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The Role of Bioenergy Utilization of Wastewater in Achieving Sustainable Development Goals for Ukraine

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Abstract
The article is devoted to the issues of Ukraine's achievement of the Sustainable Development Goals 6. Clean water and sanitation and 7. Affordable and clean energy through bioenergy recycling of wastewater. The purpose of the study was to analyze the current state of wastewater management on the example of Ukraine, as well as to investigate a successful case of bioenergy recycling by a food industry enterprise. The study was based on the principles of sustainable development, circular economy, and scientific research methods: abstract and logical, monographic, graphic and tabular, analysis and synthesis, abstraction, and generalization. The results obtained show that Ukraine has a problem with the safety and quality of drinking water, and wastewater of various origins is a significant pollutant. Among the industrial enterprises of Ukraine, one of the largest consumers of water is the food industry and utilities that belong to the sphere of housing and household services, mainly water utilities. The state of drinking water safety and quality due to pollution remains unsatisfactory. As a result of the study, the authors suggested using bioenergy recycling of wastewater. The authors illustrate a successful case of a particular food industry enterprise in Vinnytsia region, Ukraine, where this practice solved the following problems: 1) pollution of the river by untreated wastewater of the enterprise; 2) energy supply of the enterprise due to biogas from wastewater of its own production, and also additional products - organic fertilizers, which are in great demand in the market.

Keywords: recycling, bioenergy recycling, wastewater, sewage sludge, drinking water, biogas, Sustainable Development Goals.

1. Introduction.

The problem of water supply for the world's population is becoming increasingly acute. Therefore, the issue of conservation, rational use and, if possible, restoration of water resources is a key issue in the formation of water policy in many countries.

The monitoring of surface water in the EU is carried out in accordance with the Water Framework Directive (Directive 2000/60/EC, 2000), which aims to achieve good ecological and chemical status of surface waters.

However, the current state of Ukraine's water supply and sewerage network, which is in crisis, does not allow achieving high quality indicators of surface water. A common disadvantage of the existing water supply and sewage systems in Ukraine is depreciation and obsolescence. This also poses a constant threat of deterioration in the physicochemical and bacteriological indicators of water quality during transportation. The state of the water

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environment is significantly affected by the operation of sewerage networks, which, due to wear and tear, discharge insufficiently treated or even untreated wastewater into water sources. Imperfect wastewater treatment technologies at enterprises lead to surface water pollution, including pollutants such as heavy metals.

The issue of disinfected sludge disposal also needs to be addressed urgently. Until recently, the sludge was dumped into open water. Nowadays, sewage sludge utilization is constantly improving, developing in different directions. One of the priority areas of sewage sludge utilization is its application in agriculture to improve soil fertility. Another promising area of utilization of the resulting sludge is its use for biogas production.

It is the bioenergy utilization of wastewater that is the key to full or partial achievement of certain Sustainable Development Goals (SDGs), also known as the Global Goals (The 17 goals), that were established by the United Nations in 2015 as a comprehensive initiative to combat poverty, safeguard the environment, and promote peace and prosperity for all people by 2030. The 17 SDGs are interdependent, acknowledging that efforts in one area will impact outcomes in others, and that development must prioritize social, economic, and environmental sustainability.

Bioenergy utilization of wastewater will help Ukraine achieve SDGs 6. Clean water and sanitation and 7. Affordable and clean energy.

2. Literature review

The issue of effective waste management of various types is in the field of view of many scientists. Paziuk and Tokarchuk 2022 note that the urgent environmental task today is environmental restoration: rational processing of industrial and agricultural waste, restoration of land fertility from toxic chemicals, utilization of sludge from sewage treatment plants, treatment of water sources, etc.

According to Kaletnik et al, 2020a implementing a modern approach to non-waste production in Ukrainian agricultural enterprises can result in a consistently high contribution to the country's gross domestic product (12%) and lead to significant increases.

Jiang et al, 2019 investigate the potential use of crop residue as a significant source of energy for countries that rely on energy imports, indicating that power generation from crop residue may be a promising prospect. Tokarchuk et al, 2021 study the possibility of using agricultural waste as a raw material for biofuels production, mainly biogas. Pryshlik et al, 2022 propose creation of biofuel production claster with the use of agricultural crops and waste. The bioenergy potential of agricultural waste is not fully used in Ukraine (Korpaniuk et al, 2019; Kaletnik, Lutkovska, 2020). According to Patyka et al, 2021 the country faces non-diversification of the agricultural producers activities, including improper development of primary processing elements. The agricultural sector of Ukraine needs: new technological processes and equipment in agriculture (Bulgakov et al, 2019), improvement of supply chain strategy (Varchenko et al, 2020), the use of the latest biotechnologies for obtaining biofuels (Kupchuk et al), incluging waste feedstack.

Technological aspects of effective food industry waste management were investigated by Kaletnik et al, 2020b, namely vibration process of the drying of food waste – by Bulgakov et al, 2020.

