohol are also “producers” of a large amount of wastewater, which is characterized by a significant level of pollution. Thus, 95 % of the wastewater generated in the production process contains high concentrations of pollutants and without prior treatment can not be discharged into the municipal drainage system and natural reservoirs. Wastewater is characterized by a high content of suspended particles and organic impurities. The feature of the wastewater is a significant content of dissolved organic matter. Discharge of this water into the sewerage networks of cities is prohibited, and their removal and collection in the “filtration fields” leads to the formation of toxic substances that pollute the air over a large area.

The main direction of the aquatic environment protection in the industry is the transition of enterprises to work on a closed water supply scheme when a company after treatment of its own wastewater reuses it in the technological cycle, thus polluted and untreated wastewater does not enter reservoirs. Unfortunately, the level of wastewater treatment in Ukraine is very low. The existing treatment plants of most companies remove only 10–40 % of inorganic substances (40 % of nitrogen, 30 % of phosphorus, 20 % of potassium) and practically do not remove heavy metal salts.

Consequences of water pollution can be dangerous to human health. Damage can be caused by such common pollutants as fluoro-, chloro-, and organophosphorus

pollutants, nitrates, nitrites, nitro compounds, pesticides, herbicides, etc. [1].

That is why the improvement and creation of conceptually new methods of wastewater treatment of alcohol enterprises and the food industry in Ukraine is an urgent scientific task.

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 belong to the field of scientific interests of many domestic and foreign scientists [2].

Current trends existing in the world as for the use of alcohol products can solve a number of interrelated problems of social and environmental nature [3].

Analyzing the publications of R. Zakharova on biotechnological processes of methane fermentation of wastewater research, we can conclude that the use of methane fermentation for wastewater treatment and waste disposal and social effects and allows to obtain fertilizers or feed additives characterized by a high content of has significant environmental, economic, biologically active substances, including B vitamins (primarily B12) [4].

In the work of K. Ovcharenko on improving the technology of feed concentrate of vitamin B12 production by accelerating methane fermentation of acetone-butyl bard by discrete-pulsed energy input in the recirculation mode for 8–10 cycles for 40–48 hours, which will increase the concentration of B12 vitamin in methane mash by 30–35 % (up to 850 g/l), halve the duration of the process and, consequently, reduce energy consumption [improvement of biotechnology for the production of feed concentrate of vitamin b12 from distilleries waste [5].

The issues of improving the biotechnology of ethanol production with the use of non-traditional raw materials are covered in the works of Ye. Honchar and the method of the production of ethyl alcohol using Jerusalem artichoke as the main raw material is proposed as it is one of the cheapest raw materials in the industry [6].

Formulation of the objectives

The purpose of the article is the analysis of the current state and the main environmental aspects of the alcohol industry modernization in Ukraine, identification of the most promising areas of utilization and processing of alcohol waste as a secondary raw material. This is important for the development and expansion of the bioenergy market in Ukraine. The aim of the study is to

find effective methods of waste disposal and wastewater treatment technologies, as well as the levers of state regulation capable of directing existing and new enterprises of the alcohol industry to energy efficiency and implementation of socially important environmental and economic tasks.

2. Presentation of the main material of the study

The pandemic caused by the Covid-19 virus has been faster and tougher for the world community and its economy than expected. Almost all countries are activating domestic resources and Ukraine is no exception.

As a result, a number of legislative acts were adopted to resolve the situation, including the Law of Ukraine “On Amendments to Certain Legislative Acts of Ukraine Aimed at Providing Additional Social and Economic Guarantees in Connection with the Spread of Coronavirus Disease (COVID-19)” (540-I, which entered into force on April 2.

According to this law, the Ukrspyrnt State Enterprise was allowed to manufacture disinfectant (raw material for antiseptics) based on the plants of the enterprise until April 30, 2020 inclusively [7].

In three weeks, Ukrspyrnt supplied producers with 3.3 million liters of disinfectant. The disinfectant was shipped from 12 plants of Ukrspyrnt State Enterprise. For efficiency, two additional plants were launched in Lviv and Cherkasy regions [8].

In total, in the first half of 2020, the state-owned enterprise produced 3.3 million decalitres of alcohol and at the same time in 2019 – 2.5 decalitres of alcohol [9]. It indicates the significant increase in the capacity of the alcohol industry not only at the present stage of development of the food industry but also the needs of the medical and preventive treatment industry.

At the same time, such an increase in the capacity of the alcohol industry leads to the formation of huge volumes of wastewater which form wastewater from the production process (1 liter of ethanol is accompanied by the formation of 12–14 liters of wastewater) and the volume of after alcohol bard (12–15 dm³ per 1 dm³ of alcohol).

