Evaluation of the potential of commercial use of microalgae in the world and in Ukraine

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Abstract

Purpose – This paper aims to evaluate of the microalgae potential for commercial application, in particular to conduct experimental study of biogenic compounds removal from sewage waters by microalgae, and to calculate economical benefits from biofertizers and biofuel production.

Design/methodology/approach – Experimental study in the concentration change of nitrogen and phosphorus compounds in the cultivation of Chlorella Vulgaris microalgae in various types of sewage water was carried out.

Findings – The efficiency wastewater treatment by microalgae was confirmed. The economic benefit from the biomass utilization as biofuel production was calculated.

Practical implications – Implementation of wastewater treatment technology with biomass recycling for biofuel and biofertilizers production will minimize the impact on the environment.

Originality/value – As a results of experimental studies, the ability of microalgae to reduce biogenic elements in wastewater was confirmed. Microalgae can be used both for wastewater treatment to biogenic elements removal, such as phosphorous and nitrogen compounds, and biofuel, biofertilizers production. Prospects of the commercial use of microalgae are obvious. They are specially adapted to an environment dominated by viscous forces.

Keywords Biofuel, Wastewater, Biofertilizer, Biogenic compounds, Microalgae

Paper type Research paper

Introduction

The main cause of environmental crisis that is becoming increasingly apparent and large-scale is destructive in nature current production and consumption, i.e. the exploitation of the natural environment without taking into account the vital relationships and interdependencies that have developed in it. This problem relates to all natural resources, in particular to water resources. The problem of water resources depletion is associated with two groups of reasons: firstly, with the continuous increase of water intake for household and domestic needs (quantitative depletion); secondly, with the constant increase of water pollution (qualitative depletion).

So, among the huge amount of pollutants in waste water, in this paper, attention will be paid to biogenic compounds such as nitrogen and phosphorus. Phosphorus in water is in the form of inorganic, organic, organo-mineral compounds and is part of the cells of aquatic organisms. To reduce the accumulation of phosphorus in the hydrosphere, it is necessary to do the following: reduce the inflow of phosphorus into water bodies with products of human and animal life, industrial and municipal effluents with detergents that contain phosphorus; reduce the inflow of phosphorus into water bodies from soils (mainly from agricultural lands); develop and implement economically and environmentally friendly technologies for the extraction of phosphorus compounds from water by using the obtained sludge as fertilizer.

Main section

Today, many different methods and means are used to prevent qualitative and quantitative water resources depletion; they can be conditionally combined into three groups. Preventive (precautionary) measures are aimed at preventing or limiting pollution, clogging and water depletion. They primarily provide for the following:

- the development of schemes for integrated use and water resources protection in a given area;

- rational location of objects – water users; and
- development of new and improvement of existing production technologies.

Diagnostic measures, as a rule, are aimed at identifying the composition and volume of possible water resources pollution (depletion) and include the following:
- rationing of water supply and drainage;
- standardization of maximum permissible concentrations of various substances in drinking, fishery and other purposes; and
- wastewater discharge control and water bodies ecological condition.

Procedural measures are applied when water bodies are already polluted or depleted and, therefore, are aimed at eliminating existing pollution. This group of measures includes the following:
- organization of wasteless production;
- the use of reverse water supply;
- replacement of water cooling with air;
- purification of snow and drainage waters; and
- imposition of penalties for pollution, clogging and water depletion until the closure of enterprises – pollution sources.

The supply of nutrients to surface waters occurs as because of natural factors (leaching from the layer of soil, precipitation, intra-reservoir processes) and also because of anthropogenic (receipts from industrial and economic domestic wastewater, agricultural land runoff and animal complexes). The most surface water bodies in Ukraine are classified as polluted or much polluted. This condition significantly increases environmental risks. It is the use of water that does not meet quality requirements causes and spreads many infectious and non-infectious diseases.