Among other types of waste, sewage has its own characteristics: it is considered quite dangerous in terms of sanitary and epidemic, however, it has bioenergy potential.
Ibiam and Igewnyi, 2012 note that depending on the origin, wastewater can be categorized as sanitary, commercial, industrial, or surface runoff. Domestic or sanitary sewage refers to spent water from residences and institutions that carry body wastes, washing water, food preparation wastes, laundry wastes, and other waste products of normal living. Commercial wastes, or liquid-carried wastes from stores and service establishments serving the immediate community, are considered part of the sanitary or domestic sewage group if their characteristics are similar to household flows. Industrial wastes are those resulting from industrial processes or the production or manufacture of goods, and their flows and strengths are typically more varied, intense, and concentrated than those of sanitary sewage.
The term sewage sludge, or biosolids, refers to the semi-solid residual material formed as a byproduct of industrial or municipal wastewater treatment during sewage treatment, according to Kumar and Chopra, 2016.
Specifically, wastewater sludge is generated as a byproduct of various treatment stages of domestic wastewater, which may also include agricultural and commercial wastewater, as stated by Williams, 2005.
Kaletnyk and Honcharuk, 2016, note that Ukraine discharges more than 20 km^3 of wastewater annually, of which almost 6 km^3 is untreated and insufficiently treated. Disposal of wastewater sludge generated at municipal sewage treatment plants is an environmental and economic problem of environmental protection and public health.
Negi et al, 2022 note that sludge treatments aim to reduce the weight and thickness of sludge to minimize disposal costs and mitigate health risks associated with other disposal methods. While pathogens can be eliminated by heating during thermophilic digestion, composting, or incineration, the most common way to decrease weight and volume is through water absorption. When selecting a sludge treatment system, the quantity of sludge produced and the costs associated with the various disposal options must be considered.
Sabliy and Zhukova, 2022 present the findings of their research and developed technologies for treating wastewater from food enterprises. Among these are the treatment of wastewater with a high organic matter content, using a dairy plant as an example; removal of nitrogen compounds from wastewater generated by a confectionery factory; and phosphate treatment of wastewater from a meat processing plant. Ahmad et al, 2019 in the review of treatment and utilization of dairy industrial waste describe different methods of utilization with focuses on biotechnological ones. Chandra et al, 2018 propose the concept of creation of biorefinery to transform dairy waste into valuable bioproducts: biofuels, bioplastics, feed additives, chemicals. Dabrowski et al, 2017 investigated technological aspects of operating dairy wastewater treatment plant.
Tokarchuk et al, 2020 propose biogas production from waste for small agricultural enterprise engaged in animal husbandry. The use of biogas production technology through conversion of sewage sludge and other organic waste is included in the national energy programs of the world's leading countries: USA, Canada, UK, France, Finland, China, etc. (Pryshliak et al, 2021).
In the European Union, aerobic and anaerobic digestion of wastewater sludge is heavily

favored. Most often, anaerobic sewage sludge treatment is used in Spain, the United Kingdom, Italy, Finland, and Slovakia, and aerobic sewage sludge treatment technology is used in the Czech Republic and Poland (Kelessidis et al, 2012).

Studies have shown that during aerobic digestion, humic acids are formed in large quantities in wastewater sludge, and during anaerobic digestion, the main components of wastewater sludge are proteins and aromatic amino acids, which indicates the possibility of using wastewater sludge as organic-mineral fertilizers in agriculture (Du & Li, 2017).

The benefits of using organic fertilizers in crop production are confirmed by the study by Palamarchuk et al, 2021.

In general, the rationale for the feasibility of using the bioenergy potential of wastewater in Ukraine is not sufficiently studied and requires further research.

3. Materials and methods

The research was based on primary data from the sanitary and ecological laboratory of the STC Expert, Ukraine, as well as secondary data from official statistics from a number of Ukrainian institutions: State Statistics Service, Ministry of Health, State Agency of Water Resources, etc.

The purpose of the study is to analyze the need for and prerequisites of bioenergy wastewater utilization as a component of achieving certain sustainable development goals for Ukraine.

The objectives of the study, in accordance with the set goal, include: 1) to substantiate the impact of wastewater on the safety and quality of drinking water in Ukraine; 2) to analyze the volume of polluted wastewater discharges into water bodies on the example of Vinnytsia region, Ukraine; 3) to analyze a successful case of effective bioenergy utilization of wastewater from a food industry enterprise, which can serve as an example of improving water quality and obtaining both energy resources and environmentally friendly fertilizer at the same time; 4) to substantiate the need for bioenergy utilization of wastewater in the current conditions of Ukraine.

To achieve this goal and accomplish the tasks set, the following methods were used: monographic (literature review), graphical and tabular (visualization of digital data), analysis and synthesis, abstraction, generalization (in forming the author's vision of the role of bioenergy recycling in achieving the Sustainable Development Goals), abstract and logical (drawing conclusions, etc.).

4. Results and discussion

Ukraine is a water-scarce country. According to the State Agency of Water Resources of Ukraine and the State Statistics Service of Ukraine, in 2021, the water intensity of GDP was 7.32 m^3 of water used per 1000 UAH of GDP (in actual prices), and although this figure has slightly decreased compared to 2020 – by 2.69 m^3 of water used per 1000 UAH of GDP (in actual prices) (State statistics service of Ukraine, 2023; SAWRU, 2022), it still does not reach the 2020 target value for Goal 6. Clean water and adequate sanitation of the Sustainable Development Goals, which is 3.2 m^3 of water used per 1000 UAH of GDP (in actual prices). In order to achieve the goals, the GDP water intensity should be halved (Figure 1).