In terms of raw material consumption, alcohol production is the largest biotechnological production in the world, and ethanol is the third-largest in terms of the gross product value.

As of today, the concepts of balanced use of natural resources and ecologically safe, energy-efficient development of industrial and production enterprises are being gradually introduced in Ukraine. The main purpose of their implementation is to ensure that the human needs for resources do not conflict with the priorities of environmental protection and human health.

Current trends in the world as for the use of alcohol products can solve a lot of interrelated problems of social and environmental nature [10].

It should also be noted that the Law of Ukraine "On Amendments to the Law of Ukraine" On State Regulation of Production and Circulation of Ethyl Alcohol, Cognac and Fruit Alcohol, Alcoholic Beverages, Tobacco Products and Fuel" on the liberalization of production and circulation of ethyl alcohol No. 318-IX [11] from July 1, 2020 began an important stage of demonopolization of the alcohol industry.

According to the document, business entities of any form of ownership are given the opportunity to produce ethyl alcohol (in particular as a medicine), rectified grape ethyl alcohol, rectified fruit ethyl alcohol, grain distillate, and bioethanol, subject to obtaining the appropriate license.

A license for the production of alcohol is given to enterprises that have installed round-the-clock video surveillance systems for the production and release of products. Disabling 24-hour video surveillance is a ground for refusal or revocation of the license.

According to the document, the commissioning and granting permits for the construction of new enterprises for the production of ethyl alcohol, grape ethyl alcohol rectified, fruit ethyl alcohol rectified is allowed since July 1, 2021 [12].

At the same time, the technology of wastewater treatment of distilleries in Ukraine is developed by the Department of Ecology of UkrNDIspirtbioprod [13] and is mainly used at Ukrspyr SE.

Also, for the production of liquid fuels available in Ukraine, according to the project "Concepts for the development of bioenergy in Ukraine until 2035", the use of distilleries and breweries, as well as sugar factories with appropriate equipment for bioethanol, feed additives, etc. is provided [14].

One of the known methods of wastewater treatment, waste disposal, treatment of sludge from primary settling tanks and excessive active sludge from sewage treatment plants, etc. is methane fermentation (a method of biotechnology that consists in the biocenosis of anaerobic microorganisms of most organic polymeric and other compounds into methane and carbon dioxide).

In biotechnology for anaerobic fermentation of wastewater and waste sealed tanks - methane tanks are used. As the result of the vital activity of methane tanks organisms biocenosis, the concentration of organic substances decreases and ecologically clean fuel – biogas – is formed. Methane fermentation occurs at different temperatures. There is psychrophilic (<20 °C), mesophilic (20–45 °C) and thermophilic (45–65 °C) fermentation. The main methanogenic bacteria include *Methanobacterium*, *Methanospirillum*, *Methanococcus*,

Methanosarcina, *Methanotrix*, *Clostridium*. The advantages of the anaerobic method are the ability to treat highly concentrated wastewater (HSC over 2.000 mg O₂/dm³); less consumption of nutrients by activated sludge organisms; significant loads on activated sludge; the possibility of obtaining biogas as an energy source; formation of the less amount of excess sludge than in aerobic processes; small areas for buildings; the possibility of application of additional cleaning modules, etc. The peculiarity of methane fermentation is that almost 95 % of the organic matter of effluents is transformed into biogas and only 5 % is used for the energy needs of the microorganisms.

Methane fermentation is used for:

- treatment of concentrated wastewater, including food industry enterprises (sugar, alcohol, starch and molasses, meat processing, cheese);

- wastes of food enterprises (pulp of sugar factories, after alcohol bard, whey), excess aerobic activated sludge, leaves from the territory of cities);

- production of biogas used as the alternative energy source;

- obtaining fertilizers or feed additives, characterized by the high content of biologically active substances, including B vitamins (primarily B12) [4].

In particular, the production of feed concentrate of vitamin B12 includes the following technological processes: continuous fermentation of alcohol waste (bards) by biocenosis of thermophilic methane-forming bacteria in two phases, in non-sterile conditions at the temperature of 55–57 °C. In the first phase, there is an accumulation of fatty acids and ammonia, in the second, methane, carbon dioxin, and vitamin B12 are accumulated. Stabilization of methane mash and its thickening is carried out on evaporators, drying of the condensed mass is performed on spray dryers [5].

Another way to use alcohol waste is to utilize alcoholic fermentation gases to produce liquefied carbon dioxide.

Carbon and nitrogen oxides account for a significant share of emissions from the alcohol industry, as well as small amounts of H₂S, CH₄, and CO₂. Due to the obsolescence of equipment at distilleries, the amount of harmful emissions into the air exceeds the norm.