Increasing concentrations of nitrogen and phosphorus compounds leads to natural waters eutrophication, which is manifested in the phytoplankton biomass increasing, "water blooming", and, as a result, water quality decreasing. This makes impossible to use water for recreation, fishing and domestic needs. The phytoplankton toxins can cause health problems through exposure to the human body after contact with the skin or the use of contaminated water for drinking. That's why waste water treatment from biogenic compounds is so important. Urgent task is to develop effective nutrients removing methods from wastewater at the stage of treatment with waste minimization and the possibility of returning the removed nutrients to economic circulation, as they are valuable elements of mineral fertilizers, especially phosphorus compounds, which are limited in nature (Shamanskyi *et al.*, 2018).

Wastewater treatment requires special treatment facilities and units, which are used to isolate, decontaminate or neutralize contaminants. Domestic wastewater is treated mechanically and biologically. Mechanical treatment is used to extract insoluble substances from wastewater. It is provided by methods such as filtering, settling, filtration and centrifugation. Sewage seepage provides retention of relatively large parts of the pollution, the size of which exceeds 15–20 mm. Water filtration is used to trap the smallest insoluble particles of

contaminants in a suspended state. For this purpose, apply sand-gravel filters or special grids. Wastewater treatment from mechanical impurities is also carried out using a hydrocyclone – a unit that in the process of rotation of the tank with water as a result of centrifugal forces removes from the water suspended particles of contaminants (centrifugation). In order to intensify the process of mechanical treatment of domestic wastewater, they are aerated, or aeration is combined with settling in clarifiers or biocoagulators. The physico-mechanical method is divided into chemical, physico-chemical and biochemical depending on which method of purification prevails. During chemical treatment, chemical reagents are added to the wastewater, which, as a result of the reaction with the pollutants, contribute to the precipitation or evaporation of the latter. Chemical purification includes coagulation and neutralization. Coagulation is the process of adding coagulant substances to wastewater, which promotes the accelerated release of insoluble and partially soluble substances, which do not precipitate during settling. Coagulation causes the gradual sedimentation of dispersed particles and their release from solution in the form of a precipitate. This process is called sedimentation. Neutralization is a reaction that leads to the destruction of the acidic properties of the solution with the help of alkalis, and alkaline - with the help of acids. Physico-chemical and biological methods of water treatment are divided into two groups: regenerative and destructive. The former allows to extract and utilize valuable elements and substances from sewage. Destructive methods involve the destruction of pollutants or their disposal. Regenerative purification methods include: sorption, extraction, evaporation, flotation, ion exchange, electrolysis, crystallization, evaporation and the like. Destructive wastewater treatment is the oxidation of organic matter contained in wastewater. Oxidation and mineralization of organic pollutants as a result of aerobic biochemical processes are the essence of the biochemical method of wastewater treatment.

As was mentioned before 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 of the 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. In (Gersberg *et al.*, 1986; Kadam *et al.*, 2008), some of the most popular installations are used: special open oxidation ponds, where different aquatic organisms are cultivated; special agricultural tanks filled with hydroponics, where different aquatic plants are grown; special soil filter systems, where different soil plants can grow; and others (Healy and Cawleyb, 2002). One of the promising methods can be considered the use of wastewater for the microalgae cultivation (Sorokina *et al.*, 2012; Sasikanth *et al.*, 2014).

Microalgae are a great biological resource. They are used in various branches of science and technology. Biotechnological investigation of microalgae has been actively developing lately.

Microphytic algae (microalgae) live in various ecosystems. They can be found not only in water but also in earth environments. There are 50 000 microalgae species.

Nevertheless, only approximately 30 000 species have been studied (Danilovich, 2012). Microalgae are a broad group of photosynthetic organisms that includes cyanobacteria diatoms unicellular greens and some other species of algae. They can to develop in difficult agro-climatic conditions and to produce a number of useful ones' products fats proteins carbohydrates dyes biologically active compounds, etc.