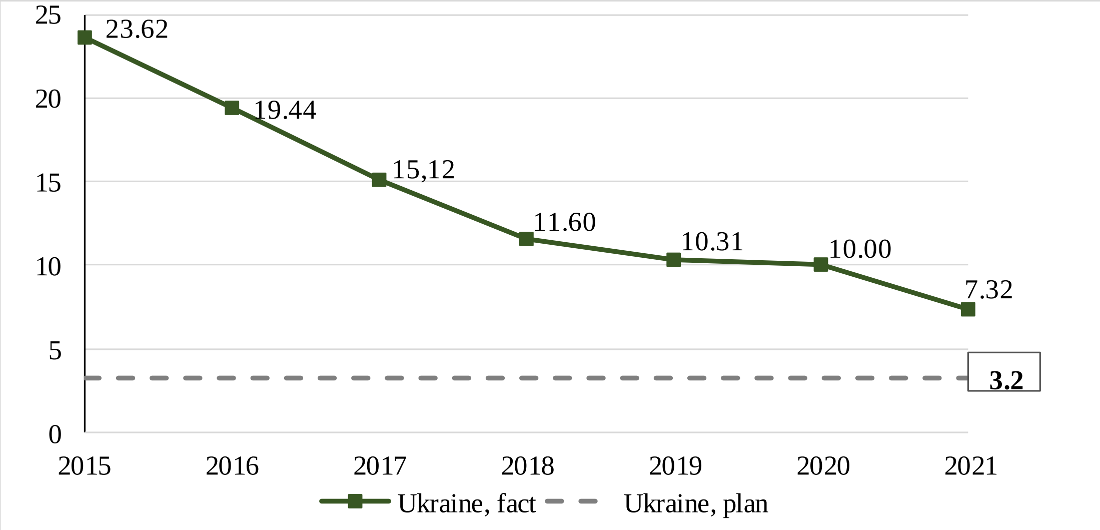

Fig. 1. Water intensity of Ukraine's GDP in 2021, cubic m of water used per 1000 UAH of GDP (in actual prices)
Source: compiled from (SAWRU, 2022)

The consequences of intensive urbanization are an excessive concentration of industrial facilities in a limited area. This leads to the destruction of the natural environment of large cities. High pollution with emissions and waste, poor condition of life support systems, outdated sewage treatment facilities, rapid growth of the urban population and the need to expand the territories have made most surface waters, which are the source of drinking water for more than 70% of the population of Ukraine, unusable. In addition, the problem of the ecological state of water bodies is relevant for all water basins in Ukraine. Water in most of them is classified as "polluted" and "dirty" (IV-V quality class).

All this has a catastrophic impact on the quality of water resources and drinking water. Table 1 shows the indicators of safety and quality of drinking water in Ukraine in 2021 according to the Ministry of Health of Ukraine, 2022, which, unfortunately, are disappointing. As a result, many Ukrainians do not trust tap water and are forced to buy bottled water. The pollution of water bodies – sources of drinking water supply – leads to a deterioration in the quality of drinking water and poses a serious threat to public health in many regions of Ukraine. Ukraine's lagging behind developed countries in terms of average life expectancy and high mortality are to some extent related to the consumption of poor quality drinking water.

Table 1. Indicators of drinking water safety and quality in Ukraine in 2021, (by % of non-standard samples)

Indicators	Drinking water safety and quality indicators (by % of non-standard samples)		
	by microbiological indicators	by radiation indicators	by organoleptic, physicochemical, sanitary and toxicological parameters
by type of place of residence			
urban area	5.1	2.0	18.2
rural area	11.9	2.8	28.9
by type of water supply			
centralized	7.5	1.9	21.2
decentralized	22.9	7.1	33.5

Source: (Ministry of health of Ukraine, 2022)

The Association Agreement between Ukraine and the European Union contains six EU directives in the field of water quality and water management (including the marine environment) that Ukraine must implement. One of the main goals of this legislation is to improve the quality of drinking water for people. The implementation of these directives will also ensure that Ukraine has a modern water policy, in particular in the management of rivers, urban wastewater, the marine environment, agricultural water pollution and floods.

Zero pollution is included in Ukraine's commitments under the Association Agreement. Zero pollution is one of the sectoral elements of the European Green Deal. This sector includes priorities for water, air, and soil pollution, industrial facilities, and chemicals management. The potential for Ukraine's involvement in the European Green Deal in this area is quite high in terms of improving environmental safety by introducing a chemicals management system; modernizing the environmental monitoring system in accordance with European standards; reducing and controlling industrial pollution, preventing environmental degradation and man-made disasters and accidents; conserving natural resources and rational environmental management; implementing the principles of sustainable development and gradual transition to a green economy.

For the vast majority of industrial and municipal enterprises, pollutant discharges significantly exceed the maximum permissible level. By type of economic activity, the largest share of polluted (untreated and insufficiently treated) wastewater discharges into water bodies is occupied by industry, housing and households, and agriculture (Figure 2).

