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NATIONAL AVIATION UNIVERSITY
FACULTY OF ENVIRONMENTAL SAFETY,
ENGINEERING AND TECHNOLOGIES
DEPARTMENT OF ENVIRONMENTAL SCIENCE

APPROVED TO DEFENCE
Head of the Graduate Department
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«_____» ____________ 2021

MASTER THESIS

(EXPLANATORY NOTE)

SPECIALTY 101 "ECOLOGY",
EDUCATIONAL AND PROFESSIONAL PROGRAM:
"ECOLOGY AND ENVIRONMENT PROTECTION"

Theme: «Evaluation of the efficiency of photobioreactors for wastewater treatment»

Done by: student of the EK-211Ma group, Hanna O. Omelchenko
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KYIV 2021

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_____________ Т.В. Дудар
«_____» ____________ 2021 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗА СПЕЦІАЛЬНІСТЮ 101 «ЕКОЛОГІЯ»,
ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
«ЕКОЛОГІЯ ТА ОХОРОНА НАВКОЛИШНЬОГО СЕРЕДОВИЩА»

Тема: «Оцінювання ефективності фотобіореакторів для очистки стічних вод»

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КИЇВ 2021

NATIONAL AVIATION UNIVERSITY

Faculty of Environmental Safety, Engineering and Technologies

Department of Environmental Science

Specialty, Educational and Professional Program: specialty 101 "Ecology", Educational and Professional Program: "Ecology and Environment Protection"

(code, name)

APPROVED
Head of the Department
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«____» _________ 2021

MASTER THESIS ASSIGNMENT

Hanna O. Omelchenko

1. Theme: «Evaluation of the efficiency of photobioreactors for wastewater treatment» approved by the Rector on September 15, 2021, № 1872/ст

2. Duration of work: from 15.09.2021 to 15.12.2021

3. Output work (project): Calculations of efficiency of photobioreactors for wastewater treatment by microalgae cultivation.

4. Content of explanatory note: (list of issues): to analyze the main contaminants of fresh water and their impact on the environment, to investigate technologies for the cultivation of microalgae, to compare different types of photobioreactors designs, to evaluate the efficiency of photobioreactors to reduce nutrients in wastewater and to cultivate biomass for biofuel production.

5. The list of mandatory graphic (illustrated materials): tables, figures.

6. Schedule of thesis fulfillment

№	Task	Term	Advisor's signature
1	Receive themes task, search the literature and legislation	05.09.2021-15.09.2021	
2	Preparing the main part (Chapter I)	16.09.2021-30.09.2021	
3	Preparing the main part (Chapter II)	01.10.2021-15.10.2021	
4	Preparing the main part (Chapter III)	16.10.2021-26.10.2021	
5	Consultation on section IV (Occupational safety)	27.10.2021-04.11.2021	
6	Preparation of the main part (Chapter IV)	05.11.2021	
7	Formulating conclusions and recommendations of the thesis	21.11.2021-25.11.2021	
8	Making an explanatory note to the previous presentation of the department, consultation with the standards expert	26.11.2021-30.11.2021	
9	Presentation of the work at the department	15.12.2021	
10	Taking into account the comments and recommendations and training to protect	01.12.2021-28.12.2021	
11	Thesis defense at the department	29.12.2021	

7. Consultant(s) of certain chapter(s):

Chapter	Consultant (academic rank, S.N.P)	Date, signature	
		Given by	Accepted by
Labor Precaution	PhD, Associate Professor of the Department of Civil and Industrial Safety, Kateryna I. Kazhan		

8. Date of task issue: «15» September 2021

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Task is taken to perform: ____________________ (graduate's signature) Hanna O. Omelchenko (S.N.P.)

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ЗАТВЕРДЖУЮ
Завідувач кафедри
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«____» _________ 2021 р.

ЗАВДАННЯ
на виконання дипломної роботи
Омельченко Ганни Олегівни

1. Тема роботи «Оцінювання ефективності фотобіореакторів для очистки стічних вод» затверджена наказом ректора від «15» вересня 2021 р. №1872/ст.

2. Термін виконання роботи: з 15.09.2021 р. по 15.12.2021 р.

3. Вихідні дані роботи: розрахунки ефективності фотобіореакторів з використанням мікроводоростей для очищення стічних вод.

4. Зміст пояснювальної записки: проаналізувати головні забрудники прісної води та їх вплив на стан навколишнього середовища, дослідити технології для культивування мікроводоростей, порівняти різні типи конструкцій фотобіореакторів, оцінити ефективність фотобіореакторів з метою зниження біогенних елементів у стічних водах та культивування біомаси для виробництва біопалива.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: таблиці, рисунки.

6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Отримання теми завдання, пошук літератури і законодавства	05.09.2021-15.09.2021	
2	Підготовка основної частини (Глава І)	16.09.2021-30.09.2021	
3	Підготовка основної частини (Глава ІІ)	01.10.2021-15.10.2021	
4	Підготовка основної частини (Глава ІІІ)	16.10.2021-26.10.2021	
5	Консультація з розділу IV (охорона праці)	27.10.2021-04.11.2021	
6	Підготовка основної частини (Глава IV)	05.11.2021	
7	Формулювання висновків та рекомендацій з диплому	21.11.2021-25.11.2021	
8	Зробити пояснювальну записку до попередньої презентації кафедри, консультації з нормоконтролером	26.11.2021-30.11.2021	
9	Презентація праці на кафедрі	15.12.2021	
10	Врахування коментарів та рекомендацій та навчання для захисту	01.12.2021-28.12.2021	
11	Захист диплому на кафедрі	29.12.2021	

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ABSTRACT

Explanatory note to thesis «Evaluation of the efficiency of photobioreactors for wastewater treatment»: 85 pages, 17 figures, 12 tables, 32 references.

Object of research – wastewater treatment with microalgae cultivation.

Aim of work – to evaluate the efficiency of photobioreactors for wastewater treatment.

Methods of research: analysis, data comparison, statistical data processing.

WASTEWATER, MICROALGAE, PHOTOBIOREACTORS, BIOGENIC ELEMENTS, BIODIESEL, EFFICIENCY, ENVIRONMENTAL SAFETY

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LIST OF SYMBOLIC NOTATIONS, ABBREVIATIONS AND NOTIONS

BAS – the Bortnitska Aeration Station;

NASA – the National Aeronautics and Space Administration;

SAS – surface-active substances;

UV – Ultra Violet;

WHO – the World Health Organization.

INTRODUCTION

Relevance of the work. The problem of surface water pollution exists in all countries. It can be argued that it has long acquired a global scale. The strongest source of water pollution is a person and its livelihood, as a result of which many dangerous pollutants fall into the environment: petroleum products, microplastics, phosphates, nitrites and nitrates, heavy metals, gearboxes, viruses, oils, and others. It is impossible to solve it without proper wastewater treatment. Existing wastewater treatment methods and technologies do not always provide the required level. Microalgae culture offers an interesting step for wastewater treatments, because they provide a tertiary biotreatment coupled with the production of potentially valuable biomass, which can be used for several purposes. Microalgae cultures offer an elegant solution to tertiary and quandary treatments due to the ability of microalgae to use inorganic nitrogen and phosphorus for their growth. Compared to higher plants, microalgae are simple in structure, being unicellular, filamentous or colonial, and energy is directed via photosynthesis into growth and reproduction; they do not need to establish and maintain complex tissues and organs. More recently these photosynthetic microbes have also become the focus of considerable attention as a potential source of oils for biodiesel production.

Thus, the cultivation of microalgae, especially in closed systems – photobioreactors, is an urgent task.

Aim of the work – to evaluate the efficiency of photobioreactors for wastewater treatment.

Tasks of the work:

1. To analyze the main pollutants of water bodies;
2. To investigate technologies for wastewater treatment and microalgae cultivation;
3. To analyze the efficiency of photobioreactors for wastewater treatment and biodiesel production.

Object of research – wastewater treatment with microalgae cultivation.

Subject of research – evaluation of the efficiency of photobioreactors.

Methods of research – analysis, data comparison, statistical data processing.

Scientific novelty of the obtained results.

1) For the first time the method for evaluation of the efficiency of photobioreactor was proposed;

2) Has further developed the study of microalgae metabolism for removing of biogenic elements from wastewater.

3) Has further developed the study of microalgae cultivation for biodiesel production.

Practical importance of the obtained results. The main criteria of the efficiency of photobioreactor for wastewater and microalgae cultivation were developed.

Personal contribution of the graduate: analysis of previous research, criteria of the efficiency of photobioreactor for wastewater and microalgae cultivation were developed, calculations of the efficiency of photobioreactors for wastewater treatment from biogenic elements were carried out.

Publications:

1. Pavliukh, H. Tsysar. Microalgae as a sustainable energy source. *Сучасні проблеми екології*. XVII Всеукраїнської наукової on-line конференції здобувачів вищої освіти і молодих учених з міжнародною участю: 15 квітня 2021 р.: тези доп., Житомир, 2021. С.136.

2. L. Pavliukh, H. Tsysar. Analysis of the impact of microplastics polluted water on the environment. *Екологічна безпека держави*. XV Всеукраїнська науково-практична конференція молодих учених і студентів: 22 квітня 2021 р.: тези доп., Київ, 2021. С. 57-58.

3. L. Pavliukh, H. Tsysar Microalgae application for public ecobiosafety. *Еколого-гігієнічні аспекти здоров'я та біобезпеки населення.* Міжнародна науково-практична конференція: 7-8 квітня 2021 р.: тези доп., Київ. 2021. С. 294-298.

4. Tsysar H.O. Biological treatment of water bodies. Using the bio plateau as ecological treatment of water bodies. *Sustainable Development: Environmental Protection. Energy savings. Balanced natural resources*. 6th International Youth Congress.: тези доп., Lviv, Ukraine, 2021. С. 114.

CHAPTER 1
ASSESSMENT OF WATER QUALITY IN UKRAINE

A sharp increase in industrial, transport, agricultural, energy and other anthropogenic emissions led to a violation of water quality, the appearance in the water supply sources of uncharacteristic of the environment chemical, radioactive and biological agents.

1.1. The main sources of water pollution

Questions about pollution of water and its quality for safe use in the 21st century become more discussed and relevant. Every year the condition of water objects deteriorates, however, humanity cannot clear the amount of water that is amenable to negative anthropogenic influence.

On the planet about 3% of fresh water, which we can use in consumption, for nutritional purposes, industrial and agricultural, however, every year of clean freshwater becomes less and less: the rivers are drying, melting and polluted. The lakes are blocked, glaciers are melting creating a threat to a change in the water level in the ocean, groundwater is poisoned by chemicals and heavy metals. Regular non-compliance with sanitary and hygienic standards leads to an invisible, but toxic change in water composition, the destruction of unique ecosystems, and an increase in the death percentage of infectious diseases associated with the development of pathogenic microorganisms.

Pollution of water in the modern world is a serious environmental and hygienic problem. According to WHO, more than 2 billion people on Earth are not secure for healthy drinking water [1]. Each year, the water bodies are subjected to various contaminants with household waste, industrial, waste as a result of emergency situations, and others. Only in the United States every year in water bodies are reset more than a trillion gallons of wastewater, which pollute the ocean and destroy the biosphere.

The most commonly encountered water pollution is bacterial and chemical, however, do not forget for physical indicators.

Chemical pollution of water is more stable, so many chemicals remain in a water body due to the impossibility of cleaning them, absorption by living organisms, and constant accumulation due to a daily increase in concentration with wastewater. Chemical pollution includes organic pollution (pesticides, phenols, and petroleum products), inorganic (acid, alkalis, salts), toxic (heavy metals, poisons), and non-toxic.

Bacterial pollution is characterized by hitting pathogenic microorganisms, fungi in the aquatic environment and their rapid development. It has the nature of the temporary phenomenon, as it is closely related to climatic and weather conditions (for example, water flowering occurs in the summer in hot weather, from July to August).

Thermal pollution of water occurs as a result of effluent from the heat-power stations and nuclear power plants, which leads to an increase in water temperature, the destruction of living organisms, and accelerates the process of eutrophication, accumulating methane and hydrogen sulfides.

Radioactive water pollution is most dangerous, as for many elements we settle and accumulate at the bottom, making it dangerous for all living organisms. The danger lies in the long period of decay of radionuclides. Finding into water bodies due to non-compliance with standards and safety measures at nuclear power plants and during the disposal of radioactive waste into open soil, where they pass through the soil and fall into underground and surface water.

Mechanical water pollution occurs due to the ejection and ingress of solid household waste into the water object, discharge of building materials, ashes, and slags from the thermal industry, waste industry waste, falling into the water in the water purification at the aeration stations, and others [2].

In most developed European countries, such as Norway, Switzerland, and Finland, water can be used for drinking purposes, however, this statement does not apply to Ukraine. According to world ratings, Ukraine is located on 95-96 place in the level of purity of drinking water and is not safe. Approximately 15-20% of Ukrainians use groundwater for nutritional purposes, and almost 80% use surface waters, which includes rivers, such as Dnipro, Desna, The Southern Bug, and others. In these rivers, the nitrogen, manganese, and heavy metals exceed MPC 15-30 times. However, the quality of water in these rivers critically does not correspond to sanitary and hygienic standards. In freshwaters, the eggs of helminths, bacteria, sulfates, nitrates and nitrites, iron, and other pollutants are discovered, who do not undergo thorough cleaning before use due to the lack of new technologies. In addition, presumably purified water enters the cranes of people in old, rusty pipes which installed in the middle of the last century.

When analyzing the card of the condition of drinking water in Ukraine, it was found that the most polluted waters are located in Kyiv, Cherkasy, Donetsk, Zaporizhia, Odesa, Kherson, and Lugansk regions. This water is not suitable for use due to industry and agriculture are represented in Figure 1.1.

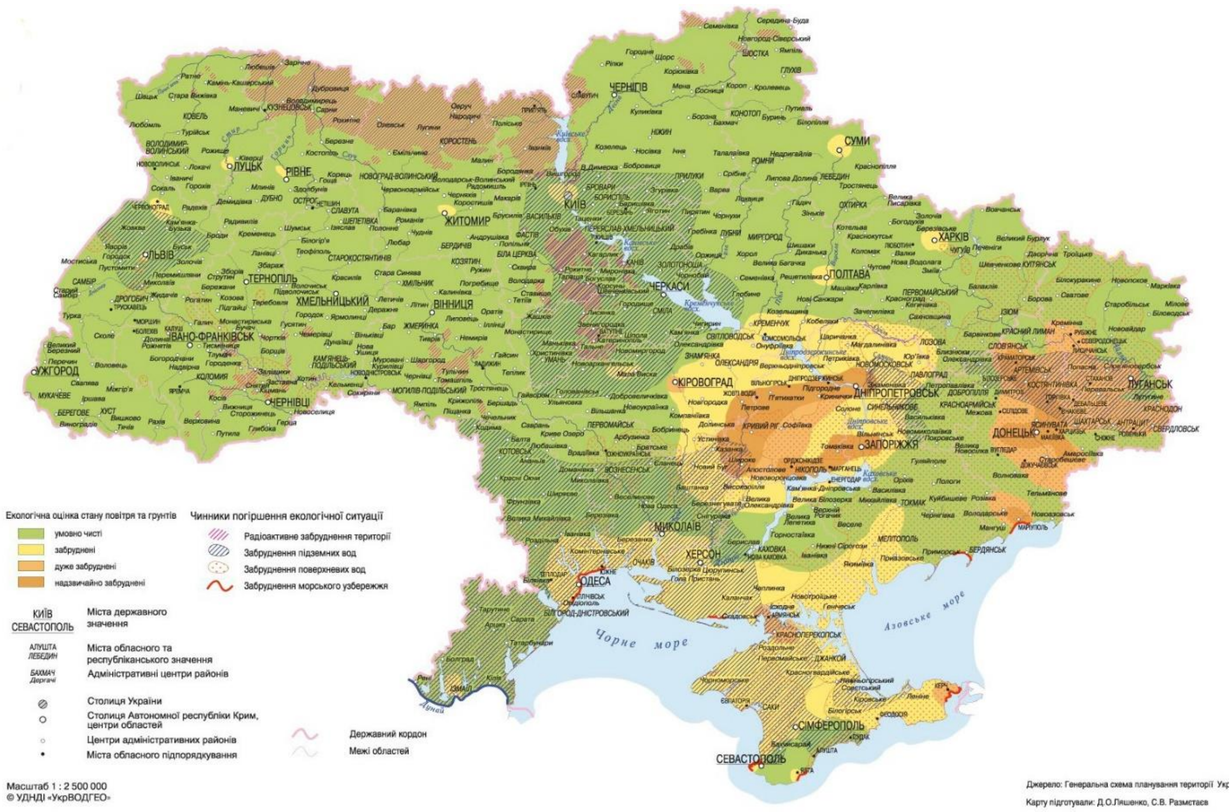

Fig 1.1. The ecological map of drinking water quality

Most fresh reservoirs respond to 4 (very polluted) and 5 (dirty) classes of water quality, precisely, for this reason, the main method of cleaning freshwater is chlorination that is safe to public health. In the rest of the regions (Western Ukraine), water quality also does not correspond to sanitary and hygienic standards due to the lack of cleaning technologies and disinfection of fresh water for use, as they exceed organoleptic indicators, exceed the concentration of chemicals and mineralization [3].

The main and main river of Ukraine, namely, Dnipro, has the highest level of pollution in Kyiv. The most contaminated Dnieper influx is the place of resetting the "purified" wastewater after the Bortnitska Aeration Station. Thanks to scientific research, monitoring, and self-identity items, there is a site that shows various types and levels of water pollution, in which we have the ability to analyze the state of the river, which is the main source of fresh drinking water in the capital [4].