Microalgae are unicellular species which exist individually, or in chains or groups. Depending on the species, their sizes can range from a few micrometers (μm) to a few hundred micrometers. Unlike higher plants, microalgae do not have roots, stems, or leaves. They are specially adapted to an environment dominated by viscous forces. Microalgae, capable of performing photosynthesis, are important for life on earth; they produce approximately half of the atmospheric oxygen (Robyn Williams, 2013) and use simultaneously the greenhouse gas carbon dioxide to grow photoautotrophically. Microalgae, together with bacteria, form the base of the food web and provide energy for all the trophic levels above them. Microalgae biomass is often measured with chlorophyll a concentrations and can provide a useful index of potential production. The standing stock of microphytes is closely related to that of its predators. Without grazing pressures, the standing stock of microphytes dramatically decreases.

Due to microalgae natural metabolism, they are efficient absorbers of nutrients and carbon dioxide, while increasing their biomass. However, the biomass of many strains of microalgae can be used to manufacture many types of products (Naruka *et al.*, 2019). When using this method of wastewater treatment at municipal treatment plants, excess biomass can be directly processed into biogas at treatment plants (Magdalena *et al.*, 2019; Głowacka and Gaduš, 2019; Gonzalez Fernandez *et al.*, 2018; Koyandea *et al.*, 2019; Milledge *et al.*, 2019). This can be done in methane tanks together with excess activated sludge. Biomass can also be processed into liquid motor biofuels of the third generation, or into phosphate and nitrate fertilizers (Raheem *et al.*, 2018; Bhagea *et al.*, 2019; Saad *et al.*, 2019). Many studies are focused on biomass utilization for biofuel production, it can be not only pure fuel from various types of lipid resources also fuels with additives decreasing emissions. Therefore, various ratios of additives (ethanol and pentanol) are blended with biofuel (rapeseed and canola-sunflower oil) to form the JET-A fuel blends by using Kay's and Grunberg–Nissan mixing rules. The combustion, performance and emission parameters under different engine loads were examined. Results showed that all the blends logged higher static thrust with an appreciable reduction rate in the consumption of the fuel. Among different fuel blends, R20E (Jet-A 70% fuel, 20% Rapeseed and 10% ethanol) showed 35% increase in static thrust associated with 41% reduction in thrust specific fuel consumption. Moreover, the blends R20E and CS20E (Jet-A fuel 70%, Canola-Sunflower 20% and 10% ethanol) indicated 24% and 10% increase in thermal efficiency, respectively, owing to the influence of ethanol concentration and higher oxygen content. In addition, these fuel blends generate less emission of environmental unfriendly harmful gases, including NOx, CO and HC, compared to neat Jet-A fuel (Manigandan *et al.*, 2020).

The analysis of optimum engine conditions operating under hydrogen and multiwall carbon nanotubes (MWCNTs) blends using the Taguchi L16 approach were examined. The effect of hydrogen (10%, 20% and 30%) and MWCNTs (30, 50 and 80 ppm) with different fuel blend proportions were evaluated at different engine loads of 25%, 50%, 75% and 100%. Results revealed that the L16 orthogonal array was a suitable method to find the optimized working conditions of the diesel engine for higher performance and less emission of NOx, HC, CO, and CO_2. Compared to neat diesel, the addition of hydrogen and MWCNTs reduces the emission with improved brake thermal efficiency. Moreover, results showed improved brake power by 13% and reduced brake specific fuel consumption by 8% at full engine load conditions. 22%, 20%, 8%, and 47% emission reductions of HC, NOx, CO, and CO_2 were observed due to the influence of hydrogen and MWCNTs (Manigandan *et al.*, 2020).