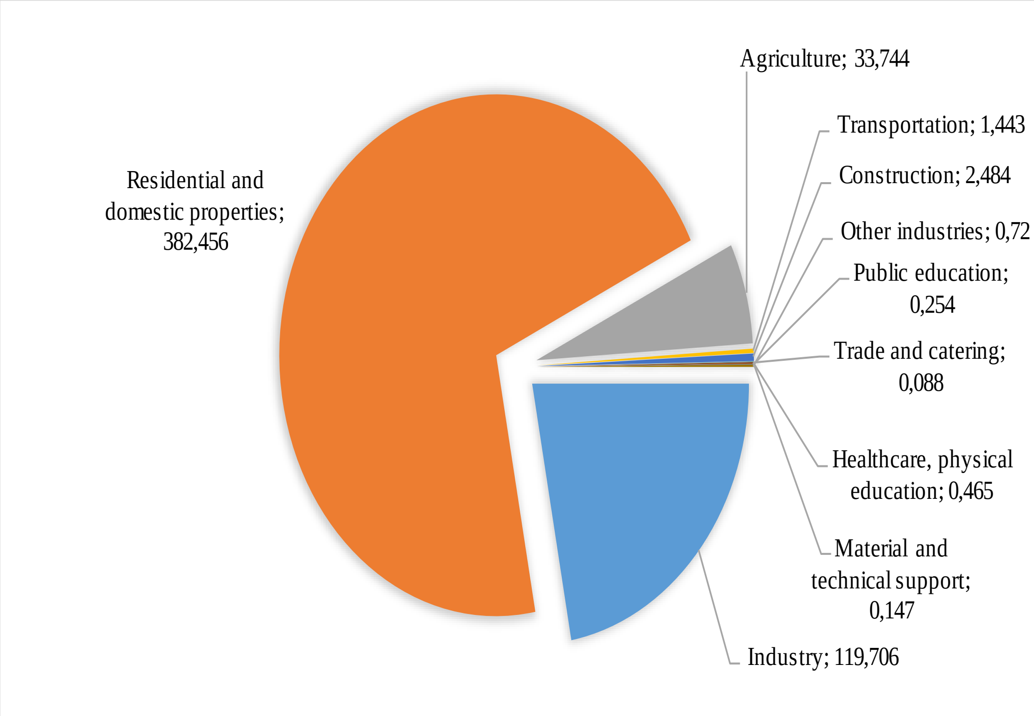

Fig. 2. Volumes of discharges of polluted (polluted without treatment and insufficiently treated) wastewater into water bodies of Ukraine by type of economic activity in 2021, million cubic m
Source: based on data from (SAWRU, 2022)

Among Ukrainian industrial enterprises, one of the largest consumers of water is milk processing, butter and cheese production. In 2021, they used 10.694 million m^3 of fresh water, and the percentage of polluted water discharged into surface water bodies of waste water is more than 13% of all wastewater discharged, which negatively affects the safety and quality of drinking water in Ukraine (SAWRU, 2022).

A similar picture regarding the volume of discharges of polluted (untreated and insufficiently treated) wastewater into water bodies is observed in Vinnytsia region. For example, the largest water polluters in Vinnytsia Oblast include municipal enterprises related to housing and utilities, mainly water utilities, and industry – Haisynskyi Dairy Plant LLC and Agrarian Fruit Ukraine LLC (Table 2).

Table 2. General indicators of water use in Vinnytsia region, Ukraine in 2021, million m³

№ n/a	Indicators	Total volume of waste water discharged into surface water bodies, mln cubic meters	Volume of polluted wastewater, mln. cubic meters	including:	
				contaminated without treatment (CBT), mln. cubic meters	of contaminated insufficiently treated (ICT), mln. cubic meters
1	Vinnytsia region, total	2.792	0.814	0.019	0.795
Polluting enterprises in Vinnytsia region					
2	GAISINSKY DAIRY PLANT LTD.	0.043	0.014	0.014	-
3	Municipal enterprise “Illintsivodokanal”	0.113	0.113	-	0.113
4	MUNICIPAL ENTERPRISE “KHMILNYKVODOKANAL”	0.834	0.002	-	0.002
5	MUNICIPAL ENTERPRISE “Kommunservice”	0.059	0.005	-	0.005
6	MUNICIPAL ENTERPRISE “YAMPILVODOKANAL”	0.078	0.067	-	0.067
7	MUNICIPAL ENTERPRISE “KALINOVKA VODOKANAL”	0.418	0.003	-	0.003
8	Agrana Fruit Ukraine LLC	0.014	0.014	-	0.014
9	HLUKHIVTSI WATER SUPPLY AND SEWERAGE UTILITY “HLUKHIVTSIVODOKANAL”	0.005	0.005	0.005	-
10	Vapnyarka Vodokanal, a municipal production and operational enterprise	0.056	0.056	-	0.056
11	MUNICIPAL ENTERPRISE of Vinnytsia City Council “VMTE”	0.097	0.097	-	0.097
12	Private enterprise “Company Versailles”	0.031	0.031	-	0.031
13	MUNICIPAL ENTERPRISE “ZHILKOMUNSERVIS-T”	0.003	0.003	-	0.003
14	Municipal enterprise “Tulchinvodokana”	0.454	0.042	-	0.042
15	MUNICIPAL ENTERPRISE “ZHMERYNKA WATER UTILITY”	0.44	0.33	-	0.33
16	MUNICIPAL ENTERPRISE “NEMYRIVVODOKANAL”	0.022	0.022	-	0.022
17	MUNICIPAL ENTERPRISE “PISHCHANKA-VODOKANAL”	0.017	0.001	-	0.001
18	MUNICIPAL ENTERPRISE “KRYZHOPILVODOKANAL”	0.108	0.009	-	0.009