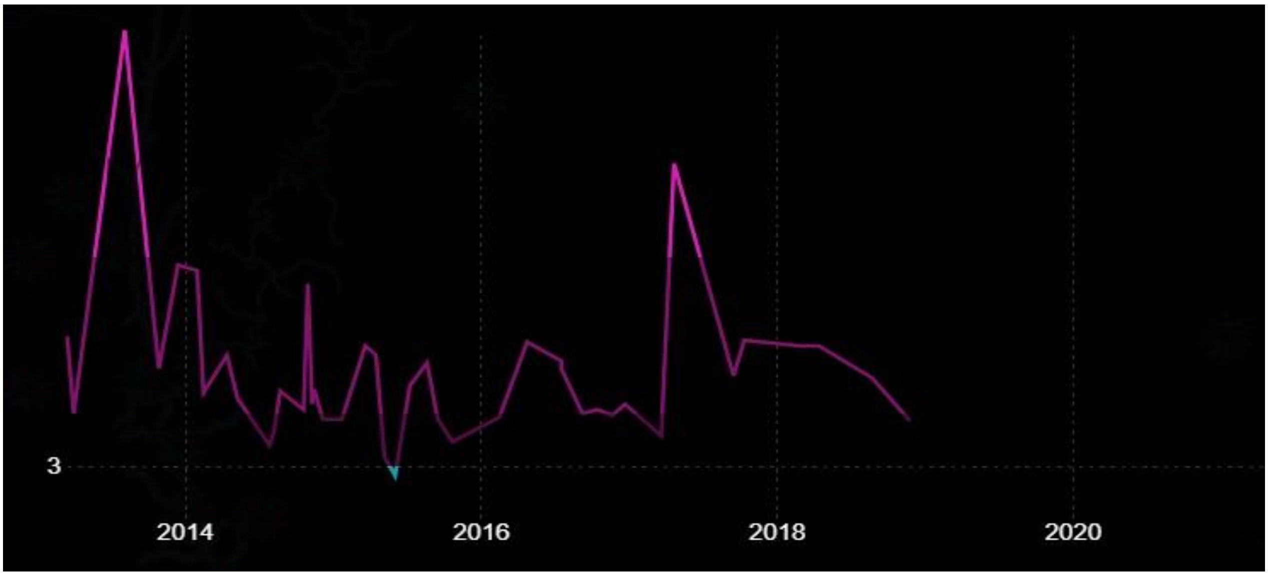

Fig. 1.2. The biochemical oxygen consumption in the water dump channel from BAS

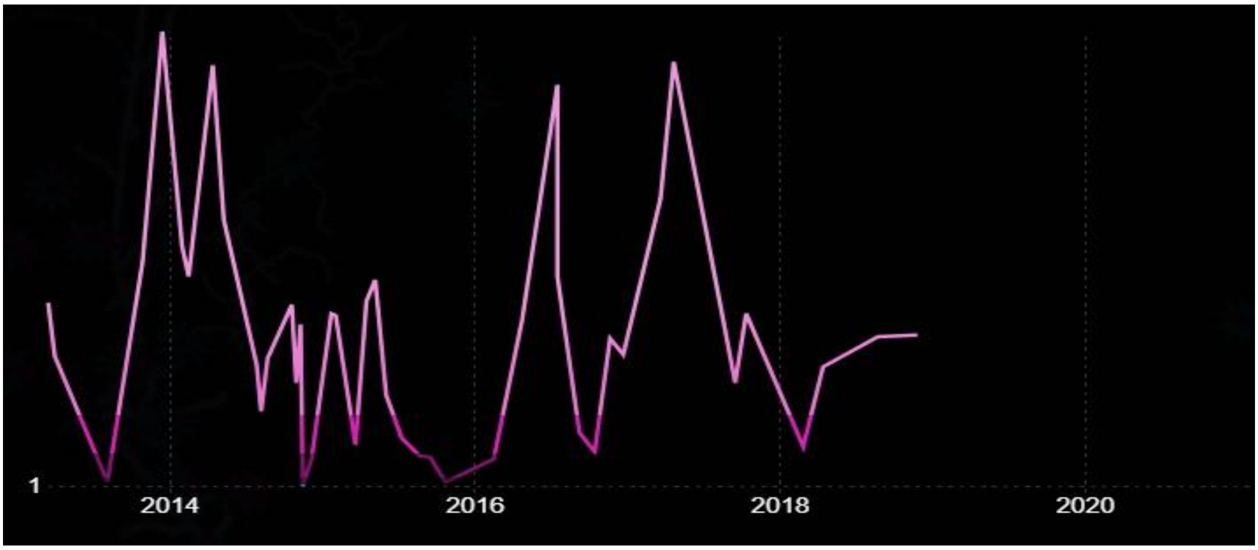

Fig. 1.3. Ammonia ions in the water dump channel from BAS

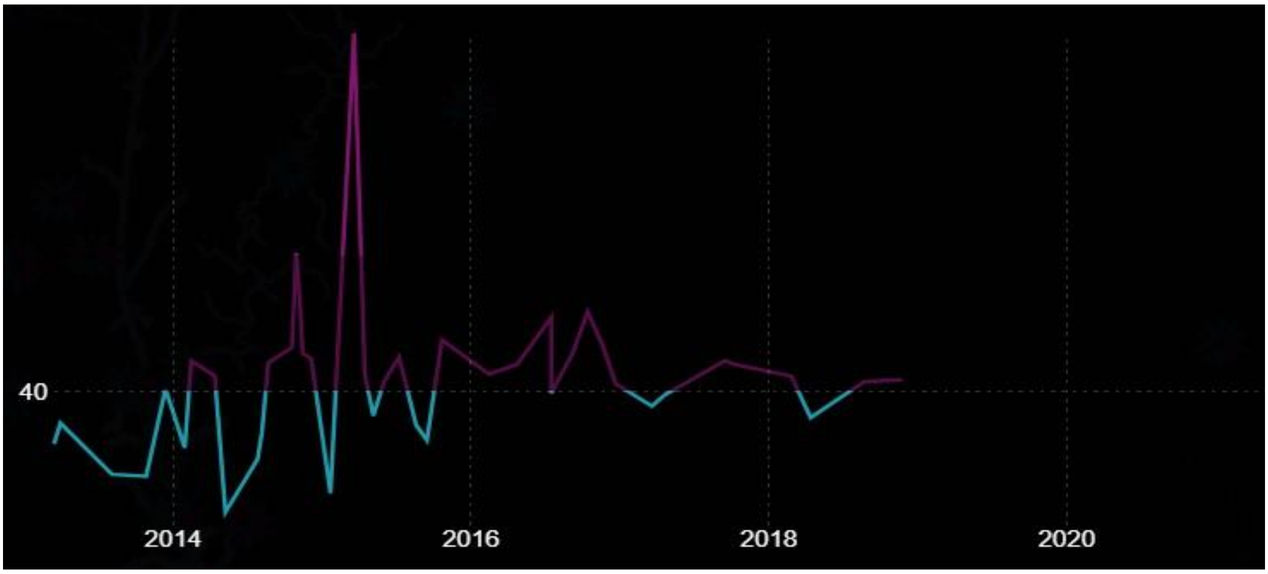

Fig. 1.4. Ions nitrates in the water dump channel from BAS

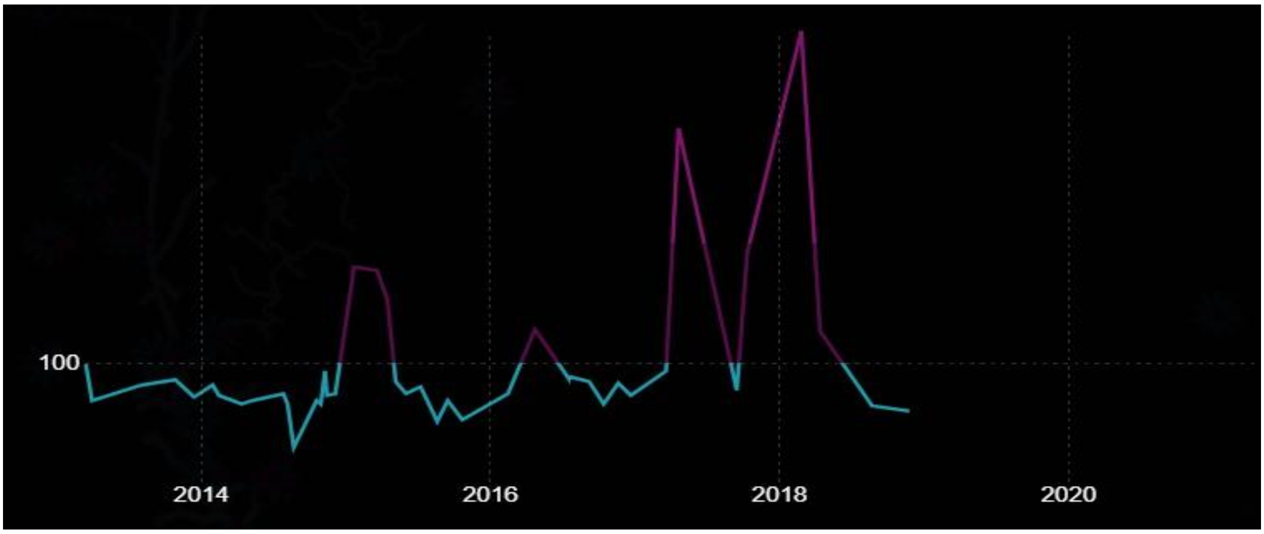

Fig. 1.5. Sulfate ions in the water dump channel from BAS

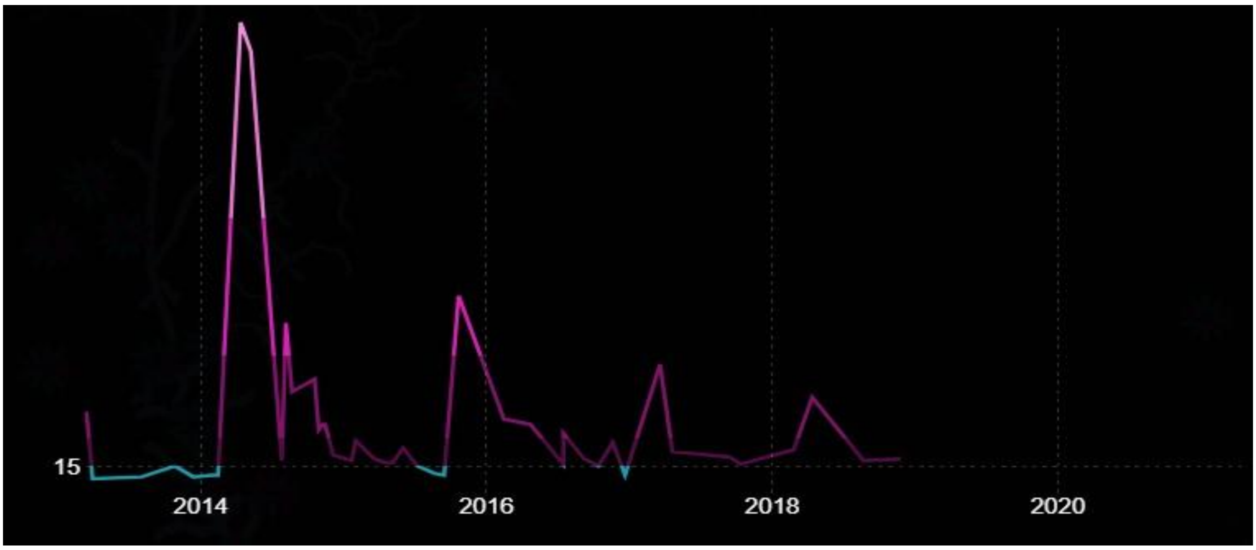

Fig. 1.6. The heavy metals in the water dump channel from BAS

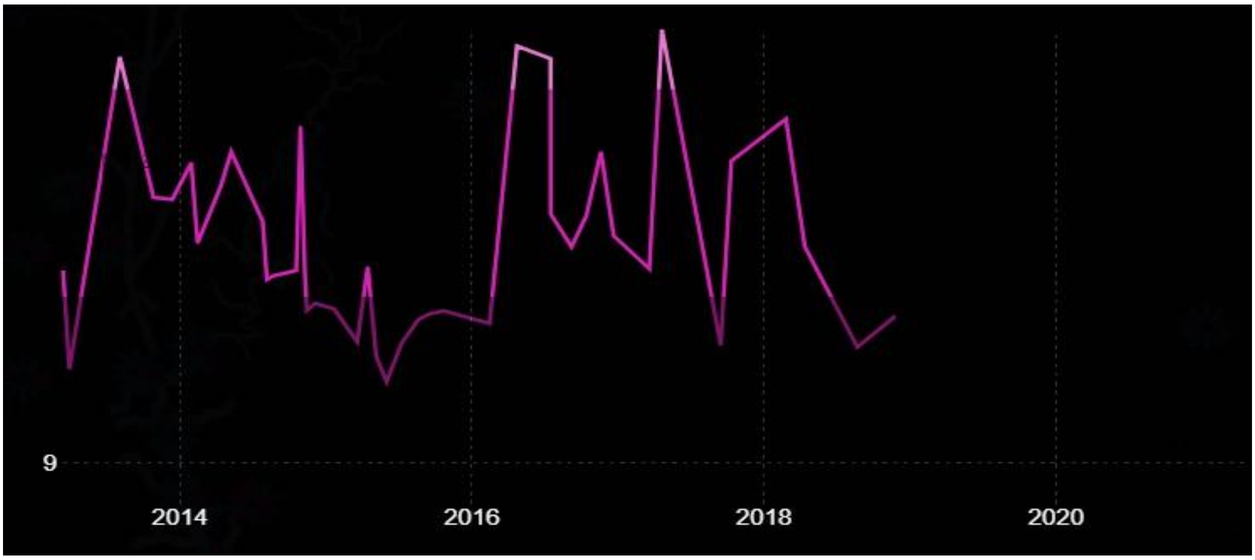

Fig. 1.7. The chemical uses of oxygen in the water dump channel from BAS

The levels of water pollution by chemicals due to poor quality wastewater treatment are further on the Figure 1.2, 1.3, 1.4, 1.5, and Figure 1.6, 1.7.

As we can see, the level of contamination by sulfates, nitrates, and nitrites, as well as other indicators, exceeds the permissible norm. This dirty water is reset to the river, from where it is filtered again and served in the cranes of Ukrainians. Unfortunately, nitrates, sulfates, and nitrates are in fact not cleaned chemical compounds for which the creation of new technologies and equipment to reduce pollutants. These compounds directly affect the strong flowering of the river annually, as well as the health of the population. Excess these indicators also indicate an irresponsible attitude and poor work of the Ministry of Natural Resources of Ukraine, which are responsible for various violations and environmental deviations. The sewage treatment plant needs improvement, reconstruction, and modernization. This procedure has allocated a sufficient amount of state budget, however, due to a high level of corruption, positive changes will not occur soon.

Intensive increase in the area of cities, the exhaustion of land and their fertilizer in the agricultural industry, heavy industry, and other human activity, lead to rapid changes in the chemical composition and physical condition, the destruction of flora and fauna, and the lack of drinking water, without which person's life is impossible (Table 1.1).

Table 1.1

The basic sources of water pollution

The source	Examples of contamination
Wastewater	Sewage, storm drains, strokes from roads and settlements, solid stock of non-fermentation soils.
Agriculture	Pesticides, herbicides, and organic waste, animal vital products, drainage waters, inorganic salts, insecticides.
Industrial waste	Iron, mercury, copper, fluorine, radioactive particles of elements, ash, slags, waste of ferrous metallurgy, waste of the pulp and paper industry, oil leakage from oil industry, river forest alloy.
Solid waste	Plastic bottles, gravel, crushed stone, plastic bags, packaging and other.
Transport	Wastewater from gas stations, maintenance stations, power miles, roads, movement of river and sea transport.
Atmospheric pollution	Ash, ashes, soot, CO, CO_2, NO_X, SO_2, and other gases.
Natural pollution	Destruction of rocks, volcanic activity, livelihoods of living organisms.

The main source of water pollution is a human and his way of life, as well as an irresponsible attitude to the environment (Table 1.2).

Table 1.2

The main pollutants of water contamination

The main pollutants	Examples	The impact of pollutants
1	2	3
Petroleum products	Oil, gas, kerosene	Petroleum products fall into water facilities from industrial enterprises, with wastewater from roads, or due to accidents at oil production stations. When inserting into the aqueous

Continue of Table 1.2

1	2	3
		object, oil forms a multi-kilometer film, which gradually kills the marine inhabitants, destroys the condition of the soil and gas exchange in water, destroys the structure of biocenoses. Finding on the body of the animal, oil hinders the regulation of heat exchange, causes irritation of the mucous membrane and poisoning, failure of the internal organs.
Household waste	Ammonia, nitrates, phosphates, nitrites	Every day we use washing powders, detergents, shampoos, and other hygiene products, sewage that are rich in nitrogen and phosphorus. Nitrogen and phosphorus are complexly cleaned compounds that require high costs, which, when entering the aqueous objects, affect the increase in the amount of plankton and algae, which leads to flowering and stress water. As a result, the balance of water saturation with oxygen, the permeability of the sun rays and also means the death of many living organisms.
Heavy metals	Iron, manganese, lead, zinc, mercury	Heavy metals fall water as a result of plots from industrial enterprises, wastewater from roads (exhaust gases). Heavy metals are accumulated in the body, are toxicants, and cause a number of diseases of the nervous system, a digestive tract, with a reproductive system, cardiovascular diseases, renal and pulmonary failure.
Plastic	Microplastic	The main sources of microplastics are washing synthetic clothes, roads, and cars, hygiene supplies (for an abrasive effect, plastic granules are added to toothpaste, creams, cosmetic powders, etc.), paint, household plastic waste, wearing synthetic clothes. Plastic tends to accumulate toxic substances that lead to cancer, leads to endocrine system disorders, obesity, problems of the reproductive organs, hormonal changes, asthma, and other dangerous diseases.
Pesticides	Carbon trioxide, nitrogen fertilizers	Pesticides fall into the water as a result of the treatment of fields from pests, such as rodents, fungi, insects. Finding into the soil, many pesticides reach superficial waters that are a source of drinking water in many countries. Finding into the human body poisoning it, causing neurological and reproductive problems, poisoning, diabetes, and in large quantities lead to death.

1.2. The water pollution by organic compounds

1.2.1. Microplastics pollution

Water pollution by microplastics in the modern world is very relevant. Until recently, they did not think about it seriously, however, every year scientists say that the amount of non-filterable microplastics in water bodies is increasing.

As known, microplastics are micro-particles (less than 5 mkm) of plastic waste (contact lenses, telephones, rubber, particles of plastic bottles and bags, hygiene items, etc.) that cannot be cleaned by modern methods.

The Washington-based group of journalists and the University of Minnesota School of Public Health conducted an investigation: water samples were taken on 5 continents [5]. The results of the water analysis showed that microplastics were found in 80% of the water samples. This suggests that we consume plastic with every glass of water (Table 1.3).

Table 1.3

The impacts of microplastic

The main sources	The polluted regions	Diseases
Washing synthetic clothes	USA - 94%	Endocrine system disorders
Roads	Lebanon - 94%	Cancer
Hygiene supplies	India - 82%	Obesity
Paint	Uganda - 81%	The reproductive organs disorders
Household plastic waste	Indonesia - 76%	Hormonal changes
Wearing synthetic clothes	Ecuador - 75%	Asthma
Medicine	the World - 83%	Endometriosis

It has been proven that when wearing synthetic clothing, microplastics are released into the atmosphere just like a cat's fur does when it sheds. So, in 2015 in Paris, it was recorded that from 3 to 10 tons of micro-payment enters the atmosphere every year. Paint for interiors, on-road signs, or paint on ships is a 10% source of microplastics in the ocean. When clothes are washed, with a stream of water from the washing machine, about 1 million tons of microplastics end up in the ocean every year.

Why is microplastic dangerous? Plastic tends to accumulate toxic substances that lead to dangerous diseases. Thus, microplastics have been found in the organisms of fish and mammals.

Microplastic was found in roundworms (in the walls of the digestive tract), in crustaceans (in the respiratory system), on the surface of algae and corals (reduces life expectancy), in marine life (in 14 days microplastic leaves the body of fish, however, when it gets into gills remain there forever). More than 85% of marine life contains microplastics, which then enter the human body.