The effect of biofuel blend such as butanol, jatropha methyl ester, soya methyl ester and rapeseed methyl ester as an additive for the aviation fuel was assessed (Milledge, J.J., *et.al.*, 2019). In addition to the blends, the nanoparticle TiO_2 of 3% is added to the biofuel. The nanoparticle mixed at the concentration of 300 ppm by ultrasonication process. The fuel Jet A, B27T, J27T, S27T and R27T are investigated for combustion and emission characteristics for various throttle settings in micro gas turbine engine. Addition of additives improves the ultimate property of the fuel by reducing the kinematic viscosity. The fuel blend B27T reports 25% increase in total static thrust and 22% reduction in thrust specific fuel consumption. From the results it is evident that, all fuel blends showed a significant reduction in emission values owing to high oxygen content. In addition, the thermal efficiency of the B27T and J27T is improved appreciably to 30% and 10% higher than Jet A fuel owing to the influence of the nanoparticle TiO_2. On the other hand, the emissions such as CO and NOx reduced drastically up to 70% and 45%, respectively.

Authors (Manigandan *et al.*, 2020).) have evaluated the influence of Zinc oxide and Titanium dioxide nanoparticles addition in hydrogen-corn blended biodiesel combustion performance and exhaust emission using a dual direct-injection compression-ignition engine. 5% of Zinc oxide and Titanium dioxide were mixed with corn-vegetable oil methyl ester under ultrasonication. Results revealed that the addition of nanoparticles improved the Brake power by 22% (Titanium dioxide) and 4% (Zinc oxide). Consequently, 18% and 15% reduction in brake specific fuel consumption indeed at 50% load was compared to neat diesel. Furthermore, the addition of nanoparticles also resulted in a reduction of emission values of 37% and 26% in hydrocarbon, 26% and 36% for carbon monoxide, 19% and 15% in nitrogen oxide and followed by 13% and 8% of smoke opacity. Therefore, the results proved that hydrogen-corn biodiesel blended with nanoparticles additive reports a positive effect on compression-ignition diesel engines without major modifications in engine.

The next culture can be recommended for cultivating, which have percentage of lipids in them (Shamanskyi and Boichenko, 2016, 2018): ●*Botryococcus braunii* – 25%–85%; ●*Neochloris oleoabundans* – 35%–54%; ●*Stichococcussp* – 40%–59%; ●*Nannochloropsissp* – 31%–68%; ●*Dunaliella tertiolecta* – 36%–42%; ●*Dunaliella salina* – 16%–44%; ●*Haematococcus pluvialis* – 25%–45%; ●*Scenedesmus dimorphus* – 16%–44%; ●*Prymnesium parvum* – 22%–38%; ●*Tetraselmis suecica* – 20%–30%;

●*Chlorellasp* – 28%–32%; ●*Chlorella vulgaris* – 14%–22%; ●*Isochrysis galbana* – 22%–38%; ●*Euglena gracilis* – 14%–20%.

Usually about 20%–30% of the total production expenses for microalgae production is related to harvesting the biomass (Harun *et al.*, 2011). The main problems in harvesting are the low biomass concentration in the open-pond cultivation system and the small cell size that makes the separation process consumes a great deal of energy. Common methods of harvesting microalgae biomass include: coagulation, flocculation (or sedimentation), flotation (Harun *et al.*, 2011), centrifugation (Molina Grima *et al.*, 2003), membrane filtration (Lourenco *et al.*, 2002; Feofilova *et al.*, 2010), and ultrasonic separation (Bosma *et al.*, 2003).