Source: compiled from (SAWRU, 2022)

Food industry enterprises (dairies, wineries, confectioneries, meat processing plants, etc.) are the largest water consumers; consuming several times more water than the raw materials they process to produce their finished products. Despite the high water consumption, wastewater from food processing companies is highly concentrated and has unstable quality and quantity. These wastewaters are complex polydisperse systems and contain various contaminants: fat, milk, scales, wool, blood, salts, mineral insoluble impurities, detergents, etc. These waters are characterized by high rates of biochemical oxygen consumption, chemical oxygen consumption, suspended solids, fats, etc. Without preliminary treatment, such wastewater cannot be discharged to municipal wastewater treatment plants or natural water bodies. The flow of such wastewater to municipal wastewater treatment plants leads to a violation of the oxygen regime, species changes in microflora and other processes that negatively affect the course of biological treatment processes.

Companies must treat all the water they discharge into rivers. But sometimes they cannot do so because they have outdated technologies and modernization is too expensive. Sometimes the necessary equipment is not available at all. At the same time, some companies deliberately save money on wastewater treatment facilities to generate additional profit. In such cases, the state may grant the company the right to discharge polluted water into rivers. However, the amount of substances they can discharge is limited. It establishes "maximum permissible discharges" (hereinafter – MPDs). MPDs are needed to gradually reduce the level of pollution. Companies pay an environmental tax for the right to pollute the environment. If they exceed the established standards, they must pay a fine. One of the functions of the State Environmental Service is to make river pollution unprofitable. Ukraine has a national strategy for environmental policy. It stipulates that the amount of pollutants should be reduced by 15% by 2020. Therefore, enterprises must modernize their wastewater treatment facilities to meet the new requirements (Clean water, 2023).

For example, let's take a dairy enterprise, for which wastewater treatment is very difficult. Dairy enterprises produce highly concentrated wastewater containing insoluble protein flakes, fat particles, soluble milk sugar, solutions of protein substances, detergents and disinfectants in the process of milk processing and washing of technological equipment, pipelines, containers and production facilities. Whey accounts for the largest share of contaminated wastewater at dairy processing plants. The chemical oxygen consumption of whey, depending on the quality of milk, can reach 60,000 mgO_2/dm^3, which significantly complicates wastewater treatment. The qualitative and quantitative characteristics of wastewater depend on the capacity of the enterprise and the range of products, while fresh water consumption averages 3-12 m^3/ton of milk.

The methods and technologies used today to treat highly concentrated wastewater are imperfect and in some cases do not provide the required degree of treatment and utilization of all by-products generated in this process. In addition, the solutions used are not always economically viable and energy efficient.

We offer an innovative energy-saving technology for treating highly concentrated wastewater and utilizing by-products with biogas production. This environmentally friendly food waste processing technology not only ensures the disposal of food waste, reduces environmental pollution due to discharges of treated wastewater into water bodies, saves money on environmental fines and allows you to get an additional source of energy and profit through the sale of environmentally friendly organic fertilizer produced by aerobic controlled thermophilic biodegradation of organic raw materials under the action of an enzyme at a temperature not exceeding 750°C, making the products completely safe for the environment.

For this purpose, we propose to use the successful case of Lustdorf LLC on bioenergy recycling of food waste for the production of biogas and the production of treated wastewater and organic fertilizer (digestate).

LLC «Loostdorf» – one of the largest producers of dairy products in Ukraine, that produces more than 100 items of products and exports its products to EU countries. The company's production capacity is able to process 450 tons of milk per day, which is supplied by more than 50 farms in Vinnytsia, Khmelnytskyi, Zhytomyr and Cherkasy regions.

The company includes:

- high-tech production facilities certified according to the quality management standards DSTU ISO 9001 and food safety standards DSTU ISO 22000, located in Illintsi, Vinnytsia region;
- regional direct distribution offices in ten cities of Ukraine: Kyiv, Lviv, Odesa, Kharkiv, Dnipro, Zaporizhzhia, Vinnytsia, Mykolaiv, Lutsk, Kryvyi Rih;
- a 7.3 thousand m^2 wastewater treatment plant, which has no analogues among Ukrainian dairy producers ("Lustdorf" company, 2023a).

Let's focus on the wastewater treatment plant. On October 10, 2019, the Lustdorf wastewater treatment plant was opened. This is an important project aimed at introducing European practices of responsible resource consumption and environmental care into modern Ukrainian realities.