Alcohol bard often negatively affects alcohol production. Alcohol bard is the waste from the production of alcohol. It is used in agriculture as animal fodder and soil nutrition. At a significant dose, the soil is acidified, because the alcohol bard has an acidic environment, and thus has a negative effect on crops and soil microflora.

Industrial water in distilleries is discharged by a general stream, which causes the release of gaseous substances, the formation of sludge, carcinogens, and

toxic substances. To reduce the environmental impact of the alcohol industry, it is necessary to modernize equipment and implement environmental systems that will lead to drastic changes in resource costs and environmental pollution.

The operation of distilleries requires a large amount of water, which the company contaminates with impurities and discharges them into reservoirs, which leads to a decrease in clean fresh water and deterioration of the environment. Therefore, the analysis and monitoring of food companies are extremely relevant.

Fermentation gases of alcoholic beverages contain 98–99.8 % of carbon dioxide.

Up to 3.5–4.5 tons of liquefied carbon dioxide can be obtained from 1000 dal of ethyl alcohol. Today, the use of average annual CO₂ capacity at distilleries in Ukraine does not exceed 2 %. At the same time, there is an increase in demand for carbon dioxide, which is obtained from exhaust gases from ammonia production and flue gases from boilers. This is due to the absence of such product odor, characteristic of alcoholic fermentation, while not taking into account the presence of other harmful impurities.

At the same time, according to the State Statistics Service in 2017, carbon dioxide emissions into the atmosphere amounted to 124 million tons and the share of Ukrainian distilleries in CO₂ emissions is about 60.000 tons.

Thus, the revival of carbon dioxide production in distilleries will help address several issues at once – an increase of profitability, production of an additional valuable product – biocarbon dioxide, reduction of greenhouse gas emissions. A necessary condition for the utilization of carbon dioxide from fermentation gases is

its preliminary purification from associated impurities. During the fermentation of raw carbohydrates into alcohol, a significant amount of concomitant volatile organic fermentation products is formed together with carbon dioxide, namely higher alcohols, esters, aldehydes, organic acids, the quantitative composition of which varies and depends on many factors: type of raw material, the race of yeast for fermentation, speed and conditions of fermentation [15].

3. Results of the investigation monitoring

Wastewater generated as a result of production processes in the food industry is characterized as a concentrated multi-component aqueous solution (suspension) with a high content of pollutants. Therefore, they cannot be cleaned in one way without the combination of different methods and appropriate equipment.

Most of the water involved in the production process is discharged from it and enters the environment in the form of contaminated effluents. Their main feature is the high content of dissolved organic substances.

The characteristics of wastewater from the food industry are given in Table 3.1 [16].

The implementation of food industry technology is accompanied by the formation of a significant amount of wastewater. About a third of the processed raw materials come into wastewater, and the concentration of pollutants in it is from 10 to 100 times higher than in household wastewater. The amount of wastewater generated at the food industry plants, for example, is given in Table 3.2.

Table 3.1

The composition of wastewater from various food industries

Production	pH	CL, mg/l	COD, mg O ₂ /l	BOD ₅ , mg O ₂ /l
Sugar production	6–9	1200–2600	4900	1400–3600
Yeast production	6.8	1900	1800	1500
Breweries	6.9	2650	2000–6000	1500–4000
Distilleries (bard)	4	32000–45000	20000–48000	15500–29900
Production of low-alcohol beverages	6	–	1760	1200
Starch processing plants (potatoes)	7.2	600–4700	100–2520	300–1300
Dairy enterprises	6.5–9	350–600	1200–3000	500–2000
Distilleries	3.55	400–750	51200	40000
Fruit and vegetable production	4	20–1800	440–2690	350–2175
Meat processing plants	6.5–7.5	410–12000	1800–12500	650–5100
Confectionery (average stock) enterprises	4.5–9.9	1220–1790	6060	2190
Ice cream production	6–11	8000	6000	4000

Table 3.2

The amount of wastewater (WW) generated in the food industry

Enterprise	Amount of WW
Bakery with the capacity of 30 tons / day	2.8 m ³ / t of products
Bakery with the confectionery shop with the capacity of 40 tons / day	3... 4 m ³ / t of products
Pasta factory with the capacity of 105 tons / day	5.3 m ³ / t of products
Yeast factory	170 m ³ / t of yeast
Cannery processing cucumbers	4-5 m ³ / 1000 conventional cans
Sand sugar factory	1.7 m ³ / t of beets
Primary winery	0.2 m ³ / t of grapes
Secondary winery (vintage wines)	28 m ³ / t of grapes
Champagne factory (tank method)	6.7 m ³ / 1000 bottles of champagne
Butter and alcohol factory with bakery yeast shop	830 m ³ / 1000 dal of alcohol
Grain processing plant	1300 m ³ / 1000 dal of alcohol
Malt plant	18 m ³ / t of malt
Brewery	76 m ³ / 1000 dal of beer

The most important in the choice of effective and resource-saving methods of treatment of such industrial effluents are the characteristics of wastewater (necessary to determine the method of treatment), the possibility of discharge into reservoirs, and the presence of valuable or toxic impurities. Then the methods for wastewater treatment are determined, which is later submitted for re-treatment in compliance with all water quality requirements provided by law.