Centrifugation is regarded as the most efficient method to harvest the biomass using mechanical forces, but their application in large-scale is limited because of the energy costs. Centrifugation can be cost-effective but it requires a two-step process. The typical concentration of algae in open pond cultivation is approximately 300 mg/L. Continuous-flow centrifuges work best if the source water has at least 1%–3% solids. Gravity settling or dissolved air floatation is two simple methods to achieve the desired solids concentration. Membrane filtration has been applied in wastewater treatment involving removal of microalgae cell, which suffers some problems such as bio-fouling and also it is not cost-effective for large-scale biofuel production. Recently, ultrasonic separation (Varfolomeev *et al.*, 2010) and electro-coagulation-flocculation (Vandamme *et al.*, 2011) have been exploited for microalgae harvesting. Promising laboratory-scale results show that these methods are effective and have low-power consumption comparing to centrifugation, but full-scale testing is still in needed to evaluate their cost and performance. After harvesting, the next major challenge is the de-watering the concentrated biomass. Usually, 90% of the post-harvest weight of the microalgae paste is water which needs to be reduced below 50% by weight for efficient oil extraction (Reijnders, 2008). Water is removed by heating the biomass that could consume a great amount of energy. However, this process often uses waste heat from power plants to reduce the cost. It is crucial to minimize water contents after harvesting process to decrease energy demand and increase downstream extraction and fuel conversion efficiency.

The ability of microalgae to reduce nitrate and phosphorus levels is widely discussed in the literature and the ability to use this property to treat wastewater waters from biogenic elements (Veber, 1984; Ghorbunova, 2007). At the same time, the issue of assimilation of phosphorus compounds has been studied much less.

Bio-treatment with microalgae is particularly attractive because of their photosynthetic capabilities, converting solar energy into useful biomasses and incorporating nutrients such as nitrogen and phosphorus causing eutrophication. This fascinating idea launched some 55 years ago in the USA by Oswald and Gotaas (1957) has since been intensively tested in many countries. According to the various study, the nutrients removal efficiency of microalgae based wastewater treatment system is very high as it removes 78%–99% of Nitrogen and Phosphorus (W. J. Oswald *et al.*, 1957). The treatment system also succeeds to remove 40%–65% of COD, BOD and other impurities present in wastewater. The microalgae treatment system is economical, green, and environmental friendly option of wastewater treatment. Palmer (1974) surveyed microalgal genera from a wide distribution of waste stabilization ponds. In order of abundance and frequency of occurrence the algae found were *Chlorella, Ankistrodesmus, Scenedesmus, Euglena, Chlamydomonas, Oscillatoria, Micractinium* and *Golenkinia* (Palmer, 1974).

This paper aims to evaluate of the microalgae potential for commercial application, in particular to conduct experimental study of biogenic compounds removal from sewage waters by microalgae and to calculate economical benefits from biofertilizers and biofuel production.

Methods and materials

Two experimental sessions were held in the laboratory of the National Aviation University Faculty of Environmental Safety, Engineering and Technologies was chosen as the site of the experiment. For the experimental sessions, the summer period was chosen, since warm temperatures are more favorable for the growth of algae.

Conditions for microalgae growing

It was decided to use transparent bottles for growing microalgae to create the most favorable conditions for growing. The average temperature in the laboratory is 22°. The average pressure on the dates of the experiment was 746 millimeters of mercury. The concentration of microalgae is equal to 1 liter of water per 200 ml of suspension of microalgae. *The first experimental session* included three parallel experiments for each type of water: one control without microalgae, one with wastewater and microalgae, one with a connected CO_2 generator in wastewater with microalgae. The tanks were in a well-lit laboratory and had the same conditions. *The second experimental session* included four parallel experiments for one type of wastewater: the first control, the second in wastewater with microalgae, 3 and 4 identical samples with a connected CO_2 generator.

Measurement of nutrient rate

To measure the levels of nutrients (phosphates, nitrates and nitrites), the following measurement frequency was chosen:
- in the first session – the first three days every day, then every two days; and
- in the second session – every 6 days.

Experiment progress

For the first experimental session, three reservoirs (bottles) were installed for each type of water (wastewater from a residential building in Kyiv before treatment, wastewater from a utility in Novograd-Volynsk before and after treatment). Totally 9 samples. The initial hypothesis was that the bulk of nutrients will go away in the first three days, so measurements of nutrient levels were carried out for the first three days every day, and then every two days. Immediately after the installation of all tanks, phosphate, nitrate and nitrite levels were measured to record the initial data.