Lustdorf has set up a wastewater treatment plant next to the plant in Illintsi, Vinnytsia region. These stations purify 2 million liters of water per day. The company invested USD 6.5 million in the project, and its implementation lasted for 6 years. The technology development and equipment supply was carried out by the German company Hager Elsasser Gmbl, and the Polish company WaWaTech was directly involved in the launch itself.

The area of the treatment complex is 7.3 thousand m^2, and thanks to the automation of many processes, only 8 employees are involved in the stable operation of the facilities. The result of such processing is purified water that is sent to water bodies, biogas that meets the treatment plant's own needs, and organic fertilizers. The volume of biogas produced is about 1.2 thousand m^3 per day, and mineral fertilizers – 2-3 m^3 ("Lustdorf" company, 2023b). And as laboratory tests show, wastewater that has undergone the treatment process is cleaner than the natural water bodies where it flows (Table 3).

Table 3. Results of measurements of the composition and properties of Lustdorf LLC's wastewater and surface waters of the Sob River as of January 14, 2021

Name of the indicator	Designation of the unit of measurement	Measurement result			Normalized value (return water – permissible concentration)	Measurement error
		Water from the Sob River above the discharge 100 m	Wastewater discharge No. 1 after the treatment plant	Water from the Sob River below the discharge 500 m		
Water pH value	mg/dm³	7,8	7,5	7,8	-	±0,1
Suspended solids	mg/dm³	19.58	14.00	19.59	15	±10%
Chlorides	mg/dm³	46.25	271.14	46.50	350	±20%
Sulfates	mg/dm³	24.00	70.58	24.32	500	±2.5
Phosphates	mg/dm³	1.80	1.98	1.81	3.50	±10%
Ammonium nitrogen	mg/dm³	2.36	1.88	2.38	2.00	±9%
Nitrates	mg/dm³	15.02	17.00	15.00	45.00	±37.6%
Nitrites	mg/dm³	1.19	2.91	1.20	3.30	±0.08
Biochemical oxygen demand (BOD_5)	mgO_2/dm^3	6.98	6.14	6.90	15.00	±50%
Chemical oxygen demand (COD_5)	mgO_2/dm^3	40.12	37.88	40.00	80.00	±30%
Petroleum products	mg/dm³	0.17	0.10	0.19	0.30	±14%
Dry residue	mg/dm³	475.59	778.98	482.12	1000.00	±5%
Iron	mg/dm³	0.09	0.14	0.09	0.27	±34%
Dissolved oxygen	mg/dm³	6.00	5.98	6.02	>4.00	±20%
Anionic surfactants	mg/dm³	-	0.22	-	0.31	±0.5

Source: according to the protocol of measurements of the composition and properties of water samples of the sanitary and ecological laboratory of the STC "Expert"

Thus, the utilization of food waste begins to bring direct profit, being a source of valuable products – energy and organic fertilizers.

The introduction of bioenergy recycling technologies for the production of biogas allows not only to ensure the energy autonomy of the enterprise, but also to obtain an energy resource, an additional source of profit, as a result of the sale of fertilizers and makes it possible to discharge treated wastewater into a water body or implement water recycling schemes.

It is worth adding that the Law of Ukraine "On Waste Management" 2022 has recently entered into force, which should create the preconditions for solving the problem of waste, including wastewater and overloading sludge storage facilities, which will support Ukraine's aspirations for EU membership with concrete actions.

The European community sees biomethane and biogas production as an important

component of the future energy mix. In 2021, the total production of biogas and biomethane in the EU amounted to 18.4 billion m^3, which was 4.5% of gas consumption in Europe, according to EBA, 2022. Seeing the prospects for the development of this area, we note that the trend towards biomethane production will only increase in Ukraine.
However, Ukraine has been under martial law for more than a year due to the aggression of the Russian Federation. A significant part of the country's territory is occupied, and the economy suffers significant losses on a daily basis, which limits the possibility of implementing biogas production projects. The state plans post-war reconstruction, which will include greening the economy. The draft Recovery Plan of Ukraine includes the construction of biogas production complexes from sewage sludge. By dehydrating the sludge, it will be possible to reduce its volume by 5 times and prepare it for further thermal utilization, biogas and electricity production.

Conclusions

1. The analysis of literary sources showed the relevance of the bioenergetic direction of wastewater utilization and the need for in-depth research into the possibility of using it for the production of biofuels.
2. The quality and safety of drinking water in Ukraine does not always meet standards, and there is pollution with hazardous substances that enter the water due to problems with equipment and outdated wastewater treatment technologies. There is a threat to Ukraine's achievement of Sustainable Development Goal 6: Clean water and sanitation.
3. The example of Vinnytsia region, Ukraine, has shown high volumes of water pollution by wastewater: both untreated (2.3% of all wastewater) and insufficiently treated (97.8%). The main polluters are food industry enterprises and public utilities that need to modernize their treatment equipment and apply advanced bioenergy waste disposal technologies.
4. The energy-saving technology for treating wastewater including one from dairy plants with biogas production is proposed.
3. The analysis of the successful case of the Lustdorf company, Vinnytsia region, Ukraine, showed the benefits of bioenergy utilization of the company's wastewater – obtaining both biogas and organic fertilizers, as well as improving the condition of drinking water.
4. It is substantiated that the issue of wastewater sludge utilization should be addressed in a comprehensive manner with wastewater treatment. The utilization of sewage sludge is of particular importance when it solves not only the environmental problem, but also the economic one, contributing to the replenishment of raw and material resources not only in Ukraine but also in the world, and also makes it possible to turn water protection facilities into waste-free and self-sustaining ones. Ukraine's further integration into the EU implies greening the economy and the post-war reconstruction that Ukraine is waiting for, which takes this into account and provides for the construction of biogas complexes from sewage sludge. It is necessary to intensify the bioenergy direction of wastewater utilization in Ukraine, which will help achieve the Sustainable Development Goals 6. Clean water and sanitation and 7. Affordable and clean energy.