It has been proven that there is more microplastic in bottled water than in surface water and tap water: the amount of microplastic in bottles is 1.5-3 times more (Table 1.4).

Table 1.4

The main types of microplastics and their impact on human health

The main markers of plastic	Using for/ Impacts on the human health
Polyethylene Terephthalate (PET)	Is used for plastic bottles for juices, Coca-Cola, drinking water are the most popular; synthetic clothing. Accumulation in the body leads to nausea, diarrhea, and poisoning.
High Density of Polyethylene (HDPE)	This a product from cartons for storing milk, water, shampoos, household chemicals. It affects estrogenic chemicals and leads to cancer, endometriosis, infertility, impotence.
Polyvinyl Chloride (PVS)	Is used for wrapping meats and sandwiches, packaging toys, making bath toys, making plumbing fixtures. It leads to disruption of the endocrine system and causes corresponding diseases.
Low Density of Polyethylene (LDPE)	Is used for milk cartons, tea or coffee cups, bread packaging, newspapers, and dry cleaning of clothes. It is identified as the least hazardous plastic.
Polypropelene (PP)	Is used to pack yogurts, tablets, and syrup bottles.
Polystyrene (PS)	Is used for various packaging in the fishing industry. It accumulates in the body and negatively affects human health.
Others	Are used for various packages. The most dangerous plastic that accumulates in the body and leads to cancer, various disorders of the digestive and endocrine systems, causes asthma.

1.2.2 Petroleum products pollution

Petroleum products are organic compounds obtained in consequence of oil refining, which represent a greater danger of not only seawater but also fresh.

Water pollution by petroleum products occurs in different ways and should be clearly regulated, however, with an increase in the area of cities, oil becomes more and more often.

The most frequent causes and sources of oil products in freshwater are products of combustion of fuel from water transport, non-compliance with technical and sanitary and hygienic conditions during oil transportation, wastewater industry associated with the production and processing of oil; Incorrect use of and maintenance of pumps in wells, non-compliance with measures and precautions at gas stations, which resulted in drains of stock oil waters in the reservoirs; Household drains (cosmetic substances containing oil in composition) [6].

The risk of oil in surface and groundwater is obvious: oil has a property to break up and influence in three directions:

1. The oil film is formed, which prevents the intake of oxygen into water and the carbon dioxide yield, which leads to the death of animals and plants.
2. accumulated as precipitation at the bottom, which also leads to a decrease in the water level and breaks the ecosystem, poisoning the soil.
3. It dissolves in water and is a dangerous component, which in the case of ingestion of a living organism, poisoning it and kills.

Oil leakage in groundwater is dangerous situations, as it is difficult to assume and analyze the length and migration of the oil spots. Oil in underground soil waters can easily get into the well, and from there in the drinking water of a person. Unfortunately, in Ukraine there is no control of water quality in private houses, and especially in villages, which leads to frequent poisoning and infectious diseases [7].

1.2.3. Biogenical elements in water bodies

Wastewater has become the most dangerous and main problem of pollution of freshwater. The daily comfortable existence of a person creates a huge burden on the world around us and also becomes dangerous for humanity itself.

In Ukraine, almost every year, about 50 tons of hazardous wastewater, containing toxic substances that become part of the "water cycle in nature" are reset into the aqueous objects [8]. Municipal enterprises are the most active sources of effluent, which processes human life waste.

The striking example of technological degradation in the field of wastewater filtration is a Bortnitska Aeration Station, the state of which is critical. The Bortnitska Aeration Station is located in the Kyiv region, in Bortnichy, and all the drains of Kyiv, Vyshgorod, Irpen, Bortnich, Bucha, and other urban-type villages, are sent there. The station is not designed for such a number of drains and works almost at maximum capabilities. The status of the station has long been critical since from the last century it was not reconstructed, the technique and technology of wastewater treatment were not updated. That is why, already filtered water has a turbid color, and a distinct smell of feces, has impurities of phosphates, nitrates, and nitrites, which descend into the Dnipro River and which is the main source of fresh drinking water. Due to the lack of modern and safe technologies of cleaning, hard laws, and restrictions, as well as a mediocre attitude to sanitary and hygienic rules, water objects that are the source of drinking water are exposed to the strongest pollution are represented in figure 1.8.

Fig. 1.8. The water in the Dnipro river in the summer of 2021

Wastewater is transported using pipeline transport and represent a whole system from the "consumer" to the water site. Outdated pipes, as well as the absence of their reconstruction, lead to breakdowns and drainage to the soil, which leads to contamination of surface and groundwater (Table 1.5).

Table 1.5

The wastewater composition

Pollutants	Examples	The impacts of pollutants
A plasticizer	Esters, chlorinated paraffin, low-drying vegetable oils, plastic, surface-active additives of concrete mixture.	Carcinogenic effects, toxic impact on reproductive functions, internal organs, problems with respiratory system, problems with hormonal system.
Phenols	Plastic, rubber, medicines, detergents, chemical poisons, fuel, antioxidants, pesticides.	Phenol and its products affect the reduction in the number of fish in water bodies and alarming hormone in fish, which violates the ecosystem balance; Human entry leads to intoxication; Through groundwater, phenol enters the soil and depresses vegetation, accumulates in agricultural cultures, changes the composition of the soil and oppress the soil processes.
Surface-active substances	Higher-fatty alcohols (phosphates and polyphosphates, alkyl sulfates).	Surfactants are used in the production of detergents. Especially dangerous due to lowering the surface tension, which leads to a decrease in the holding of CO_2 and O in water and affects Global warming.
Polyaromatic hydrocarbons	Benzopire, ovalen, benzanttracen.	If it gets into living organisms, there are high carcinogenicity and mutagenic, which leads to embryo development disorders.
Bacteria	Enterococci, Salmonella	Fall into the water as a consequence of the discharge of untreated and peeled wastewater from the meat processing industry. Leads to infectious diseases, cause nausea, the disorder of the gastrointestinal tract, elevated temperature, in rare cases to death.
Medications	Diclofenac, antibiotics, hormones	In the water consequence of waste discharge from the pharmacological industry. Certain compounds of drugs increase the level of danger of water and are carried out to violations of the central nervous system, the malfunction of the body, poisoning, and others.

Wastewater leads to the development of diseases in living organisms, destroys the integrity of the ecosystem and affects the annual blossom of water caused by microalgae.

1.3. Biological wastewater treatment

In the modern world, microalgae are special danger to aquatic ecosystems but is also a technological discovery that can be positively displayed in our world in the future. Microalgae are the simplest microorganisms, which consist of one eukaryotic cell, or prokaryotes (Table 1.6).

There are many types of microalgae, which science is trying to use for practical purposes (wastewater treatment, obtaining biofuels, fertilizers, food additives and more). For example, the most popular microalgae are Chlorella vulgaris and Euglena gracilis by their lifecycle.

Table 1.6

Impact of various types of microalgae on the environment

Name of microalgae	A definition	Impacts
1	2	3
Cyanobacteria	A unicellular and colonial bacterium has the adaptation of photosynthetic pigments in light green and dark blue colors, it is most of the sea phytoplankton.	Cyanobacteria are the main species that participate in the creation of water flowering and eutrophication, as it is easy and quickly multiplied. Most types of cyanobacteria have pathogenic and toxic properties.
Chlorella	The type of unicellular microalgae of green (due to the presence of chloroplasts), for the reproduction of which water, light, and carbon dioxide are necessary.	The effect of chlorella on the environment is more positive, thanks to accurate control; Used in new technologies of biological wastewater treatment. Chlorella has a high nutritional value, so it is common as food additives feed for livestock, for medical purposes.

1	2	3
Chlorella	The type of unicellular microalgae of green (due to the presence of chloroplasts), for the reproduction of which water, light, and carbon dioxide are necessary.	The effect of chlorella on the environment is more positive, thanks to accurate control; Used in new technologies of biological wastewater treatment. Chlorella has a high nutritional value, so it is common as food additives feed for livestock, for medical purposes.
Arthrospira	It is one of the representatives of cyanobacteria, found in water with a high level of acidity, therefore dominate in tropical and subtropical latitudes.	Spirulina is a valuable food additive, which is used as a full protein. Modern research in the field of biofuels is interested in this type of microalgae due to a high indicator of effective cultivation at high temperatures.
Dinochetic algae	Eukaryotic organisms, in the cells of which are formed toxins.	They cause water flowering, as well as the toxins of their microalgae data cells, have the property of accumulating in fish, mollusks, corals, and crustaceans, which leads to poisoning of animals and humans.

Cyanobacteria is the most malicious microorganisms. These bacteria are ancient organisms that easily adapted to the environment and were controlled by its terms. However, man's anthropogenic intervention broke the balance of microalgae in the aquatic environment, and at the moment we are confronted with the "green flowering of water".

For a comfortable development of cyanobacteria, water is needed, sunlight, increased water temperature, and carbon dioxide. Human life activity in the form of wastewater drains with farms and pesticides are fertilizers and provoke a rapid increase in the population of these microorganisms.

Every year, a huge amount of freshwater bodies, in the summertime, change their color to green and turn into a swamp. The development of cyanobacteria negatively affects the water ecosystem: microalgae covers the surface of the water and prevent the ingress of sunlight into the depths of water, overlap the saturation of water with oxygen and the release of carbon dioxide, increase the level of the bottom due to the final productivity products of cyanobacteria, and lead to the moor of the fish and the destruction of other unique plants. in certain ecosystems. Water bloom occurs not only in static ecosystems, like a lake, but also in rivers, seas, and oceans. Cyanobacteria are toxic and pathogenic microorganisms that poison water and make it unsuitable for any use. Certain poisonous types of cyanobacteria lead to a violation of the central nervous system and liver dysfunction, respiratory diseases (due to the presence of toxins in the atmosphere) and disruption of the work of the kidneys, burns, and irritation of the mucous membrane, and, in some cases, cancer [9].

Another source of "red water flowering" invites algae. The properties of these algae negatively affect the integrity of ecosystems, as they are very poisonous and affect a large number of animals.

Why is the problem of water flowering so relevant? The fact is that the flowering of water has acquired a huge scale and appeared where it was not there before. Every year the power and level of water flowering are enhanced, and cause tremendous damage to state economies, as well as poison and destroy a huge number of living organisms. Along with other environmental issues, water bloom not only makes it unsuitable for food and recreational purposes but also develops the problem of global warming. Therefore, every year, the NASA World Organization explores and monitors water management using electronic analysis [10].

In comparison, in Ukraine, it is not serious about this environmental issue, therefore the state of freshwater sources deteriorates, and the frequency of poisoning and deaths from poisoning increases.

So, for what reason there is a massive increase in water flowering areas?

The flowering of water influenced the anthropogenic activity of man, more precisely, wastewaters, which consist of fertilizer components and are reset in rivers, lakes, sea, and oceans.

The most dangerous chemicals for human health and the environment, which are in wastewater are nitrates, nitrites, and phosphates.

Phosphates are easily water-soluble phosphoric acid salts. The danger of phosphates in the absence of methods of filtering, as well as several milligram data of these substances, provokes rapidly the development of algae. Approximately, with the help of 1 gram of the substance in water, almost 10 kg of algae is formed [11]. Thus, there is a rapid increase in biological microorganisms and the degradation of ecosystems (eutrophication). With aggressive reproduction of microalgae in water, the level of nitrogen, phosphorus, and toxins increases, which are not actually absorbed by the environment, worsen the quality of the water and the atmosphere, poison coastal soils and destroy the ecosystems. The main source of phosphate entering the environment is household detergents, such as shampoos, shower gels, toothpaste, detergents for dishes, powders, bleach, and air conditioning for laundry.

Nitrates are an oxidized form of nitrogen, which autotrophic microalgae is converted to nitrites (ammonia half-decay), and, on the contrary, anaerobic bacteria turn ammonia into nitrates. Thus, nitrates and nitrites are not only filtered by aeration stations but also remain closed poison in the ecosystem. Nitrates and nitrites disrupt the acidic balance of water, stimulate the development of microalgae, violate the natural removal of phosphorus and water objects, worsen water quality indicators and make it unsuitable, and also cause poisoning [12].

However, due to the emergence of this problem, scientists are trying to use microalgae as a solution to many problems. The last few years have been very popular research in the field of biofuel from microalgae, which will replace minerals and weaken the load on the atmosphere, its pollution, and will slow down global warming. Therefore, scientists are looking for the most easily cultured types of algae, and also lead the mass of the advantages of microalgae.

One of the most relevant solutions to the problem of environmental pollution is the use of microalgae to clean water objects and obtain biofuels to reduce contamination.

Microalgae is a type of prokaryotic algae (cyanobacteria), no longer than 1 micron. A feature of this species is the development of organisms solely due to the presence of chlorophyll and the transformation of sun rays into energy and organic compounds - glucose and oxygen (photosynthesis). Microalgae are popular because they have a high speed of development and, accordingly, a high biomass growth rate. Many states such as Japan, India, China, Thailand, Mexico, and the United States are made from the 20th century to microalgae in artificial water bodies due to the high nutritional value and attempts to obtain environmental biofuels.

The most relevant type of microalgae is Spirulina, as it has high adaptation to the environment (in the usual sense, it dwells in fresh water in tropical belts, but also develops well in salt seawater) and high biomass growth and high protein indicator.

However, to obtain fuel, a large number of fats are needed, which are few in algae, in comparison with plant cultures, which are used to obtain fuel (rape, soy, sunflower, corn).

Despite this, biofuels, obtained from microalgae, is more relevant for several reasons:

1. For dilution of microalgae, it is not necessary to extend the environment. For their cultivation, sun rays and water are needed, unlike Brassica napus: soil, regular watering, technique, fertilizer (herbicides, nitrogen and mineral fertilizers, insecticides), and after a given culture of the area, on which RAPS has not increased, cannot be used about 10 years.
2. The microalgae grow faster, multiply and have a high biomass indicator. Special care for microalgae for successful biofuel production is not necessary.
3. High indicator of oil production (for biofuels) on l / ha Unlike many plant crops: soy - 447 l / ha, RAPS - 71,000 l / ha, microalgae with a low-fat rate (25-30%) - 58 600 l / ha, microalgae with high fats (60-70%) - 137 000 l / ha.
4. To obtain biofuels, the microalgae can be located in different territories (marine water areas, uncomfortable areas of unused land) in reservoirs, while not occupied by huge areas.
5. Since microalgae are photosynthetic organisms, then with their cultivation, the environment is obtained by an increased positive effect: the saturation of the atmosphere of oxygen and carbon dioxide absorption.
6. Microalgae is a reducing source of energy, unlike oil, gas, coal or oilseed plants and in comparison.

The indisputable minus of obtaining biofuels is the use of nitrogen fertilizers to obtain high efficiency of microalgae, as well as the use of different cultivations due to a decrease in the efficiency of algae in open reservoirs. Accordingly, it is necessary to use a bioreactor, which requires higher costs to obtain biofuels and will have a high cost per liter.

The costs of obtaining biofuels directly depend on the type of algae, methods of production and dilution of algae, as well as environmental factors (exploding, climate, and others). At the moment, algae are used as nutritional supplements, drugs, and extremely rare in the form of biofuels. The first company, which began to engage in obtaining environmental biofuels from algae, was the American company “Fort Myers Co”. Currently, the company is looking for new methods of growing and content of algae, as well as a new type of algae with a higher indicator of lipid content, for the globalization of this type of fuel.

Nevertheless, despite the negative properties of biofuels, humanity has no other choice. Minerals have the property to end, and to preserve our everyday life while restoring the balance of the biosphere, we need to develop and improve alternative methods for producing green energy: the use of solar panels, windmills, hydroelectric power plants, energy during garbage processing, and obtaining environmental biofuels from microalgae.

1.4. Conclusion to the Chapter 1

Thus, pollution of the hydrosphere is closely associated with the contamination of the atmosphere, the lithosphere, and the biosphere as a whole. Unfortunately, with intensive change in the world, many animals, plants, and other living organisms, including a person, do not have time to adapt and annually turn out to be in the risk area. The hydrosphere is an important resource of water for the entire living, and deterioration of freshwater indicators, the change in oxygen exchange in lakes, rivers, and oceans, leads to a decrease in biodiversity and leads to new global problems. The topic of water pollution is very relevant, however, new technologies and attempts to slow pollution are vain. Every year the amount of swamps increases, water flowering occurs even in the open seas, where there is a flow and movement of water, which leads to huge losses. Freshwater sources in Ukraine are under the greatest threat due to the lack of compliance with security measures, sanitary and hygienic standards, due to the lack of laws that protect water bodies and their inhabitants, the irresponsible attitude of the population to freshwater, not observing water purification after its use for industrial purposes. Around the world, scientists study the methods of using microalgae to transform them into biofuels, medicines, and use in the food industry in attempts to take control of the consequences of the chemicals entering water that we use every day and cannot refuse.

CHAPTER 2

ANALYSIS OF MICROALGAE CULTIVATING TECHNOLOGIES

Conventional sewage water treatment facilities usually apply such methods as mechanical treatment, biological treatment, and biochemical treatment. Using these methods, treatment plants are not always able to provide sufficient purification ofthe water, especially when pollution content in received sewage water substantially varies. It is advisable to apply additional purification facilities for after treatment of sewage waters. Methods of nature purification are often used for these purposes. Some of the most popular installations are used: special open oxidation ponds, where different aquatic organisms are cultivated; special agricultural tanksfilled with hydroponics, where different aquatic plants are grown; special soil filter-systems, where different soil plants can grow, and others. One of the promising methods can be considered the use of wastewater for the microalgae cultivation.

2.1. Types of bioreactors

Pollution of water and the relevance of this problem leads to the development of the latest technologies for disposal and processing, water purification for its further use and continuation of the comfortable life of humanity and the animal world. Since one of the problems is a strong fever and flowering of the World Ocean due to microalgae, scientists are trying to use living organisms as useful raw materials and are looking for ways to use microalgae as biofuels. One of the leading technologies is the cultivation and processing of microalgae using bioreactors. Bioreactors will help not only clean the water bodies from pathogenic organisms, but also reduce the load on the ecosystem to reduce the number of microalgae, as well as reduce the use of natural fossils, such as oil and gas, which will lead to a decrease in the pollution of the atmosphere and lithosphere, hydrosphere and biosphere.

The bioreactor is a device for cultivating the simplest living organisms, in which biochemical reactions of living cells occur [13]. The use of bioreactors is widely used in medicine (veterinary and drugs, vaccines), in the food industry (food additives, enzymes), biotransformation of starch and polysaccharides, widely applicable in wastewater treatment. There are several varieties of bioreactors (Table 2.1).