The technology of treatment of industrial effluents of enterprises of the choral industry is a combination of the most frequently used treatment methods and consists of the following blocks:

The averaging and phase division unit. Since the bard is a suspension, the first block of treatment facilities is the block of averaging and division of the bard into phases: cake – solid component and supernatant – liquid component. To divide the bard into phases, special devices are used (eddy current devices, centrifuges, decanters, etc.). Also, to intensify the process, chemical reagents are dosed.

The solid phase (cake) can be used as fodder for cattle, fertilizer it, or can be taken to the landfill (if necessary, a unit for additional dehydration or drainage is installed). The liquid phase (fugate) is sent to treatment plants.

The physico-chemical treatment unit – reagent treatment, flotation. This stage of industrial wastewater treatment includes treatment with reagents. It is provided in reactors while maintaining a high pH environment and constant ozone saturation. Separation of the formed suspension by flotation is provided on flotators when dosing chemical reagent for consolidation of the suspension. The additional saturation of the

floated sludge with air creates favorable conditions for sorbed organic compounds.

The biological treatment unit – aeration tanks, biofilters when discharging treated wastewater into the reservoir (drainage). In aeration tanks and biofilters, the process of biological wastewater treatment takes place, namely, the oxidation of organic pollutants and the conversion of nitrogen compounds into the nitrate form. For this purpose, activated sludge is used, which is a biocenosis of microorganisms - mineralizers able to sorb on their surface and oxidize in the presence of oxygen organic matter of wastewater.

A promising method of increasing the level of environmental safety of enterprises in the alcohol industry is the creation of closed water circulation schemes and the reuse of purified water in production.

This combination can be used as the basis for the creation of standard treatment plants for further use in new enterprises and distilleries, which are allowed to be built in Ukraine from July 1, 2021, under the Law of Ukraine “On Amendments to the Law of Ukraine “Regulation of production and circulation of ethyl alcohol, cognac, and fruit alcoholic beverages, tobacco products, and fuel” on the liberalization of activities in production and circulation of ethyl alcohol 318-IX [11].

At the same time, the justification of the choice of the method of water purification of a particular enterprise depends mainly on the composition of its pollutants. In each case, it requires experimental studies of the effectiveness of the particular method of purification, types, and doses of reagents, etc.

It is planned to select, calculate and conduct experimental studies of the efficiency of the main technological parameters of the process of a specific method of wastewater treatment of food industry

enterprises, which will provide sufficient quality of treatment for reuse.

Conclusions

The alcohol industry of Ukraine is one of the largest consumers of water required for technological processes, and therefore, a significant producer of wastewater, which significantly affects the environment of Ukraine through the discharge of insufficiently treated or untreated wastewater into reservoirs.

Industrial wastewater from alcohol enterprises is characterized as a concentrated multicomponent aqueous solution (suspension) with a high content of pollutants, so water protection standards do not allow them to be discharged into the sewer network, as well as in open water without prior treatment. The complexity of such wastewater treatment is due to the polydisperse composition of contaminants and the combination of organic, inorganic soluble, and insoluble compounds that form stable colloids and dispersed systems.

Therefore, it is usually impossible to treat wastewater from alcohol plants in one way without the combination of different methods and appropriate equipment.

A promising method of increasing the level of environmental safety of enterprises in the alcohol industry is the creation of closed water circulation schemes and the reuse of purified water in production. This requires the creation of water purification systems that will provide sufficient quality for reuse purification. The justification of the choice of the method of water purification of a particular enterprise depends mainly on the composition of its pollutants. In each case, it requires experimental studies of the effectiveness of the particular method of purification, types and doses of reagents, etc.

Biological methods of purification deserve special attention at the enterprises of the food and alcohol industry. Advances in recent decades in microbiology, hydrobiology, and biotechnology suggest that modern biological methods can be successfully used to treat wastewater from most contaminants. Modern biological methods, which include anaerobic (methane) fermentation, allow not only treating wastewater but also obtaining high-quality fertilizers and electricity from biogas combustion.

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