References

Ahmad T. et al. 2019. Treatment and utilization of dairy industrial waste: A review. *Trends in Food Science & Technology,* 88, 361-372. DOI: https://doi.org/10.1016/j.tifs.2019.04.003

Bulgakov, V., Kaletnik, H., Goncharuk, I., Ivanovs, S., Usenko, M. Results of experimental investigations of a flexible active harrow with loosening teeth. *Agronomy Research*. 2019. № 17(5). 1839-1845. DOI: https://doi.org/10.15159/AR.19.185

Bulgakov, V., Sevostianov, I., Kaletnik, G., Babyn, I., Ivanovs, S., Holovach, I., 2020. Theoretical Studies of the Vibration Process of the Dryer for Waste of Food. *Rural Sustainability Research*, 44, pp. 32-45. DOI: https://doi.org/10.2478/plua-2020-0015

Chandra R., Castillo-Zacarias C., Delgado P., Parra R. 2018. A biorefinery approach for dairy wastewater treatment and product recovery towards establishing a biorefinery complexity index. *Journal of Cleaner Production,* 183, 1184-1196. DOI: https://doi.org/10.1016/j.jclepro.2018.02.124

Clean water, 2023 – Interactive map of river pollution in Ukraine. [Online]. https://texty.org.ua/water/ [Accessed: 2023-03-01].

Dabrowski W., Żyłka R., Malinowski P. 2017. Evaluation of energy consumption during aerobic sewage sludge treatment in dairy wastewater treatment plant. *Environmental Research,* 153, 135-139. DOI: 10.1016/j.envres.2016.12.001

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy of October, 23 2000. [Online]. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32000L0060 [Accessed: 2023-03-10].

Du, H., & Li, F. 2017. Characteristics of dissolved organic matter formed in aerobic and anaerobic digestion of excess activated sludge. *Chemosphere,* 168, 1022–1031. https://doi.org/10.10165/j.chemosphere.2016.10.108

EBA, 2022 – European Biogas Association. [Online]. https://www.europeanbiogas.eu/ [Accessed: 2023-03-01].

Ecodevelop, 2022. – Innovative local treatment facilities for dairy enterprises [Online]. https://ecodevelop.ua/innovatsijni-lokalni-ochisni-sporudi-dlya-pidpriyemstv-molochnoyi-galuzi [Accessed: 2023-03-01].

Ibiam, O. F. A, Igewnyi, I. 2012. Sewage management and its benefits to man. *International Research Journal of Biotechnology*, 3(10), 174–189.

Jiang, Y., Havrysh, V., Klymchuk, O., ...Balezentis, T., Streimikiene, D. 2019. Utilization of Crop Residue for Power Generation: The Case of Ukraine. *Sustainability (Switzerland)*, 11(24), 7004. DOI: https://doi.org/10.3390/su11247004

Kaletnik, G. and Lutkovska, S. 2020. Strategic Priorities of the System Modernization Environmental Safety under Sustainable Development. *Journal of Environmental Management and Tourism* XI (5(45)), 1124–1131. DOI: 10.14505/jemt.v11.5(45).10.

Kaletnik, G., Honcharuk, I., Okhota, Y. 2020a. The Waste-free production development for the energy autonomy formation of Ukrainian agricultural enterprises. *Journal of Environmental Management and Tourism,* 11(3), 513–522, DOI: 10.14505//jemt.v11.3(43).02.

Kaletnik, G.M., Honcharuk, T.V. 2016. Prospects for the use of Vinnytsia sewage water for the fertilization of field crops: domestic and foreign experience. *Balanced nature management,* 3, 42–47.

Kaletnik, H., Sevostianov, I., Bulgakov, V., Holovach, I., Melnik, V., Ihnatiev, Ye. 2020b. Development and examination of high-performance fluidised-bed vibration drier for processing food production waste. *Agronomy Research*, 18(4), pp. 2391–2409, DOI: https://doi.org/10.15159/ar.20.234

Kelessidis, A., Stasinakis, A. S. 2012. Comparative study of the methods used for treatment and final disposal of sewage sludge in European countries. *Waste Management*, 32(6), 1186–1195. DOI: https://doi.org/10.1016/j.wasman.2012.01.012

Korpaniuk, T., Ishchenko, Y., Koval, N. 2019. Backgrounds for improving resource management of agricultural enterprises based on economic diagnostics of biofuel consumption. *Journal of Social Sciences Research* 5(2), 367–380, DOI: 10.32861/jssr.52.367.380.