Table 2.1

The types of bioreactors

The bioreactor	The principle of operation
Mechanical	Mixing the contents of the bioreactor occurs due to the mixer, but leads to uneven stirring and the death of microorganisms.
Airlifted	Stirring is carried out using a gas phase through a liquid, which leads to the unwanted formation of foam.
Gas-vortex	Stirring occurs by a quasi-stationary flow with axial countercurrent, which is created by a gas swirl due to changes in the pressure and the friction force of the airflow on the surface of the fluid.
Aerobic	It occurs due to the active biological process when applying oxygen (aeration) and purifies water from biological substances, solid particles, and other impurities.
Anaerobic	Works on the basis of fermentation, the invention relates to the environmental processes of water purification of fine particles and droplets with flocculation and coagulation and can be used when removing surfactants, fats, oils, petroleum products, and other weighted substances, suspensions, and emulsions.
Membrane	Works on the basis of biological purification and membrane separation purify water from organic substances, bacteria, viruses, and pesticides.
Cascading	It works on the basis of biological water purification, organic substances, nitrogen, phosphorus, is designed for the cultivation of microalgae for use as biofuels.
Mixed	It is used as the cultivation of anaerobic and aerobic crops at the same time to obtain biogas and heat, which is trained to heal the cultivation medium of microorganisms.

Any bioreactors are designed to create comfortable conditions for the livelihoods and cultivation of microorganisms and the simplest, more precisely, ensuring their breathing, nutrition, and removal of life products, comfortable temperature, and so on.

The main detail of the bioreactor is the fermenter. The fermenter is a reservoir, which creates comfortable conditions for cultivating microorganisms, product synthesis, and biomass accumulation. The main material from which bioreactors are made is high-quality steel or titanium, since they are most stable and less susceptible to corrosion, also be polished in the inner part of the bioreactor. Mandatory bioreactor conditions are mass exchange and hydrodynamics. The fermenters are equipped with all the necessary details, such as stirrers, pumps, air filters for sterilization, and others, to maintain the necessary temperature, gas mode, and the correct mass movement in the reactor. In the process of biosynthesis, a fluid sample is taken from bioreactors, which is why the sampler is also a mandatory detail in bioreactors. Depending on the purpose and specificity of the use of the bioreactor, it may also be additional details. The bioreactor operation is monitored using instruments that measure the acidity of the medium, temperature, pressure, gas consumption and aeration, and so on. Details of the bioreactor, as well as control of all its processes, directly affect the cultivation of microorganisms.

The bioreactor is not just an apparatus, but also complex physical, chemical, physicochemical, and biological processes that occur to achieve maximum efficiency of the goal. Bioreactors should be in an affordable place, in order to ensure easy access to replace the necessary parts in case of breakdowns. Also, the procedure must be as sterile as possible and the necessary security measures must be respected to minimize the negative consequences on the cultivation process. For cleaning bioreactors, steam under high pressure is used, since the main reactor pollutants are fungi, bacteria, and viruses, the simplest and yeast, which appear as a result of dust entering, working solutions, or enterprise employees. Bioreactors must comply with certain criteria: absolute sealing, stable volume of cultured fluid, access to all parts of the bioreactor, and sterilization. Also, bioreactors are divided into types depending on the volume of fermenters.

Prior to the use of cultured fluid or raw materials, it is stored in frozen form and a small number of microorganisms are increasing in the laboratory to the required volume and maximum efficiency in the bioreactor. After, in a sterilized bioreactor, microorganisms are placed in comfortable conditions in order to ultimately get biomass or useful substances during the metabolism of microalgae.

Bioreactors are open and closed. A closed bioreactor is a closed cultivation system in which components do not fall, and are also not output from the reactor, that is, accumulate (Table 2.2). To avoid the depletion of the nutrient medium, the closed reactors were modified into open to add nutrients and maintain the maximum amount of biomass [14].

Table 2.2

Different Photobioreactor Designs for Microalgae Cultivation

Conceptual design	Raceway Pond	Flat-Plate	Tubular	Vertical-Column
1	2	3	4	5
Design characteristics	Consist of closed-loop recirculation channel (oval shape)	Bioreactor with rectangular shape	Consists of an array of straight, coiled, or looped transparent tubes	Bioreactor with vertical arranged cylindrical column
	Usually built using concrete or compacted earth-lined pond with white plastic	The flat-plate are usually made of transparent plastic or glass	The tubes are usually made of transparent plastic or glass	The columns are usually made of transparent plastic or glass
	Mixing and circulation are provided by paddle wheels	Usually coupled with gas sparer	Usually coupled with a pump or airlift technology	Usually coupled with a pump or airlift technology
Advantages	Easy to construct and operate	Large illumination surface area gives maximum utilization of solar energy	Large illumination surface area	High mass transfer rate with good mixing
	Low energy input and low-cost	Low concentration of dissolved oxygen	Relatively higher biomass productivity	Compact, easy to operate, and relatively low-cost

1	2	3	4	5
	Can be position vertically or inclined at an optimum angle facing the sun	Potential of cell damage is minimized if airlift system is used	Lower power consumption	Can be position vertically or inclined at an optimum angle facing the sun
Disadvantages	Water loss due to high evaporation rate	Scale-up require many compartments and support materials	Require large land area because long tubes are used	Small illumination surface area
	Can be position vertically or inclined at an optimum angle facing the sun	Potential of cell damage is minimized if airlift system is used		Can be position vertically or inclined at an optimum angle facing the sun
	Difficulty in controlling the temperature and pH	Difficulty in controlling culture temperature	Potential in accumulating high concentration of O_2 (poison to microalgae) in culture medium if tubes are too long	Cell sedimentation may occur if airlift system is not used
	Susceptible to contamination		Decreasing CO_2 concentration along the tube may cause the microalgae deprived of carbon source	

End of Table 2.2

1	2	3	4	5
	Can be position vertically or inclined at an optimum angle facing the sun	Potential of cell damage is minimized if airlift system is used	Lower power consumption	Can be position vertically or inclined at an optimum angle facing the sun

2.2. The mechanical bioreactor

Mechanical bioreactors operate according to the principle of mechanical stirring of the culture medium using a mechanical stirrer. A feature of each type of bioreactor is the principle of stirring of the culture medium, which determines the method of supplying the energy and the effect of mixing the mass in the machine. The mechanical bioreactor is often used in the cultivation of suspension crops and redemption (alkaloids, steroids, food dyes, Phyto virus inhibitors, menthol, and others). The use of one or another bioreactor is determined depending on the desire to obtain certain amounts of bioproduct. In the mechanical bioreactor in the culture medium, the air is supplied using a sprinkler (tube with a single hole or a ring with a plurality of holes). If the sprinkler is in the form of a ring, then the air turns into small bubbles, which are evenly distributed in the liquid, however, the use of tubes will avoid frequent closure. That is why, in mechanical bioreactors, the sprinkler in the form of tubes is often used. For uniform air distribution in the bioreactor, mixers are used (one large or slightly smaller). The mixer breaks the air bubbles, which provides a long and stable oxygen medium for cultivation. The effective distribution of oxygen in the bioreactor depends on the size of the agitator, on the type of mixers, the number of revolutions, chemical properties, and physical properties of the medium. For the most efficient distribution of oxygen in the bioreactor, the mixer is placed in the diffuser. Mechanical bioreactors exist in different types, depending on the volume of culture mass, mixing velocity, and environmental conditions that allow using high specific energy, intensive turbulization of the medium, and the transmission of oxygen to the masses.

Another important criterion for using a mechanical bioreactor is the financial cost, which includes the operation administered by the external energy, the supply of microorganisms, mixing with oxygen [15].

The mechanical bioreactor is used to grow aerobic cultures and refers to biotechnology. The result of using a mechanical bioreactor is the intensive transmission and distribution of oxygen, which corresponds to the needs of cultured microorganisms and affects the density of the final mass due to the absence of the use of chemical defoamers, which creates the diffusion resistance of oxygen turning into the liquid when transmitting to the mass.

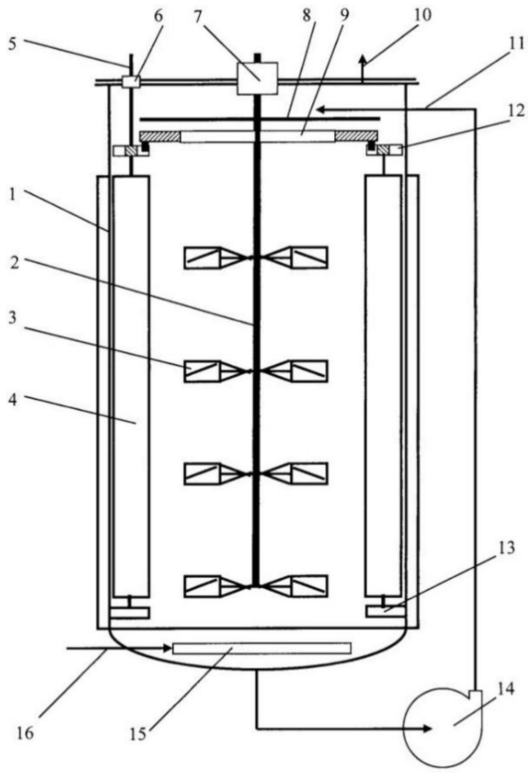

Fig. 2.1. The structure of mechanical bioreactor — 1 is Bioreactor Case with Heat Explain Shirt, 2 is Mixing Val, 3 is Mixer Tier, 4 is Rotary Reflective Partition, 5 is Reflective Partition Drive Shaft, 6 is Reflective Sealing Unit, 7 is Mixing Shaft Seal, 8 is Foam Disk, 9 is Remove Ring Reflective Partitions, 10 is Exhaust Air Output, 11 is Cultural Supply Liquids, 12 is gears turning reflective partitions, 13 is reflective partition support units, 14 is pump, 15 is bubbler, 16 is the air supply tube

The operation of the bioreactor is based on the following steps: a nutrient medium is poured into the reactor and a small number of cultured microorganisms is fed, the air is supplied and the mixer turns on. The foam arising from stirring is extinguished due to the impact of the disk on the foam, as well as due to drops of cultured microorganisms, which fly from the surface of the discs, which are supplied by the pump. The certain disadvantage of mechanical bioreactors are stagnant areas that occur during the mixing process with a stirrer, which is due to the uneven supply of oxygen to the mass, many cultures of microorganisms are not suitable for cultivation in a mechanical bioreactor due to superficial gas exchange, as well as the death of microorganisms as a result of the effects of waves from stirrers. At the same time, an excessive oxygen supply is avoided, as it can lead to a decrease in the efficiency of the process due to an increase in substrate and oxidation. With any number of cultured mass, the foam harvesting system is uninterrupted and with a maximum speed without excessive energy use, as well as without the need to maintain the velocity of the regulation of the rotation engine (Fig. 2.2.). Mechanical bioreactors are used in the field of cultivation of crops for obtaining alcohol, yeast, vitamins, and amino acids, enzymes [16].

2.3. Airlift and gas-vortex bioreactors

The airlifted bioreactor works on the basis of gas purging through a liquid, however, does not allow the maximum mixing efficiency and forms a foam that adversely affects microorganisms. The Babbage principle of operation of the airlifted bioreactor is advisable to apply for mixing liquid reagents, which may adversely affect the mechanism of another type of bioreactor (for example, mechanical) and cause corrosion. The airlifted bioreactor is rarely used to mix biological masses since the mixing fluid should not be volatile. The only advantage of bubble mixing is the lack of mechanical parts, device primitiveness, and easy maintenance of suspensions. However, due to the high weight of the culture fluid and masses, the airlifted bioreactor does not cope with intense stirring, which leads to the oppression of the vital activity of active microorganisms. The volumetric foaming in aerial bioreactors prevents the full use of the apparatus, and the use of defoamers leads to a decrease in the resulting raw materials as the final product and leads to the loss of financial investments [17].

The bubbling mixing is more economical, due to the cheapness of the bubble colon, in which the mixing of the liquid occurs by ascending gas flows and is distributed evenly throughout the bioreactor. The absence of a mixer in this type of bioreactor prevents pathogenic microorganisms in the culture medium. Also, in the airlifted bioreactors, there is no sharp pressure, which positively affects the number of final products. In the airlifted bioreactors, the air is fed to the lower compartment of the vertical channel, thus, when lifting air, bubbles raise the liquid into the top compartment of the channel, where the gas-liquid separator producing air is located. More dense masses settled on the bottom of the bioreactor and the mixing process is repeated again. Thus, the culture fluid is constantly circulating in the airlift bioreactor. The airlifted bioreactors have two construction species. The first look is a container with a pipe in the middle, which provides a stable fluid movement (internal circulation). The second design consists of individual and independent channels (external circulation). Another advantage of the airlifted bioreactors is the absence of risk of bubbles and destruction of the structure of cellular microorganisms [18].

The gas-vortex bioreactors are stirring occurs by a quasi-stationary flow with axial countercurrent, which is created by a gas swirl due to changes in the pressure and the friction force of the airflow on the surface of the fluid. The method of preserving and propagating heat in the reactor determines the cost of the final product and the effectiveness of the device. Gas-vortex bioreactors in this case are largely more efficient than other bioreactors. The mixing of the fluid with this bioreactor occurs due to the intensive airflow and the pressure drop on the surface of the fluid and friction of the flow on its surface layer. Accordingly, there is an active three-dimensional vertical movement. The absence of mechanical exposure leads to energy-efficient and comfortable stirring, without the formation of foam, cavitation, turbulent zones, and zones with increased and unfavorable temperatures.

When using this bioreactor, as a result of changing the purpose of cultivation, it is possible to lightly replace one type of producer with another.

The gas-vortex bioreactor has high efficiency, soft and spatial mixing of the mass, the absence of foam during the cultivation process, energy-efficient, has a high rate of saturation of masses, corresponds to the initial characteristics (unlike the aerial), the gas whirlwind acts as a natural defoamer, the bioreactor is easy scaled-depending on the purposes and scale of production, the high percentage of the probability of cultivation of sensitive cells (for example, stem, embryonic), simple pipeline system, savings in the field of costs and resources due to versatility (water, energy, drain, raw materials, salary and other), the low cost of the final product is effective when stirring a viscous fluid [19].

Due to its universal capabilities, the gas-vortex bioreactor is used not only in biochemistry but also in other industries (Table 2.3).

Table 2.3

Scope of gas-vortex bioreactor use

The industry	The scope
The microbiological, pharmaceutical	• production of drugs (using particularly sensitive embryonic, hybridoma, stem cells); • production of monoclonal antibodies; • production of a wide range of microbiological preparations for agriculture and veterinary medicine; • cultivation of plant tissue cells, insects, animals and a person for the needs of virology; • production of enzymes; • production of polysaccharides and petrol builders for the oil industry.
Petrochemical	• chemical synthesis of various products; • production of surfactants and enzymes for the chemical industry.
Food industry	• production of saccharide products from grain starch - various molasses, glucose syrups; • production of margarine products; • brewing; • production of therapeutic and prophylactic nutrition.
Other	• used in the processes of mixing heavy and very viscous liquids.

2.4. Wastewater treatment technologies with membrane and anaerobic bioreactors, and new technology as bio-plateau

The membrane bioreactor consists of biological treatment with the help of active silt and mechanical membrane filtering of contaminated water masses. The membrane installation separates the meal mixture and is an alternative to the deposition method of the active silt in secondary septic tanks, which is widely used in canonical wastewater treatment in aero tanks.

The membrane bioreactor during wastewater treatment is not made enough, but high-quality waters that can be calmly discharged into natural reservoirs or used in the agroindustry (for example, for irrigation, watering plants within the city, and other green plantings). Membrane bioreactors have a number of different advantages, such as compactness, the overload of the membrane apparatus due to an increase in active silt in the installations will not lead to a deterioration in the work, due to the membrane apparatus, the high efficiency of cleaning the active silt and eliminating the risks of pollution of purified water without reducing the efficiency of the bioreactor and reduce its efficiency performance; comfortable use and easy installation in the modernization of wastewater treatment facilities.

The use of membrane installations began in the 1960s, however, was not widely applied, since it was not an economical process. The membrane sheets were expensive for regular replacement, the resulting water could not be used for nutritional purposes and therefore was low quality, as well as the membrane was regularly and quickly contaminated, the installation did not pay off the final product. That is why the use of the membrane as a method of water purification has not been widespread and used on sewage treatment plants with specific needs. Only in the 1980s, when the Japanese placed the membrane into a bioreactor, this device became more ergonomic: due to the high pressure of large volumes of wastewater, the membrane installation was less contaminated. The water purge cleaning system with a bioreactor in which the membrane is located at a low amount of wastewater and is energy efficient. In addition, one of the important factors of the membrane bioreactor is aeration. Thanks to aeration, solids are in a state of suspension, it purifies surface membranes and provides good oxygen exchange in the biodegradation, which affects the high biodegradation efficiency and the synthesis at the cellular level.

Another important aspect when creating a membrane bioreactor is to introduce a two-phase bubble fluid into the system, which helped automate wastewater treatment and control the level of contamination. Thanks to the new and complementary design of the membrane bioreactor, this technology began to be actively used since the 1990s. From that moment, the membrane bioreactor was improved and modified, various experiments were carried out, which led to another addition - to the return washing of the membrane, which influenced the efficiency and ergonomics of the technology. However, nothing can serve forever, therefore the membrane is polluted by solid particles from the drains (particles of silt) and still needs to be replaced to increase efficiency.

The membrane bioreactor has a major problem - this blockage of the membrane by particles of active sludge, and this is a difficult drawback to this day. To improve the performance of the membrane bioreactor, regular cleaning or replacement of the membrane is needed, which occurs with a circulation pump and requires a uniformly washing of the membrane throughout the area and is an emblematic effect that occurs for several hours and is required 1-2 times a year. The membrane bioreactor exists in two species and depends on the location of the membrane (internal location or external) (Fig 2.2). The inner membrane is immersed in the reactor and is the main filter for wastewater treatment. The outer membrane is separated from the total bioreactor and it is necessary to bring the pumps to its use (Fig.2.3).

The membrane bioreactor with an internal membrane is a classical version of this reactor and is widely used (for example, the Bortnitska aeration station) and purifies water from solid particles, as well as pathogenic microorganisms. Due to the low rate of membranes, this type of bioreactor is most popular, as well as purified water can be reused in households or industry, during watering green plantings, agriculture, and others.

Thanks to innovative changes in the structure of the bioreactor, wastewater treatment does not pass long, is energy-efficient, as well as expensive cycles and wastewater is within local cleansing and reuse.