Kumar, V., Chopra, A.K. 2016. Effects of sugarcane press mud on agronomical characteristics of hybrid cultivar of eggplant (Solanum melongena L.) under field conditions.*International Journal of Recycling Organic Waste in Agriculture,* 5,149–162. DOI: https://doi.org/10.1007/s40093-016-0125-7

Kupchuk, I., Burlaka, S., Galushchak ,A., Yemchyk, T., Galushchak, D. 2022. Research of autonomous generator indicators with the dynamically changing component of a two-fuel mixture. *Polityka Energetyczna*, 25(2). 147–162. DOI: https://doi.org/10.33223/epj/150746

"Lustdorf" company, 2023a. [Online]. https://www.loostdorf.com/about-company/about-us/ [Accessed: 2023-03-01].

"Lustdorf" company, 2023b. [Online]. https://www.loostdorf.com/press-center/yevropeyskiy-podkhod-eto-ostavlyat-posle-sebya-chistuyu-vodu [Accessed: 2023-03-01].

Ministry of health of Ukraine, 2022 [Online]. https://en.moz.gov.ua/news [Accessed: 2023-03-01].

Negi, P., Verma, H., Singh, S.P., Mahapatra, B.S., Jatav, H.S. 2022. Global Scenario of Sewage-Sludge Management. In: Sustainable Management and Utilization of Sewage Sludge. Cham: Springer International Publishing, 383–401.

On waste: Law of Ukraine of 05.03.1998, №187 / 98-BP (as amended on 16.10.2020)]. [Online]. https://zakon.rada.gov.ua/laws/show/187/98-%D0%B2%D1%80#Text [Accessed: 2023-03-01].

Palamarchuk, V., Krychkovskyi, V., Honcharuk, I., Telekalo, N. 2021. The modeling of the production process of high-starch corn hybrids of different maturity groups. *European Journal of Sustainable Development*, 10(1), 584–598. DOI: https://doi.org/10.14207/ejsd.2021.v10n1p584.

Patyka, N., Khodakivska, O., Pronko, L., Kolesnyk, T., Klymchuk, O., Kamenschuk, B., Zayed, N. 2021. Approaches To Evaluation Of The Agriculture Competitiveness Level: Empirical Evidence In Ukraine. *Academy of Strategic Management Journal,* 20(1), 1–15.

Paziuk, V.M., Tokarchuk, O.A. 2022. Basic characteristics of sewage sludge. *Engineering, Energy, Transport AIC,* 1(116), 96–104. DOI: 10.37128/2520-6168-2022-1-11.

Pryshliak, N., Tokarchuk, D., Shevchuk, H. 2021. The socio-economic and environmental importance of developing biofuels: the Ukrainian case on the international arena. *Polityka Energetyczna,* 24, 1, 133–152. DOI: https://doi.org/10.33223/epj/131829.

Pryshliak, N., Bondarenko, V., Sokoliuk, S., Brovarets, O. 2022. The formation of a bioenergy cluster for the production of biofuels from agricultural crops and waste: the experience of Ukraine. *Polityka Energetyczna,* 25, 4, p. 149–164. DOI: 10.33223/epj/156210.

Sabliy, L.A., Zhukova, V.S. 2022. Efficient treatment of industrial wastewater using immobilized microorganisms. In: Supply and Wastewater Disposal. Lublin: Politechnika Lubelska, 248–262.

SAWRU, 2022 – State Agency of Water Resources of Ukraine. [Online]. https://www.davr.gov.ua/ [Accessed: 2022-09-11].

State statistics service of Ukraine, 2023. [Online]. https://www.ukrstat.gov.ua [Accessed: 2022-09-11].

The 17 goals. [Online] https://sdgs.un.org/goals [Accessed: 2023-03-10].

Tokarchuk, D., Pryshliak, N., Shynkovych, A., Mazur, K. 2021. Strategic Potential of Agricultural Waste as a Feedstock for Biofuels Production in Ukraine. *Rural Sustainability Research,* 46(341), 1–12. DOI: 10.2478/plua-2021-0012.

Tokarchuk D. M., Pryshliak N. V., Tokarchuk O. A., Mazur K. V. 2020. Technical and economic aspects of biogas production at a small agricultural enterprise with modeling of the optimal distribution of energy resources for profits maximization. *INMATEH – Agricultural Engineering*, 61 (2), 339–349. DOI: https://doi.org/10.35633/inmateh-61-36

Varchenko, O.M., Krysanov, D.F., Shubravska, O.V., Khakhula, L.P., Gavryk, O.Y., Byba, V.A., Honcharuk, I.V. 2020. Supply Chain Strategy in Modernization of State Support Instruments for Small Farms in Ukraine. International Journal of Supply Chain Management, 9, 1. 536-543 https://ojs.excelingtech.co.uk/index.php/IJSCM/article/view/4326

Williams, P.T. 2005. Waste treatment and disposal. 2nd ed. John Wiley & Sons Ltd.