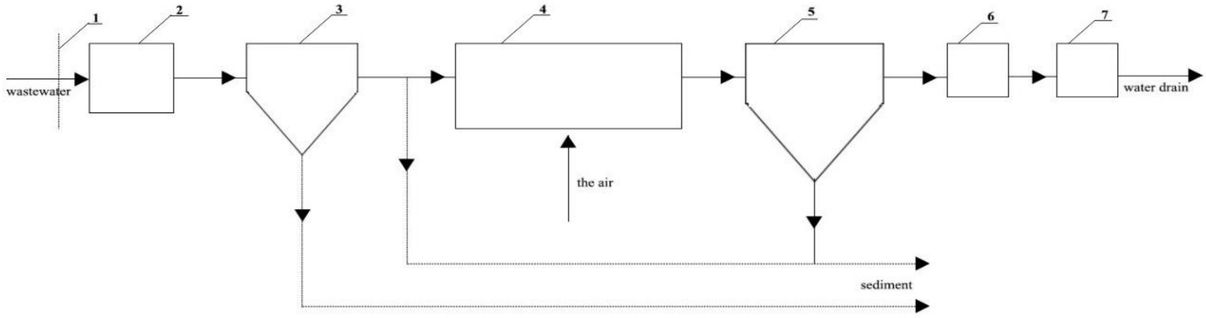

Fig. 2.2. The structure of the membrane bioreactor with internal membrane system — 1 is a mesh, 2 is removal of solid particles, 3 is pre-treatment of wastewater, 4 is aeration zone, 5 is precipitator, 6 is filter from sand, 7 is disinfection zone

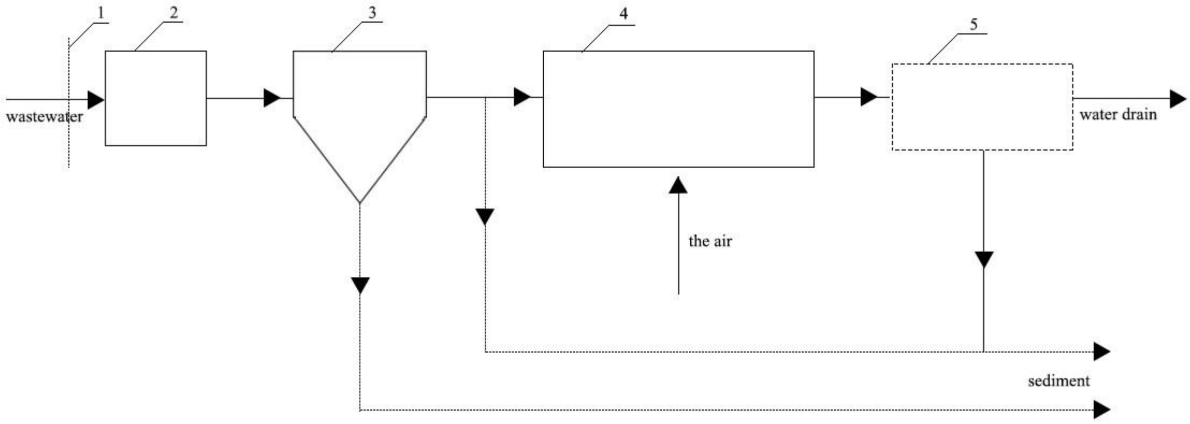

Fig. 2.3. The structure of the membrane bioreactor with external membrane system — 1 is a mesh, 2 is removal of solid particles, 3 is pre-treatment of wastewater, 4 is aeration zone, 5 is membrane

The structure of the membrane bioreactor consists of basic parts, such as aero tanks and a membrane module, which are equipped with high-quality filtration membranes and operate on the principle of fluid separation as a suspension on half-fiber membranes [20].

The first stage is the receipt of wastewater in aero tanks, where they add an active scale mixture. Polluted water circulates through membranes. The highest quality filtration membranes are necessary to increase the concentration of the sludge in the aerometer and high-quality wastewater treatment. Aero tank is more classical sizes due to the high concentration of active sludge. The membrane module consists of 20 membrane planes, which contain about 15 fiber bundles. The fiber membrane has the structure of a hollow tube with a diameter of several millimeters and a few meters long. The outer part of this thread tube is an ultrafiltration membrane with pores of several dozen micrometers. Each bundle consists of thousands of fibers and is connected to the filtrate removal tube. These small sizes are necessary for wastewater treatment of solid particles and active sludge, as well as reducing the concentration of the precipitate. Water filtration occurs in vacuo, which appears as a result of the operation of the pump filtering. To filter water, the pressure drop is created between the inner surface of the membrane and the membrane block. At this stage, the water filtering from solid particles occurs outside inside, that is, all heavy particles remain on the outer surface of the membrane module. Thus, the separation of solid particles on the membrane increases the concentration of active sludge in the block and aero tanks and affects the decrease in the volumes of aero tanks, and also deeply cleans the wastewater.

Purified of solid particles and bacteria, viruses, water enters under the piping in the disinfection section, and the precipitate from the active sludge is delayed in the membrane reservoir and circulates in water using aeration to avoid sedimentation to the bottom. Aeration occurs due to the pipes from which air flows. Depending on the desired amount of final result, for more efficiency, membrane modules are connected to the membrane block.

Filtering is necessary to avoid clogging the membrane pores and depositing pathogenic bacteria on the membrane grid. The movement of the sludge in the liquid with the help of the pump helps to reduce the waste into electricity and provides a stable pressure state, as well as control the membrane filtering obtaining maximum efficiency.

Stable active filtration and aeration helps for maintaining all biological synthesis. Regular flushing membranes crushes bacteria into a suspension, which leads to the avoidance of point major bacteria formations, thanks to which bacteria are in contact with pollutants and are in oxygen saturation. Thanks to this system, the ratio of pollutants for oxidation and bacteria is greater than in other primitive bioreactors, which use active sludge. Microorganisms in the membrane bioreactors do not leave the active sludge system, so the bioreactor works with high biomass and efficiency. Maintaining a stable level of biomass in the reactor occurs for the light of regular destruction of the outer shell, so microorganisms spend all their energy to maintain vital activity, and not to increase the population.

High content, as well as a concentration, active sludge in the bioreactor, helps the most efficiently used bioreactors at low loads, which affects the stability of the biocenosis to high loads and changes in the composition of the aqueous medium, and creates a good oxidative ability that directly affects the quality of wastewater treatment. As well as the oxidative capacity in conditions of high concentration of active sludge, it is helped by cleaning very polluted by organic sewage substances. Due to the change in technology in the use of sludge from the gravitational method into the membrane, allows to increase the viability of microorganisms from 25 days to 70. The main part of the active sludge is represented in the form of microorganisms, which processes the complex and seriously purified organic. Microflora in active sludge breeds slowly, respectively, it affects the reduction of the number of sludges. The dimensions of the active sludge do not exceed the standard sizes, unlike classical methods in aero tanks. These sizes of the sludge lead to an increase in the likelihood of interaction between microorganisms and dirty water, which leads to high-quality absorption of heavy metals and organic matter.

Since the pores in the membrane disks have a smaller size, rather than the cells of pathogenic living microorganisms, then in this case there is a partial disinfection of water. The efficiency of destruction of bacteria and the virus is almost 100% and after this phase of purification, this water can be used in many needs, except for household.

The membrane bioreactor is used in many industries, such as cleaning wastewater from household pollutants, water treatment water supply (for example, dairy), poultry farm, textile industry, and others [21]. The membrane bioreactor has several advantages:

- Obtaining, cleaned until the moment of use in domestic purposes, water, without complex structures
- Water production, which meets the requirements for resetting water in reservoirs

- Raising or reducing the number of microflorae in the reactor depending on the purpose of production
- The number of active sludges at the disposal stage does not exceed high indicators, and therefore disposal and other fraud will be financially beneficial
- Active sludge does not fall into the tank-sump due to the membrane apparatus
- Purification of water from pathogenic microorganisms and heavy metals reaches 99.9%
- Savings of the area occupied by the diaphragm bioreactor, due to the absence of blocks of sump or platforms with sludge.

Reducing the consumption of natural resources directly affects the environment and its pollution. Freshwater bodies are the most susceptible to pollution, the purity of which depends on many external and internal factors. The modern method of water purification is biological water purification. This method is most often used in wastewater treatment, which requires removal from soluble and insoluble impurities, organic and mineral impurities, and microorganisms. Biological water purification takes place under aerobic and anaerobic conditions. The difference between these methods lies in the presence or absence of oxygen. In the process, some of the microorganisms oxidize organic compounds and form biomass in the activated sludge, converting the rest of the compounds into harmless substances.

This method is not suitable for local use, therefore biofilters, reverse osmosis filters, bottom aerators and bacteria, germicidal UV lamps, and others are used to clean water bodies, which not only consume electricity but also do not give the desired result, destroy the local beneficial flora and fauna. , and can harm the water body.

Bio-plateau (biological plateau) is a wastewater treatment system based on the principle of bio-ponds. When modeling a bio-plateau, physical, biological, and chemical factors of influence on water bodies are taken into account. There are 4 types of bio-plateaus: combined, vertical and horizontal, surface, which affect the treatment of certain types of wastewater.

The essence of the method is to purify water with the help of higher plants planted according to the principle of hydraulic flows. In this method of cleaning water bodies, the following types of plants are used: water hyacinth, sedge, cattail, fern, Iris laevigata, reed,

reed, butomus umbellatus, and others. Higher plants directly affect water quality, as they perform the following functions: enriching water with oxygen through photosynthesis, neutralizing toxins, filtering heavy particles, removing nitrogen, reducing oxidation, reducing the number of algae, accumulating heavy metals and decomposing them, absorbing certain types of chemical elements, purify water from waste products of living organisms and contribute to the development of fish species. The bio-plateau uses resistant plant species, especially the reed. It is used in the purification of wastewater from the pig industry, domestic wastewater, wastewater from power plants, wastewater from mines, and other industries. The indisputable advantage is the reduced use of energy, simple operation, no place for insects to accumulate, no water bloom, and as a result of an unpleasant smell, and others.

The Bio-plateau method has long been used in China, the USA, Japan, China, the Netherlands, Australia, and other developed countries.

The anaerobic reactor, in its structure, is not a complex design, cylindrical shape, and consisting of several departments: in the upper part, there is a biogas separator and biological mass, in the lower part - the collector, whose purpose is the distribution of flow streams. The upper anaerobic bioreactor unit is supplemented with a square in the shape of a square and a cover with a gas dome, which serves to seal the reactor. The separator is located in a nozzle, which includes a compartment for collecting biological mass and foam. The main goal when using an anaerobic bioreactor is high-quality wastewater treatment and preventing active sludge in reservoirs.

The operation of the bioreactor occurs as follows: the incoming contaminated water has a temperature not lower than 30 degrees, and uses the pump through the separation collector into the fermentation zone. Wastewater gradually rises, while interacting with active sludge. The microflora of the active sludge purifies water from organic compounds and leads to the preparation of foam in the upper bed, or, in other words, biogas. Because of the friction force, air bubbles increase in size and separate from the liquid, thereby rising vertically into the separator and on the gas pipe. Some of the cereal of active sludge settles on the bottom, getting rid of gas. Purified water without microorganisms and organic compounds, goes further into aero tanks, where the next phase of cleaning is passed [22].

Anaerobic bioreactor somewhat-speed. The wastewater treatment scheme is presented below.

Polluted water is fed to the primary chamber, where solid suspended particles are delayed thanks to the shallow grid. This water in the drain falls into the tank of the regulation of wastewater, in which the pump is located, which controls the amount of incoming fluid to an anaerobic reactor of the first stage, where the microorganisms are cleared of water, the change in its physicochemical properties. To improve oxidative processes in a bioreactor, a pump for water circulation is installed on an objective basis. After this purification, the wastewater enters the anaerobic reactor of the second stage, where water is purified by anaerobic microorganisms and the production of biomass. This water, good color, and components flow into filters and disinfection. This water can be used in the fishing industry. Anaerobic wastewater treatment is most used, since ergonomic and has the process of obtaining biomass. The main criterion of the anaerobic bioreactor is the water temperature, which must match the "warm" for biomass. The efficiency of microorganisms' growth is directly dependent on temperature [23]. Anaerobic biological purification is used for wastewater from the swing industry, dairy and raw and curd industries, with alcohol production and water purification from refining.

2.5. The photobioreactor for biogenic elements removing and cascade bioreactor design

A photobioreactor is an apparatus for cultivating microalgae with an integrated artificial light source that affects photosynthesis and is directly related to the final amount of biomass produced.

This bioreactor is suitable for phototrophic living organisms, mostly microalgae and protozoa, moss and others, because they need only light and carbon dioxide for reproduction. For their effective cultivation, the artificial environment in the bioreactor is carefully controlled. Accordingly, the bioreactor is designed in such a way as to get a large biomass growth as quickly and efficiently as possible under sterile conditions, unlike in the wild. Studies claim that for cultivation of microalgae, wastewater (as it is rich in organic compounds, has a suitable temperature) and gas from fuel combustion (e.g. in thermal power plants) are suitable, as they are rich in CO_2.

Photobioreactors exist in different designs, but the primary system was open. An open bioreactor is a natural or artificial water body in which a stable water flow has been established. Due to the access of carbon dioxide and nutrients in the water for microorganisms, as well as sunlight and the stable flow of water and culture fluid, people began to use the photobioreactor for production and industry.

This system is the most accessible and easiest to cultivate microflora. However, a serious disadvantage of the open system is the depth of the reservoir. If the depth is more than 2 meters, the sun's rays do not reach the bottom, which means that the area of cultivation will be limited, as well as the effectiveness of this bioreactor. Also, costly in an open bioreactor is spent energy for stable circulation of water masses, and the resulting amount of biomass does not pay back the financial investment. Open bioreactor within populated areas will be very expensive, due to population density, the cost of land and the availability of an accessible water body. Open photobioreactor system is not economical, because there are many negative factors of loss of profit, for example, due to circulation of water in the atmosphere (evaporation).

The closed bioreactor system was developed in the middle of the last century and different methods of culturing microorganisms were created. It was assumed that the closed system would save on pumping and circulation of water, as well as allow maintaining a high density of microflora. The great emphasis of the closed photobioreactor system focuses on saving water costs, eliminating evaporation, pollution due to waterfowl, destruction due to other living organisms, pollution from dust and soot, and other factors. Many different photobioreactor systems have been created; however, many have not been implemented not only at the laboratory level, much less at the industrial level. All disadvantages included too thin a layer of obtained biomass, unsuitable lighting or high cost of consumed energy to move the water masses, high costs from sponsors and institutions that could not pay off, and the frequency of microbes.

The most relevant photobioreactors are those that allow the studied microorganisms to be used in products useful to humans (e.g., moss). These microorganisms are widely used for biotechnological and industrial purposes. The simplest example is the moss reactor, which consists of a glass tank and is equipped with an artificial light source on top. At the top of this reactor, outlets are installed to saturate the culture liquid with gas. However, this type of bioreactor is not suitable for industrial purposes, so it is used locally - in laboratories.

For industrial purposes, a type of photobioreactor that looks like a multitude of stepped tubes, in other words, a tube bioreactor, is used successfully. A multitude of grids consisting of tubes in vertical or horizontal position are connected to one centralized system with pumps, temperature sensors, nutrients for the microorganisms, and, of course, with access to carbon dioxide. For example, the tube bioreactor is suitable for the cultivation of microalgae which are successfully used as food additives: they are not identified in the human body as Vitamin A, so they are absolutely safe and are used as food coloring (astaxanthin). These microalgae are successfully used as a food additive for salmonid fish to brighten the color of the meat.

The tube bioreactor is a sterile, closed system which allows high biomass growth. Due to this system design and microbial conditions, the resulting products are considered high quality (and therefore quite profitable), and at the end stage the residual biomass is successfully processed and is ergonomically sound. Due to the increased focus on alternative fuels, the price of photobioreactors has increased significantly, which has induced higher prices for the final products, which can only be found in expensive cosmetic products, or in high-priced products.

The uncomplicated design of the photobioreactor can also be used for laboratory and scientific purposes, where controlling the environment and the environment inside the bioreactor, suitable for microorganisms, has a beneficial effect on the growth and cultivation of biomass.

The next bioreactor resembles the structure of coniferous plants, namely spruce. The structure of the photobioreactor looks like a vertical installation with tubular modules, which are sporadically attached to two hoses in the middle of transparent light. This photobioreactor is universal in that it does not require clear restrictions on the area. The tubular photobioreactor can be outdoors until the scale of agriculture. Single location, soil, and smooth surface, and the situation does not have a huge effect on the amount of cultured biomass, since this bioreactor is a closed system. The key factor in the success of this installation is the material since it must prevent the increase in biological waste or living organisms, on the walls of the bioreactor, as well as produce a sufficient and profitable amount of biological mass. Good circulation of fluid in the bioreactor, as well as a closed structure, should be positively affected by the number of final products, the operation of the device, and its operational capabilities.

The next photobioreactor is like a plate for its structure. As a material for these plates, plastic is used or glass, which, in turn, is an affordable and economical option. The plates are set in such a way that between them there is a small distance in which the culture fluid is located. This design provides a good passing of light to microorganisms, that reflected on the number of biomass. The plate structure is a much simpler tubular bioreactor, as it is simpler, more efficient, and less expensive. The main driving mechanism is the bottom pump, which provides carbon dioxide microorganisms. Modern studies prove the effectiveness of the installation so much that in Germany, this bioreactor is installed on some buildings' facades. The negative side of the plate photobioreactor is the strength and reliability of the material used, access for cleaning and operation, as well as the formation of a film at the expense of biotherapy by microorganisms. Using industrial scales is still unknown, as everything is associated with the number of plates and their location, and, accordingly, with the cost of renting area.

The following structure of the photobioreactor is in a horizontal position, is a monolithic plate with structural elements, such as recesses and depressions, which are located apart from each other. This photobioreactor structure involves an effective distribution of light in all areas of the bioreactor, thereby creating a dispersion effect. This method of lighting favorably affects the cultivation of microalgae, since many types of microorganisms are sensitive to a certain intensity of light and allow to solve the problem of artificial cultivation of phototrophic microorganisms. Many microorganisms give a good biomass growth, even from a low level of lighting and low intensity (from 1000 W / m). The intensity of the incoming light can be adjusted, which will be reflected at the pace of bio cultivation. The circulation of the liquid in the horizontal photobioreactor is carried out using a rotary pump, which stirrers the culture fluid due to the cylindrical flux of rotation. A serious advantage of this photobioreactor is a thin layer of culture fluid using low hydrodynamic pressure, which is directly related to the reduction in the financial costs and ergonomics of this equipment.

Due to the increase in demand for various types of photobioreactors, technical progress in this area does not stand still, and also requires low equipment costs, maximum efficiency, and ergonomics. It is for this reason that a budget version of the photobioreactor was developed, which consists on the basis of polyvinyl chloride and polyethylene. This synthetic material uses as a reservoir in which the culture fluid is located. These vessels are completely transparent and microorganisms affect them with an artificial source of light. This type of bioreactor is not the most economical option due to savings on building materials, therefore, will lead to the formation of biofilms, and it is also necessary to have funds for additional components in the future, such as aerator, pump, and electricity costs.

The newest development in the field of creating photobioreactors and increasing the amount of biomass produced is a porous bioreactor. The versatility of this bioreactor lies in a rough or porous material that is necessary for separating microalgae from the nutrient medium. The porosity of the material contributes to avoiding the appearance of a biological film and a dense suspension on the surface of the reservoir for microalgae, and also almost a hundred times reduce the amount of water consumed to carry out this separation procedure, the bioreactor operation, and leads to ergonomics and financial cost savings. Also, this bioreactor is suitable for a wide range of cultured microalgae, as it creates the necessary comfortable conditions for microorganisms [24].

The cultivation of microalgae is one of the actual directions of biochemistry, since, theoretically, it is intended to solve the following problems:

1. Microalgae are a valuable source of protein necessary to a person. They use as food additives, dyes, medicines, and cosmetics components.

2. The search for microorganisms having a high lipid content should help humanity solve the problem with mineral resources, namely fuel. Oil, natural gas, and coal are the main sources of energy, however, their use and environmental impact, ecosystem integrity, the state of the biosphere, and human health are debatable. Microalgae, characterized by high-fat content, will synthesize biofuels, which will be alternative and more eco-friendly

energy.

3. Microalgae is also a global environmental problem of water flowering. The use of microorganisms for the necessary purposes and needs will help stabilize the environment of the planet.

4. Microalgae and cyanobacteria are successfully used in wastewater treatment, which is also one of the main sources of pollution of the World Ocean. These microorganisms are well recycled organic compounds (for example, petroleum products), the heavy metals absorb. A certain type of microalgae will help clean water from hazardous pollutants, such as nitrates and nitrites, sulfates, and others.

That is why, a new and effective design on the basis of a bioreactor was developed, which will help to satisfy one of the above criteria.

Cascading bioreactor belongs to the communal industry if more precisely, the purification of household and industrial wastewater from biogenic elements. The use of biogenic organisms and physicochemical properties of wastewater contributes to the cultivation of microalgae and the processing of pollutants. Accordingly, the main objectives of the cascade bioreactor are wastewater treatment and the cultivation of microalgae due to wastewater.

The main minus of many bioreactors is the lack of maintaining a stable temperature required for cultivation. The most vulnerable designs in the cold season (due to a sharp drop temperature and cooling of the culture fluid), as well as due to the freezing of working components, such as tubes, due to the small diameter of the structure. In the warm season, the culture fluid is at least vulnerable, since which the mandatory use of instruments for avoiding photoinhibition, as well as the possibility of forming gas thrombus inside the design. Due to the other design of the cascade bioreactor, these problems should not occur during the cultivation process of microalgae.

To create a cascade bioreactor, a prototype was used as a photobioreactor to clean wastewater taking into account environmental, financial, physical disadvantages, as well as analyzing the effectiveness of the device. The structure of this photobioreactor is as follows: a flow-up rectangular reservoir, in the middle of which there are transparent tubes, which are interconnected and recorded in the center of the tank using tubular bends. These tubular bends form a solid zigzag coil, in which a mixture of wastewater and culture fluid with microalgae is pre-mixed in the mixer. At the output of the pipes, there is a separator and a tray for wastewater purified from microalgae into the flow of the tank (Fig.2.4).

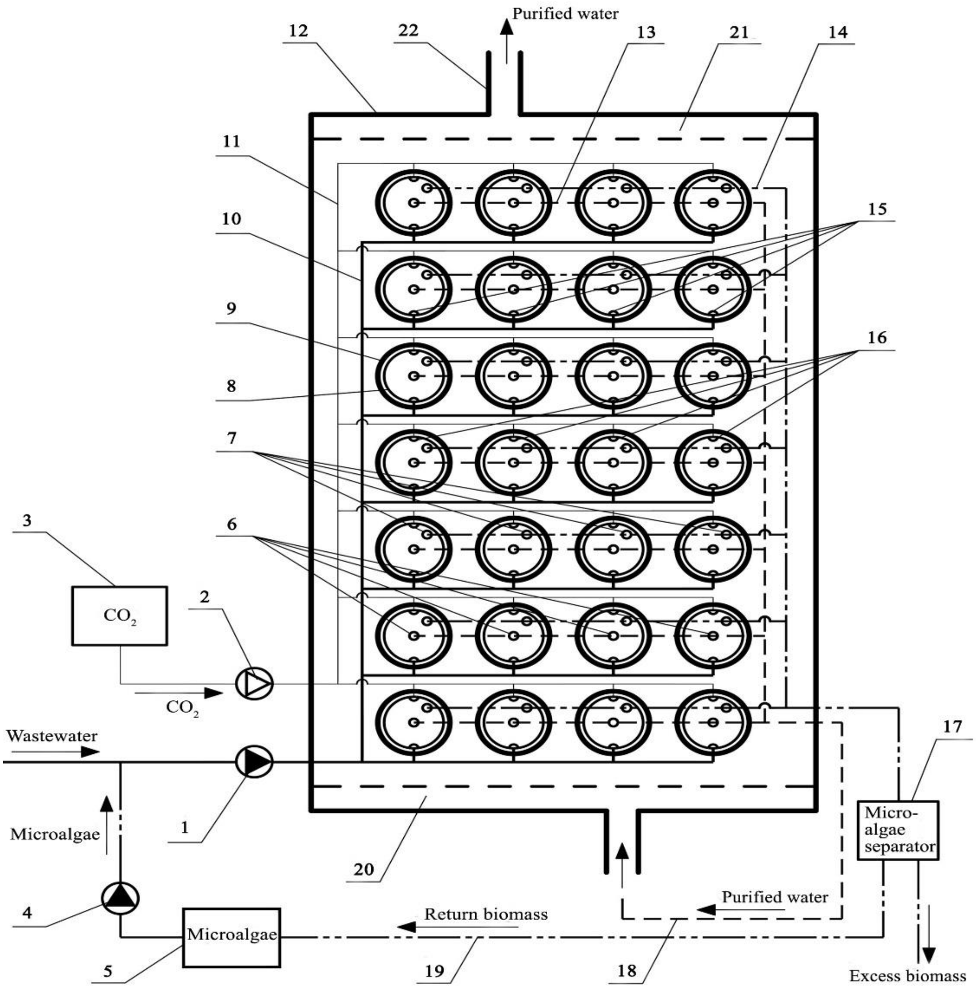

Fig. 2.4. The photobioreactor for wastewater treatment — 1 is wastewater supply pump, 2 is compressor, 3 is tank with carbon dioxide, 4 is the pump of filing microalgae, 5 is capacity for mixing microalgae, 6 is nipple, 7 is shut -ling fittings, 8 is transparent bending sleeves, 9 is floats, 10 is wastewater supply pipeline, 11 is carbon dioxide supply pipeline, 12 is bioreactor housing, 13 is removal of purified water, 14 is pipeline for the output of microalgae, 15 is revolving valves, 16 is nipple, 17 is separator, 18 is return pipeline of purified waste water, 19 is pipeline, 20 is distribution tray, 21 is collecting tray, 22 is treading tray.

A carbon dioxide is supplied to the bioreactor flask, and the gas feed tubes are horizontal, relative to the plane, and are located on the one hand along with the bend snake, and on the other hand, are opposite and above the bend. Data tubes are valves for the release of an unnecessary amount of gas.

The disadvantage of this photobioreactor is a covered area for placing this huge design due to the horizontal location of the serpentine tubes, as well as its mandatory need to use due to the impossibility of immobilization of microalgae in the working area. Operation of the coil, disassembly and cleaning from biofilms require high economic costs and investments, stopping the work of the bioreactor, which means the risk of pollution of the culture medium by pathogenic microorganisms, the temperature drops and loss of capital due to the stopping of microalgae production.

The purpose of developing the design of a cascade bioreactor is to reduce biogenic pollutants in sewage and the cultivation of microalgae. Thanks to the versatility of the structure, additional parts and connections are introduced into its structure, which affects the reduction of the occupied area for accommodation, the use of common and economically favorable building materials, immobilization of microorganisms in the area of operation (which affects the occupied area), as well as cultivation of microalgae for further use as biofuels, or as raw materials (for example, fertilizers).

Cascade bioreactor consists of the following structural elements: opaque flow rectangular capacity with an open-top or a greenhouse dome, inside which is vertically located to the bottom of the container; Pre-physically, mechanically, and chemically purified water enters a cascade type bioreactor and moves according to a translucent sleeve fixed with floats in a vertical position to stabilize in water to a pump of a certain power, which is located on the lower tier of the bioreactor, after pressure, water is supplied to the upper part of the bioreactor and drains a cascade into the internal flexible semi-transparent sleeve in such a way that water fills each cell of each tier. The water flow rate is such that water fills and remains in each capacity by allowing micropores to absorb a large part of nitrates and phosphates. Reaching the lower tier of the bioreactor water with a mixture of microalgae with the wastewater through the elements of the shut-off valves is discharged from transparent flexible sleeves and through the drainage pipeline is fed into a hydro-cyclone, which separates purified water from large cells of microbial space. The biomass recirculation pipeline is sent to microbial space and the resulting biomass will continue to be used as biofuels-raw materials or fertilizers for sale. Further purified water through the pipeline is drained into a water object without a threat to the environment.

Figure 2.5 presents a general diagram of a cascade photobioreactor, which consists of a frame 1, to the bottom of which are vertically connected pins 5. On pins 5 one above the other fixed first 2, second 3 and third 4 cascades of round tanks arranged in a checkerboard pattern. As the cascade number increases, the number of tanks decreases so as to provide access of natural light to all tanks. To the round tanks of the third stage 4 is connected to pipeline 7 for the supply of wastewater to be treated. The pipeline 7 ends with a nozzle 6 for even distribution of the mixture over the volume of the tank. A pump 8 is installed on the pipeline 7. A pipeline 9 for discharging a mixture of wastewater with microalgae is connected to the frame 1. The pipeline 9 through the pump 10 is connected to the hydro-cyclone 11. The upper outlet of the hydro-cyclone 11 is connected to the pipeline drainage of treated wastewater 12. The lower outlet of the hydro-cyclone 11 is connected to the separation device 14, which is equipped with two outlets, through the microalgae pulp discharge pipe 13. To the first outlet of the separation device, 14 is connected the supply pipe of the reverse biomass of microalgae 16 with the pump 15. To the second outlet is connected the pipeline of excess biomass of microalgae 17.

The cascade bioreactor to reduce the level of biogenic elements in sewage and growing crops of microalgae to produce environmental and economic benefits, which is executed in the form of a cascade of a certain number of bioreactors, is characterized in that the photobioreactors of a small diameter using any building material with a low wall height and a translucent a greenhouse dome for maximum efficiency located with a cascade in each other in such a way as to cover the reflected area of the lower tank as little; A small occupied area, compared with a relatively large volume, satisfies the presence of a high field of reflection.

Cascaded bioreactor consists of a reservoir for growing algae everywhere undergoing municipal wastewater with a temperature not lower than 17 degrees, where sewage is headed through a hydro cyclone for separating large microalgae cells with a precipitate (which consists of biomass for fertilizer and fuel manufacturing) and a hydro cyclone for small separation. Microbial cells with a biomass precipitate for reuse, as a result of obtaining purified water.

The cascading bioreactor is current, that is, water in the reactor is free-circulating from the bottom-up and freely drains by means of a pump that satisfies the conditions of high metabolism, free movement, and the illumination of microalgae for better development.

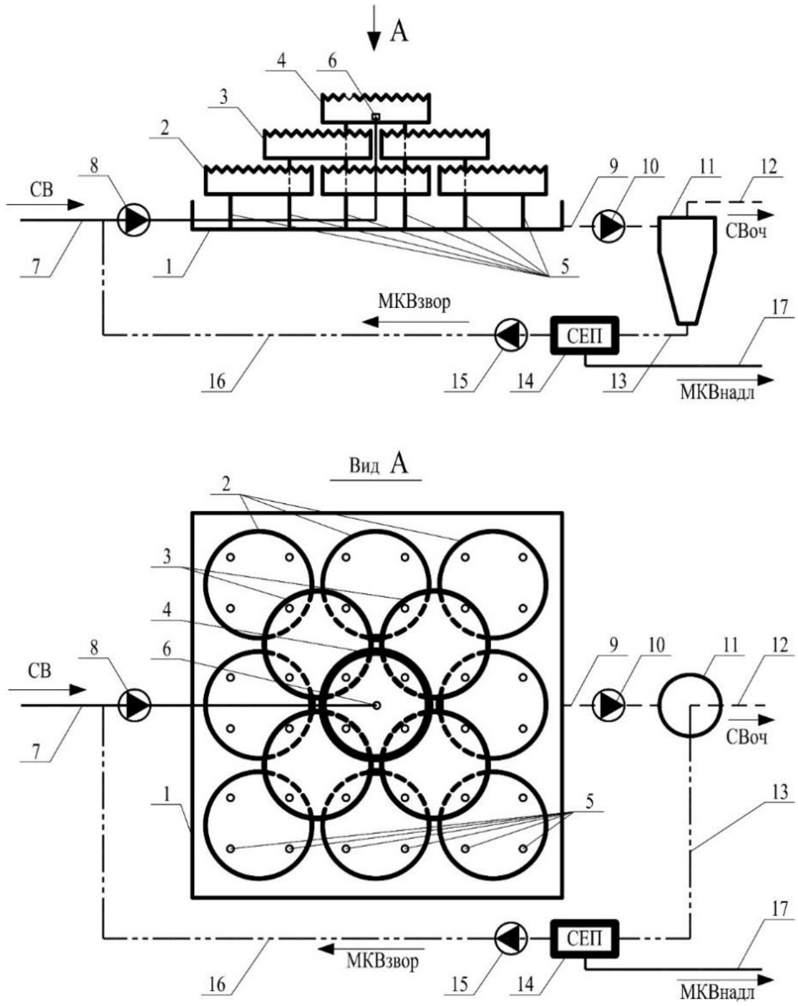

Fig. 2.5. The structure of cascade bioreactor — 1 is frame, 2,3,4 are the Cascades with Round Capacity, 5 are dowels, 6 are nozzles, 7 is wastewater supply pipeline, 8, 10, 15 are pumps, 9 is wastewater mixture topper pipeline, 11 is hydro-cyclone, 12 is treated wastewater discharge pipeline, 13 is microalgae output pipeline, 14 is separator, 16 is microalgae biomass feed line, 17 is removal of excess biomass

The greatest advantages of the cascade bioreactor are independence from weather conditions, the installation of additional non-expensive elements depending on the needs of production, the use of both laboratory and industrial scales, the lack of clear criteria for a flat surface, small size that will also help reduce waste to the area used, Universal and cheap building materials and other.

Cascade bioreactor is suitable for installation at wastewater treatment stations, where the efficiency of this unit will be highest. To achieve a high indicator of cultured microalgae, an awning is possible to a cascade bioreactor, which will act as a greenhouse. Since wastewater has a high temperature, the awning will act as a greenhouse effect, which will affect the biosynthesis and reproduction of microalgae. Installation of an artificial light source on the tent will increase biomass growth. Due to the circulation of water in bioreactors filled with microalgae, and the reserved period of time between water supply from the pump, the wastewater will be absorbed by microorganisms from sulfates and nitrates, which will reduce their number in the final purified water and reduce the negative impact on the environment. The material used for cells-bioreactors should not necessarily be made of transparent materials. For cascade bioreactor material, concrete, stainless steel types of metal can be concrete. Due to the active circulation of water under pressure, biofilms should not be formed on the walls of bioreactors or other deposits from the life of microorganisms. The resulting finite biomass can be used as biofuels or fertilizers, which significantly affects the cost of biofuels - it will not be expensive and affordable, and will be able to compete with minerals.

2.6. Conclusion to the Chapter 2

New technological studies are closely related to the purification of household and industrial wastewater, for which various methods and technologies are developed, such as different types of bioreactors or bio-plateau. Cleaning wastewater is preferably due to biological purification (microalgae, cyanobacteria, moss, fungi, and others). However, modern purification methods, for example, using a membrane bioreactor, do not give 100% of the results, are not purified from sulfates, nitrites, and nitrates that actively interfere with the environment and destroy water ecosystems, worsening physicochemical and biological indicators of fresh and seawater. For this purpose, a new concept and structure of a cascade bioreactor were developed. However, microalgae and microorganisms may not only be pathogens, but also a response to many current environmental problems today. Microalgae is not only nutritional supplements and raw materials in the field of medicine, it is also a valuable source of biofuels. At the moment, biofuels have no competitive ability to relatively other minerals. That is why, a cascade bioreactor is a new type of bioreactor, which can reduce the number of biogenic pollutants, as well as be an economical embodiment of microalgae for various purposes. Thanks to the cascade bioreactor and its concept, theoretically, biofuels can displace petroleum products and reduce the load on the atmosphere of the Earth, favorably affect the reduction of greenhouse gases and suspend Global Warming.

CHAPTER 3
EVALUATION OF THE EFFICIENCY OF PHOTOBIOREACTORS FOR WASTEWATER TREATMENT

Environmental pollution, in particular, water bodies due to insufficient levels of wastewater treatment, led to the development of new technologies, as well as the use of accommodated discoveries. Since the main objective of many bioreactors is the cultivation of microorganisms, this unit can also serve as an excellent link when achieving the goal of reducing the biogenic elements in wastewater. Many types of microalgae are an effective sorbent of pollutants; therefore, studies are conducted in the practical part of this diploma in the use of photobioreactors in wastewater treatment.

3.1. The criteria of the efficiency of photobioreactors

In biotechnology, the purpose of which the industrial scale of the manufacturing of the product exist there are two directions of occurring processes: the accumulation of biomass, as well as the preparation of valuable nutrients, which are obtained at the beginning of the cultivation process and the subsequent development of cultured microorganisms. Depending on the process, the biomass of microorganisms is cultivated by the method of continuity in fermenters of the hemostatic process, or intermittently, when in one bioreactor in the cultivation cycle, all necessary stages of cell development and the biosynthesis process occurs.

The work of photobioreactors is determined by several modes:

1. Accumulation mode (single cycle);
2. Mode of accumulation with the supply of essential nutrients;
3. In continuous cultivation mode.

To determine the effectiveness of the photobioreactor, the criteria for the effectiveness of photobioreactors were developed. Responding to several requirements, especially the ability to purify wastewater from biogenic elements by the method of efficient cultivation of microorganisms, the reactor can be considered effective (Fig.3.1).

The main criteria of the efficiency of the photobioreactor	Possibility of photobioreactor reduces or clean water from biogenic elements. In the course of using a photobioreactor during wastewater treatment, it implies the result as a qualitatively purified water with insignificant indicators of pollutants or their complete absence.
	The ratio of the surface area of the photobioreactor to volume is a simple and basic criterion for comparing different bioreactors when assessing saturation of microalgae lighting.
	Gas dissolution rate in the bioreactor. It is important when calculating the quality of mixing suspension. It is the dominant criterion for the cultivation of chemoautotroph, in the cultivation of phototrophs, has a smaller effect, since the growth of culture depends on the intensity of lighting, and not gas exchange.
	The concentration of microorganisms is 50%, and is obtained with an intensity lighting, which is minimal in cultivation process. This criteria depends on the following factors: characteristics of photobioreactor, culture quality (development rate), lighting intensity
	Homogeneity of mixing. Depends on the dynamics of the acidity of the medium with the addition of acids or alkali, and the subsequent observation of the culture medium.
	The ratio of the illuminated surface to the volume of the reactor, which is divided into the thickness of the suspension layer, is an important and simple criterion that allows to compare photobioreactors with a similar gas exchange and the speed of the suspension, neglecting the form of the reactor.
	The volume of the shadow zone of the photobioreactor should not exceed 10%.

Fig. 3.1. The main criteria of the efficiency of photobioreactor

The effectiveness of the photobioreactor also depends of the parameters:

1. Type of bioreactor. There are two types: open and closed. The closed form of the bioreactor is the most common and frequently used in the cultivation of microalgae.

2. Bioreactor form. Photobioreactors exist different forms on which the working area of the photobioreactor depends. The form of the bioreactor (for example, in the form of tubes, or flat) affects the intensity of the lighting, the speed of wastewater through the photobioreactor, and on the mode of the fermenter.

3. Temperature control. Cultivation of microorganisms should be in comfortable temperature for them, as this directly affects the speed and amount of biomass and the effectiveness of wastewater treatment.

4. Economical carbon dioxide waste. With sufficient saturation of CO^2, the microalgae are cultivated intensively, their composition and cycle of vital activity changes. However, many microorganisms require high gas consumption, therefore low carbon dioxide feed indicators in comparison of the resulting greater biomass growth will be effective.

5. Qualitative imitation of the culture medium. Creating suitable conditions is directly displayed on the development and functionality of microorganisms. The use of wastewater is a strong advantage, as they are rich in many biogenic elements that accelerate the development of microorganisms.

6. Material. Material for creating a bioreactor is very important, the glass is most often used, which is not a budget option. The minus of such a bioreactor is the rapid pollution, which means expenses for expensive service. The use of cheap and affordable materials, as well as slow pollution, is the criterion of efficiency.

7. Terrain. The area under the use of the bioreactor must comply with many requirements, which affects the number of bioreactors and their versatility. Bioreactor, for which the location and relief is not important, has a strong advantage. Accordingly, the photobioreactor installed near or in the sewage stations will be effective.

8. Controlled hydrodynamics. A bioreactor in which it is possible to control the fluid flow corresponds to the criterion of efficiency.

9. Freedom of cultivation. Not all bioreactors are suitable for the cultivation of microalgae, capable of reducing the level of polluting elements from wastewater. For example, gas-vortex or mechanical, since many microorganisms have a fragile structure.

Photobioreactor, in which it is possible to cultivate different strains of microalgae without damage to microorganisms, is also effective.

Cleaning wastewater using a photobioreactor launches a new technological cycle with subsequent tasks and solutions (Fig.3.2)

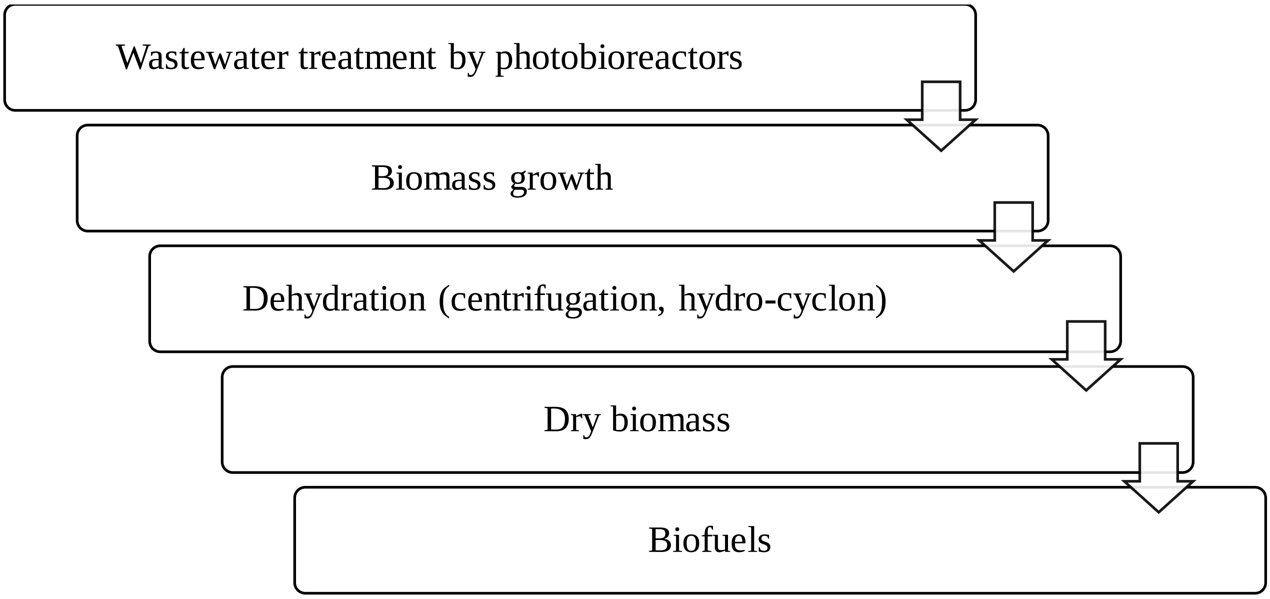

Fig. 3.2. The cycle of wastewater treatment in photobioreactors

Also, there are technologies for the production of microalgae in small-type bioreactors, which are set not far from the thermal power plants. The necessary heat, which comes from the thermal power plants, in most cases compensates for about 80% of the wretched to maintain the optimal temperature necessary for the cultivation of single-cell microorganisms. Photobioreactors are called exclusively hardware installations that cultivate microorganisms with the possibility of photosynthesis. Closed-type photobioreactors were created to optimize the resulting raw materials, in contrast, to open species, in which the most likely microorganisms are cultivated on an industrial scale and conditions, without the mandatory presence of air supply criterion for aeration and stirring of the culture fluid. Accordingly, the lack of conditions for a comfortable reproduction environment directly affects the amount of final product, its quality, and efficiency [25].

To analyze the effectiveness of photobioreactors during wastewater treatment, tubular and flat-plate photobioreactors were selected. The tubular photobioreactor is a classic model of a closed type of photobioreactor, in the form of tubes, which are located vertically or horizontally consisting of glass. This photobioreactor is flowing and works in uninterrupted mode. However, its operational capabilities are expensive: due to the nuances of the design, the maintenance of tubular photobioreactor is very expensive; Quickly pollution of the working area, the specificity of the location, the complexity of gas supply throughout the bioreactor. The flat-plate photobioreactor has the shape of two flat plates closely adjacent to each other, the material of which can be glass or plastic, and is also a closed view. The distance between the plates is filled with the culture fluid, to which light and carbon dioxide is enjoyed. In maintenance, this photobioreactor is cheaper than tubular, but the relief criterion affects as much as possible the final biomass. These photobioreactors are chosen to study the main criterion - wastewater treatment from biogenic elements with the help of cultured microorganisms.

3.2. The microalgae for wastewater treatment

The increase in biomass volumes in biotechnologies occurs in certain containers - fermenters, the design of which involves the complete provision of comfortable conditions for cultivation: optimal temperature, supply and output of gases and liquids, control of a certain composition of culture fluid, and conditions that are created inside the bioreactor.

Water objects on the territory of Ukraine can be described as dirty or very dirty. These levels of pollution are associated with wastewater and poor wastewater treatment technologies. The most modern technology for wastewater treatment is microalgae, the livelihood of which reduces, or cleans, many pollutants, such as nitrates, phosphates, bacteria, viruses, fungi, organic compounds, surface-active substances (SAS), and others. In order to introduce microalgae into active operation, the costs of re-equipment of many buildings are needed, additional investments to maintain a comfortable environment for the reproduction of microalgae.

Chlorella vulgaris is a one-cell photoautotroph that can be detected in each water object. Chlorella vulgaris multiplies with divided, and for its cultivation, it is necessary enough the amount of solar or artificial light, as well as a large amount of carbon dioxide, as it is the main source of carbon for microalgae. With comfortable conditions, the microalgae increase occurs within 7 hours, which leads to a huge amount of biomass (in 24 hours, the initial biomass increases 5 times). Chlorella vulgaris contains a variety of nutrients: 50-60% protein, 15-20% of carbohydrates, and up to 20% of lipids. For the reproduction of algae, a nutritious mineral environment is needed, or a large number of organic compounds that are rich in household and industrial wastewater. The main artificial fertilizers in wastewater for chlorella are phosphates and nitrates. To maintain a comfortable culture medium, chlorella needs salts - for this, urea is ideal, located in wastewaters [26].

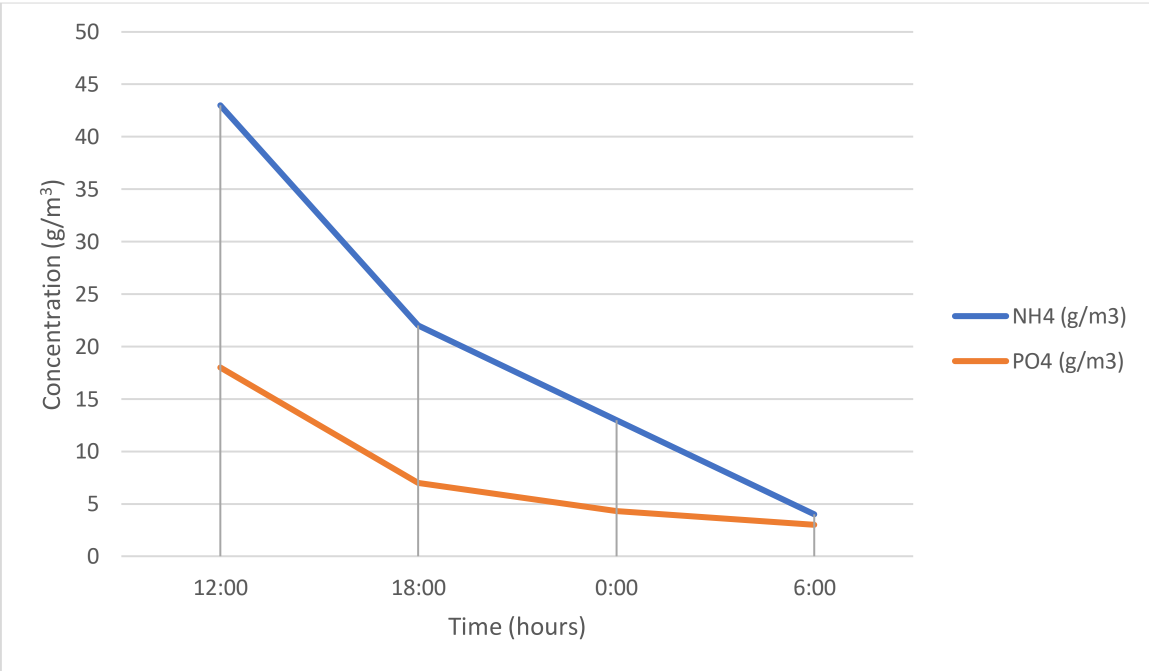

Fig. 3.3. The wastewater treatment from biogenic elements by Chlorella vulgaris

The study of the use of chlorella for wastewater treatment has shown that this type of microalgae significantly reduces the indicators of phosphates and nitrogens. Chlorella vulgaris consumes them in the course of its life, which leads to wastewater treatment from biogenic elements and biomass growth, which can be used to obtain fertilizers. Laboratory studies were conducted to reduce the concentration of NH_4 and phosphates prevailing in wastewater and which cannot be cleaned using modern wastewater treatment methods. In 24 hours, the ammonium nitrogen level with 43 g/m^3 decreased by almost 10 times (up to 4 g / m^3), and the phosphate compounds decreased 6 times, from 18 g/m^3 to 3 g /m^3 (Fig.3.3). These studies show that the use of microalgae has favorably affected water quality. Chlorella vulgaris is a high protein microorganism, however, in stressful conditions (with a lack of nitrogen), its level of lipids increases almost 2 times. Accordingly, these microalgae can also be used to obtain biofuels.

For biotechnologies in the search for high-quality raw materials for biofuels, the main and popular microorganism for cultivation is Euglena gracilis. Euglena gracilis is a single-cell organism with chloroplasts, that multiplies with division and has an increase in mass 1.5 times a day. This type of microalgae does not have a high level of lipids under normal conditions (up to 15%). For the growth and reproduction of Euglena gracilis, it is necessary solar or artificial light, carbon dioxide, a nutrient medium for which wastewater is suitable. In the process of life, the microalgae absorb organic compounds from wastewater and transform an oily film that can be used as a raw material for biofuels. This microorganism showed high results in wastewater treatment from NH_4, phosphates (Fig. 3.4). Technologies for the preparation of biofuels (biodiesel for aviation) with Euglena gracilis are actively used in Japan, as well as with biomass to reduce the level of gaseous waste [27].

At a temperature of 25 degrees and high lighting intensity, for 7 days of cultivation of microalgae, the ammonium nitrogen level was reduced from 93 mg/liter to 0.45 mg/liter; Phosphates were reduced from 27 mg/liter to 0.07 mg/liter. It was also proved that at 70 mg/liter of the dry mass of Euglena gracilis at high pollutants, biomass increased by 12 times [28].

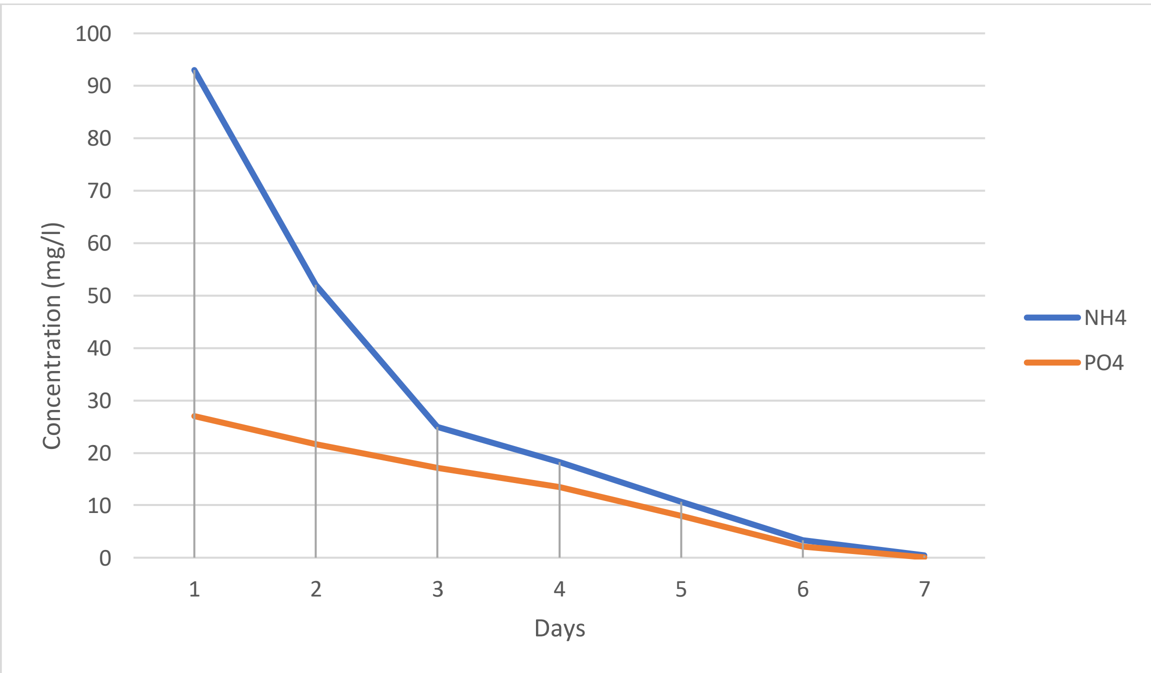

Fig. 3.4. The wastewater treatment from biogenic elements with Euglena gracilis

Accordingly, this analysis confirms the possibility of use and efficiency when cleaning wastewater using microalgae. Also, the cultivation of microalgae with photobioreactors and wastewater treatment can be connected, while saving on resources. The use of photobioreactor with these strains of microalgae will cleanse the plurality of phosphate compounds, salts, and nitrogen, which are the main factors of negative impact on the environment, but valuable organic fertilizers in the development of microalgae. The active increase in biomass of these types of microalgae in the photobioreactor will also actively absorb biogenic elements from wastewater, which will make it possible to clean the water, obtain biomass growth, save on biofuels, and positively influence the quality of water objects.

3.3. Efficiency of photobioreactors for wastewater treatment

3.3.1. The photobioreactors efficiency in cultivation of microalgae

For the experiment, two types of bioreactors are analyzed: tubular-150 liters and flat-plate-150 liters. These photobioreactors are closed types. Depending on their form, photobioreactors have a different work area, which means different indicators of the intensity of illumination, saturation rate of the culture medium with carbon dioxide, mode of work, and the cost of operation. Also, two types of the most affordable microalgae were selected for the experiment: Chlorella vulgaris and Euglena gracilis. We know that the amount of biomass obtained by Chlorella vulgaris increases 5 times/day. Also, the amount of biomass from Euglena gracilis is less due to the reproduction of the division method (an increase of 1.5 times/day). The volume of the zone with a weak lighting intensity should not exceed 10%. It has been proven that the coverage of the surface to the volume, which is divided into the thickness of the layer of the microalgae suspension, can be used as a simple and coarse approximation to the comparison of different photobioreactors with similar gas exchange and relatively identical speed of the culture fluid inside the bioreactor. However, for the experiment operation of tubular bioreactor was chosen. and it is necessary to calculate the growth rate of cultures by formula 3.1:

$$\mu = \frac{\mu_{max} * C_s}{(K_s + C_s)} \quad times, \tag{3.1}$$

where μ is real growth rate, μ_{max} is maximal growth rate, C_s is concentration of substrate (for Chlorella – 66 mg/l; for Euglena – 66.mg/l); Ks is constant equal to the concentration of the substrate at which the growth rate is equal to half the maximum (for Chlorella – 1.65; for Euglena – 49.5).

$$\mu_{Chlorella} = \frac{5*66}{(165+66)} = 1.42 \ times,$$

$$\mu_{Euglena} = \frac{1.5*66}{(49.5+66)} = 0.85 \ times.$$

For the objectivity of the calculation, take the maximum and real increase in microalgae, and calculate the average value of the biomass growth according to formula 3.2:

$$\mu_{ave} = \frac{\mu_{max} + \mu}{2} \quad times, \tag{3.2}$$

where μ is real growth rate, μ_{max} is maximal growth rate, μ_{ave} is the average value of the biomass growth

$$\mu_{ave_{Ch}} = \frac{5+1.42}{2} = 3.21 \ times,$$

$$\mu_{ave_{Eu}} = \frac{1.5+0.45}{2} = 1.18 \ times.$$

The amount of biomass obtained in the tubular photobioreactor on 150 liters for 7 days for these types of microorganisms is presented in the Table 3.1.

Table 3.1

The biomass increases in photobioreactor

Type of microalgae	Chlorella vulgaris (mg/l)	Euglena gracilis (mg/l)
Concentration of dry biomass	66 mg/l	
1 day of cultivation	93.72	77.88
2 day of cultivation	133	91.89
3 day of cultivation	188.86	108.44
4 day of cultivation	268.18	127.95
5 day of cultivation	380.8	150.99
6 day of cultivation	540.76	178.17
7 day of cultivation	767.88	210.24

There are several technologies to obtain biomass: centrifugation and hydro-cyclone. With the use of centrifugation with effectiveness of 90% (dehydration level) for Chlorella vulgaris and Euglena gracilis in tubular bioreactor on the 7 day, the amount of dry biomass calculated according to formula 3.3:

$$DB_{centifug} = 0.9 * Bm_{rec} \ kg/m^3, \quad (3.3)$$

where $DB_{centifug}$ is dry biomass by centrifugation process; Bm_{rec} is received biomass.

The dry biomass for photobioreactor by 7 days for Chlorella vulgaris – 0,767 kg/m^3,

The dry biomass for photobioreactor by 7 days for Euglena gracilis – 0,21 kg/m^3.

3.3.2. The bioreactors efficiency in order to obtain biofuels

For the experiment, the volume of tubular photobioreactor of not reaching sizes for industrial purposes was selected. This technology of obtaining biofuels is new and not accurate, and is designed to obtain lipids from microalgae to obtain biofuels in volume 130000 dm^3/year. To obtain biofuels in experimental data was chosen Chlorella vulgaris and Euglena gracilis.

The cultivation time of this microalgae will be 7 days. The mode of operation of the photobioreactor is selected continuous, taking into account 30 days/year, allocated to clean the bioreactor, unforeseen stops and other technological settings. Therefore, it is necessary to calculate the design productivity of the enterprise according to formula 3.4:

$$Q = \frac{V}{T*t}\ dm^3/group, \qquad (3.4)$$

where Q is the design productivity; V is the total planned capacity of the enterprise for the year; T is duration of the calendar year; t is the time of cultivation.

$$Q = \frac{13000}{335*7} = 2345\ dm^3/group,$$

For the 1 day the design productivity of the enterprise is equal 335 dm^3. For fermenters with an initial volume of $1m^3$, which are used in production with continuous robots, the productivity batch is $0.6m^3$ (600 liters). With standard technology for producing biodiesel from lipids, the recalculation coefficient of lipids on fatty acid methyl esters is 90%. The number of lipids necessary to obtain such a number of biodiesels (m_l=m_b) is calculated according to formula 3.5:

$$m_l = \frac{m_b}{w_{l \to b}}\ kg, \qquad (3.5)$$

where m_l is mass of lipid fraction, kg; m_b is mass of biodiesel to be obtained, kg; $w_l \to b$ is percentage of lipid transition to esters, %.

$$W_1 \to b = \frac{335}{0.9} = 372\ kg,$$

For this cultivation technology, the number of lipids is 64% for Chlorella vulgaris and 12% for Euglena gracilis. Therefore, the amount of biomass that must be raised is calculated by the formula 3.6:

$$m_m = \frac{m_l}{w_{m \to b}}\ kg, \qquad (3.6)$$

where m_m is dry biomass of microalgae; m_l is weight of lipids to be obtained, kg; $w_m \to b$ is lipid content in biomass of Chlorella vulgaris and Euglena gracilis.

$$m_{m_{Ch}} = \frac{m_l}{w_{l \to b}} = \frac{372}{0.64} = 581.25\ kg,$$

$$m_{m_{Eu}} = \frac{m_l}{w_{l \to b}} = \frac{372}{0.12} = 3100\ kg.$$

The concentration of biomass is 2 kg/m^3 for Chlorella vulgaris and 3 kg/m^3 for Euglena gracilis, so the total number of productions is calculated by formula 3.7:

$$V_{total} = \frac{m_m}{C_b}\ m^3, \tag{3.7}$$

Taking into account the data obtained, calculating:

$$V_{total\ Ch} = \frac{581.25}{2} = 291\ m^3,$$

$$V_{total\ Eu} = \frac{3100}{3} = 1033\ m^3.$$

The volume of the lid and the bottom of the bioreactor is about 30% of the total reactor. This volume can be neglected, as 30% meets the requirements of the fuel ratio. The number of bioreactors to obtain 335 kg/day of biodiesel is calculated by formula 3.8:

$$N = \frac{V_{total}}{V_{pbr}}\ things, \tag{3.8}$$

Taking into account the data obtained, calculating:

$$N_{Ch} = \frac{291}{0.84} = 346\ things,$$

$$N_{Eu} = \frac{1033}{0.84} = 1230\ things.$$

For mixing the culture fluid and gas supply, an airlift system is installed in bioreactors. Air supply is installed at 1 dm^3/min. Stirring occurs for 24 hours. The total air supply rate calculates according to the formula 3.9:

$$Q_{air} = N * 1 * 24 * 60\ dm^3/day, \tag{3.9}$$

Taking into account the data obtained, calculating:

$$Q_{air_{Ch}} = 346 * 1 * 24 * 60 = 498290\ dm^3/day,$$

$$Q_{air_{Eu}} = 1230 * 1 * 24 * 60 = 1771200\ dm^3/day.$$

From these calculations, it was analyzed that the cultivation of microalgae in comfortable and standard conditions is economically and ergonomically not profitable. The cultivation of Chlorella vulgaris which requires large areas for bioreactors, a huge amount of energy and air supply, but it has rapid reproduction (5 once/day). Euglena gracilis is requires a huge amount of gas and square, however, it's an advantage in the possibility of cultivation for biofuel production.

Based on analyzing the efficiency of cultivation of microalgae to obtain biofuels, it can be concluded regarding the use of a photobioreactor for wastewater treatment.

The least favorable wastewater favorable is Euglena gracilis. Purification of wastewater in this strain of microalgae occurs much slower - by day, not a clock, like a Chlorella vulgaris. Also, the cultivation of the microalgae in the photobioreactor does not make sense, since the photobioreactor will not be effective in accordance with the criteria.

3.4. Conclusion to the Chapter 3

The efficiency of the photobioreactor is established at the expense of certain criteria, the main of which is wastewater treatment and the elimination of biogenic elements from its composition by the method of absorbing pollutants during the life of microalgae. The use of photobioreactors during wastewater treatment leads to the emergence of new tasks, such as an increase in biomass due to organic compounds. The microalgae increase means a decrease in the concentration of compounds such as ammonium nitrogen, salts, and phosphate salts that cannot be cleaned with modern technologies without the use of microorganisms. Also, the increase in biomass means additional profits as preparation of biofuels or fertilizers. The design of existing photobioreactors, which did not show high efficiency, which means it is necessary to create new and more economically favorable structures. It was why the useful model of photobioreactor was developed and patented - a cascade bioreactor, which, presumably, will correspond to large quantities of efficiency criteria: available and cheap materials, efficient wastewater treatment with microalgae cultivation, no requirements for a specific landscape, saving to maintain comfortable temperature (wastewater have a temperature range from 17 to 35 degrees), also saving on fertilizers - wastewater has all the necessary minerals, fertilizers and trace elements to maintain the life of microorganisms, and others.

CHAPTER 4
LABOR PRECAUTION

Each technological process, which includes the interaction of individuals with the object of the enterprise, is obliged to be monitored according to THE LABOUR CODE No. 322-VIII of December 10, 1971 edition of 15.07.2021 Chapter XI Labor Precaution. This law undertakes to create safe working conditions without harm to human health. The safety of technological processes, the conditions of the workplace, mechanisms and other components of the enterprise, collective and individual protection, compliance with sanitary and hygienic standards, are obliged to meet all the requirements of the Human Labor Precaution. In this case, the specialist will be an ecologist who works in a communal sphere on the control of the cultivation process of microalgae in the photobioreactor in order to reduce biogenic elements in wastewater. The workplace of the specialist can be like an open area (maintenance and control of open-type photobioreactor), a laboratory (the closed type of photobioreactor small size control), a communal enterprise (maintenance and control of the closed type of photobioreactor industrial volumes). This diploma work discusses industrial scales that initially establish the main goal is a decrease in the biogenic elements in wastewater using an effective photobioreactor.

4.1. Organization of the working place of ecologist

To regulate the wastewater treatment and cultivation process, the specialist requires a laboratory, a set of flasks and jars, indicators for chemical analysis of water composition, respiratory mask and hygiene objects, microscope, the sensor for measuring temperature, computer and tablet for data collection and analysis according to the Ministry of Social Policy No 207 of 02/14/2018 "On Approval of the Requirements for the Safety and Health of Workers in Working with Display Devices"

The workplace of the specialist must be consistent with the following criteria:

1. Availability of 4 jobs in compliance with the distance by more than 1.5 meters to

comply with the sanitary and epidemiological rules in connection with COVID-19.

2. Intensive ventilation system to eliminate unpleasant odors of a municipal enterprise for wastewater treatment and high-quality protection against possible viruses and bacteria (ГОСТ 12.1.005-88 "Air of the working area. General sanitary and hygienic requirements ").

3. The presence of sanitizers and wet cleaning of the room at least 5 times a day to comply with sanitary and hygienic rules.

4. Comfortable location from the object of research and good access to the photobioreactor.

5. Ensuring each environmentalist specialist with a laboratory set for research and microscope.

6. Good room lighting to eliminate loads on the sensory system.

7. New monitors and computers for quick work and long-term work without harm to health.

8. Access the subject to the photobioreactor with the terms of personal safety (sterile devices, masks, and bathrobes, rubber gloves, tablet) to control lighting, temperature measurements, collecting the culture fluid analysis to analyze the growth of microalgae, collecting the purified water analysis to monitor the reduction of biogenic elements in purified water.

4.2. Analysis of harmful and dangerous production factors

The main work of the specialist is in the laboratory, where there is an analysis of the data collected and recommendations for improving and controlling processes. When the ecologist's work in the enterprise engaged in sewage treatment with a photobioreactor, there are several types of harmful factors:

1. Biological - bacteria, viruses, fungi, living organisms (helminth eggs).

2. Chemical - chemicals for cleaning photobioreactor, irritating chemical compounds in the composition of wastewater, such as chlorine, nitrogen oxides, SAS.

3. Psychophysiological - monotonous work in a sitting position with a high

concentration of attention and clear calculations creates a strong moral load.

4.2.1. Biological hazards and safety of expert

The biological threat is the most widespread threat in the activities of the environment in utilities. To monitor and study the results obtained (purified water), it is necessary to take water samples for the subsequent analysis of the composition of water and subsequent use. The sewage requirements should be complying ДСТУ 7369:2013 [29]. The main composition of wastewater is 60% of human waste and 40% industrial, which includes about 430 million streptococcal bacteria per person per day and 200 million intestinal chopsticks. Therefore, the work of the ecologist during the analysis of water must comply with the standards ГОСТ 12.0.003-74 «System of labor safety standards. Dangerous and average production results. Classification " [30] and by Law of Ukraine «On the Provision of Sanitary and Epidemiological Welfare of the Population» [31].

To provide safe working conditions, the ecologist must be equipped with the necessary instruments for collecting analysis, while having a protective mask, glasses, and cap, medical bathrobe, and shoes, as well as to prevent diseases to undergo a regular medical examination in the medical record of diphtheria vaccination reports, tuberculosis, etc., as well as additional vaccines, as a professional activity requires this. When working with microorganisms in the photobioreactor, precautionary measures should be observed (those above), since many microorganisms produce endotoxins that fall into atmospheric air and cause allergic reactions, respiratory complications (shortness of breath, oxygen shortage), conjunctivitis.

4.2.2. Chemical hazards and safety

The risk of chemical influence on the body of a specialist is high both in the laboratory and in industrial. The ecologist works with wastewater, which includes pesticides, antibiotics, heavy metals, acids and other very dangerous allergens are provided by the Ministry of Health of Ukraine of January 13, 2006, Hygienic standard "List of industrial allergens" (Table 4.1).

Table 4.1

Dangerous substances in the working place

Category of danger	Impact of allergens on human health	Examples
Highly dangerous allergens	Proof of human respiratory hypersensitivity (75%)	• heavy metals; • amines; • antibiotics; • pesticides.
Moderately dangerous allergens	Evidence of human sensitization upon contact of the allergen with the skin	• biotechnology production aerosols (natural dust, enzyme treatments); • amines, amides; • antibiotics; • aldehydes; • acids; • synthetic and polymeric products (phenoplasts, epoxy resin); • synthetic detergents, fertilizers.

4.2.3. Psychophysiological risks

The work of the environment in the enterprise or in the laboratory requires clarity and concentration, the lack of distracting factors, and a convenient workplace. Psychophysiological health risks arise in cases where a person is in an uncomfortable and intense constant position of the body, which overstays its body. Also, research suggests working at a computer, which affects the load on the sensory system (mainly for vision), the psyche irritation due to the blue monitor screen emissions, fatigue. To reduce the burden on the body, the workplace of the expert must be equipped with the following:

1. the monitor should be 5 degrees below of eyes level;
2. the distance from the eyes to the monitor should be within 75 cm;
3. the lighting source in the workplace should be located so as to avoid direct contact with the eye and provide comfortable lighting of the workspace at least 50 x 50 cm of the surface, as well as have a comfortable level of intensity;
4. to reduce vision load, a worker every hour should take a break of 5-10 minutes to

relax eyes and brain to eliminate overvoltage and possible errors in research.

4.3. The sources of illumination

The lighting of the working area of the specialist is important for the psychic and physical health of the employee, as well as for the accuracy in research and work of the environment. Lighting the working area is controlled according to ДБН В.2.5-28-2006. The work of the ecologist to control the cultivation process of microalgae and wastewater analysis with a condition for reducing biogenic elements is classified by categories VII and VIII: overall monitoring of the production process, and work with materials that are glowing (computer monitor, tablet for the results of results). The appropriate level of lighting is presented in the Table 4.2 [32]. The main lighting in the room should be fluorescent lamps that give a cold shade of light with sufficient intensity and neutral color to eliminate the distraction of the concentration of attention and preserve mental health, as well as to eliminate the eye voltage according to ДСН 733.3.6.042-99. Natural light sources are also needed, at least 2 windows with a height of 1160 x 870 cm.

Table 4.2

The illumination characteristics for normal work of ecologist

<table>
<tr><th colspan="2">Indicators</th><th>Standard value</th><th>Actual value</th></tr>
<tr><td colspan="4">Natural</td></tr>
<tr><td rowspan="2">The natural coefficient, %</td><td>Combined illumination</td><td>3</td><td>0</td></tr>
<tr><td>Side lightening</td><td>1</td><td>2.3</td></tr>
<tr><td rowspan="2">The combined coefficient, %</td><td>Combined illumination</td><td>1.8</td><td>2.2</td></tr>
<tr><td>Side lightening</td><td>0.6</td><td>0</td></tr>
<tr><td colspan="4">Artificial</td></tr>
<tr><td colspan="2">Working surface illumination by the VIII category, lx</td><td>200</td><td>260</td></tr>
<tr><td colspan="2">Direct reflection</td><td>Absent</td><td>Present</td></tr>
</table>

4.5. Fire safety

The category of the working place is D “Reduced fire and dangerous” in accordance with State Standard ДСТУ Б В.1.1-36:2016 «Definition of Category of Premises, Buildings and External Facilities According to Explosion and Fire Hazard».

For the most part, the most flammable objects in the working area of the ecologist are electrical appliances, such as a computer, tablet, telephone, recharge devices, and others. Inflammation of these items may occur only in the event of a closure of electricity, malfunctions of devices, or errors when used. To prevent fires or their destruction, the working area of the ecologist must be equipped with a loud alarm system with an instantaneous reaction to carbon monoxide, as well as an ax under glass, 1 charged fire cylinder, 2 gas masks, 2 dense blankets, or bedspreads, 2 pairs of rubber gloves, rubber boots, work phone with fire aid number. To avoid this situation, it is necessary to extremely carefully handle the equipment in the room and comply with all the standards and rules.

4.6. Conclusion to the Chapter 4

Working with a photobioreactor for wastewater treatment requires an exclusive ecologist who will be competent with regard to the device. However, work with wastewater involves a large amount of danger and influence of negative factors on the health of employees: biological, chemical, psychophysical threats. The work of the environment assumes control and study of wastewater samples after cleaning from biogenic elements with the help of microbial, however, it is necessary to observe all sanitary and hygienic standards and the laws of Ukraine, having data on all vaccinations and appropriate clothing for work. The ecologist is exposed not only to dangerous foreign risk factors but also psychophysiological since this work requires monotony and voltage to the sensory system, moral and physical exertion. For this, you must have the required number of lighting, devices, and comfortable furniture in the workplace. Also, we should not forget about utmost care in relation to electrical instruments to avoid inflammation situations and fires.

CONCLUSIONS

Environmental pollution is the most relevant problem of humanity. Every year the level of pollution increases, this is reflected in the state of the health of all living organisms. Pollution of water and all water objects leads to a change in ecosystems, climate, and the destruction of many inhabitants of the planet.

As a result of research scientific and applied task was solved to minimize negative impact on the environment.

1. The most powerful source of pollution are industrial enterprises, agroindustry, wastewater. Daily, due to the lack of the newest technologies, tons of plastic, heavy metals, viruses, bacteria, yeast, oil, nitrates and phosphates, carbon dioxide, and other pollutants fall into the water bodies. This leads to a deterioration in water quality, a change in the composition, to which living organisms cannot quickly adapt, which leads to extinction, wiping, and toxicity of the water object. The main source of freshwater for humans are fresh reservoirs, rivers. However, many of them are very polluted. Only in Ukraine, water objects are estimated as dirty or very dirty. Soon, water pollution will lead to a catastrophic deficiency. The most polluted is the Dnipro River, along which large cities with a developed industry are located, the waste of which tons are reset into the water daily. Pollution of water objects leads to their shallow and wiping.

2 The components of household chemicals, which are discharged into the water with wastewater and are feed fertilizers for simple and cyanobacteria, leading to anomalous water blossom, and it is difficult to clean. Scientific studies show that microalgae can be a valuable source of biofuels. For this purpose, various types of bioreactors with unique structures have been developed. The cultivation of microalgae gained popularity in the last decade, when scientists found that microalgae are a valuable source of protein and carbohydrates for food additives, as well as some strains have a high lipid content in the composition that is necessary to create biodiesel. In these times, Japan is an advanced state to obtain biodiesel for aviation, and in 2021, a bus was launched in the world in the world on biofuel.

3. Photobioreactors have been analyzed during wastewater treatment, and it was also

established that the efficiency of photobioreactors is achieved with the condition of certain criteria, such as a decrease in economic load when using the design, simplicity of installation and maintenance, high wastewater treatment rates from biogenic elements using microalgae, and other. Experiments in the field of biotechnology and ecology have shown that microalgae are not only a source of water pollution, as well as a sorbent. Microalgae can reduce the concentration of biogenic elements in several times. However, this requires a sufficient amount of biomass. The disadvantage of the cultivation of microalgae is the economically unfavorable component of this process, as it requires huge costs of maintaining and maintaining of a comfortable environment for cultivation, electricity, the costs of materials, rental of the square, maintenance, and other components. That is why biofuels cannot compete with other types of fuel in the modern world. To do this, there was a useful model - a cascade bioreactor, which must include two functions: cultivation of microalgae and a decrease in biogenic elements in wastewater. The uniqueness of the bioreactor in its structure and components, as well as its possible location on utilities, where there are necessary conditions for the cultivation of microalgae. Accordingly, the yield of biofuels to the world market and high-quality wastewater treatment is a temporary question that may soon change the world and the environment for the better.

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