To take measurements, it is necessary to follow this order:

- to take an equal sample volume for all experiments;
- to carry out a double filtration with paper filters (first time through a funnel with a filter, and separately a second time through a funnel with a filter);
- gently wash the cuvettes with distilled water and wipe the cuvettes without touching the walls with your fingers so as not to create an error in the measurement;
- to take the necessary program on the spectrophotometer, and following the instructions add the reagent to the control sample;
- to record the result;
- to rinse the cuvettes with distilled water and take measurements for other samples of the experiment, also record the result; and
- at the end of the measurements, rinse all tubes, funnels and cuvettes with distilled water and dry.

For the second experimental session, four tanks were installed for one type of wastewater (wastewater from a residential building in Kyiv before entering the treatment plant): 1) control, 2) with microalgae, 3) and 4) identical with the connected CO_2 generator. As the initial hypothesis was not confirmed, it was decided to take measurements every six days. The measurement progress remained the same as in the first session.

Results and discussion

As a result of our experiments the ability of microalgae to reduce biogenic elements in wastewater was confirmed. In Figure 1, the results of measurement are presented.

Table 1 demonstrates positive effect of microalgae in the case of nitrogen and phosphorous concentration.

The results of the study show that the content of nitrogen and phosphorus compounds significantly decreased, indicating the effectiveness of post-treatment of effluents using chlorella microalgae. Prospects of the microalgae use for wastewater treatment from nutrients are obvious. They are specially adapted to an environment dominated by viscous forces.

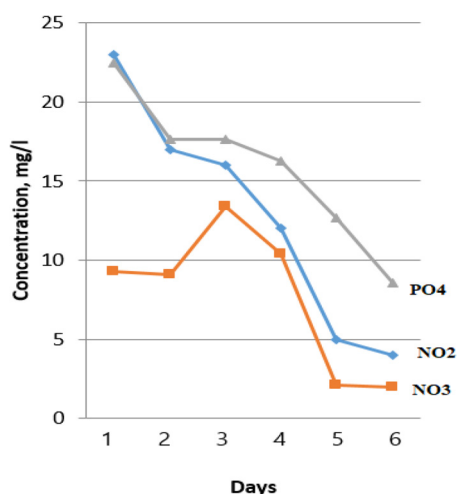**Figure 1** Nitrogen and phosphorus compounds concentration changes in wastewater

Table 1 Decreasing of biogenic compounds in wastewater

Compounds	Concentration, mg/l		Decreasing, %
	Initial	Final	
NO_2	23	4	82.6
NO_3	9.3	2	78.5
PO_4	22.49	15.55	30.9

Practical implications
Two types of waste water were talking into account by us: municipal and brewery waste waters.

Municipal treatment facilities.
A person consumes 200 liters per day of water for various needs. Ukraine has a population of 42 million, of which 69% are urban → 29 million residents who use municipal treatment facilities.

Hence, for the past 24 h, the urban population in Ukraine uses 5.8×10^9 l. After water purification now contains 4.64×10^{10} mg/l, and after purification microalgae will be 8.7×10^9 mg/l. That is, it is lost in Ukraine in a day irreversibly 37.7 tons of phosphates, causing irreparable damage to the environment, this year 3,760 t.

In phosphate fertilizer 50% of phosphates, which means that of 13,760 tons of phosphates we get 27 520 tons of fertilizer.

1 ton of phosphate fertilizer costs 25,000 UAH → 27,520 tons × 25,000 UAH =688 × 10 ^{6} UAH = 22 640 × 10^6 EUR is the profit that the state can get by applying this technology at municipal treatment plants.

Brewery treatment facilities.
Water consumption in Ukrainian breweries is 55 million m^3 per year. In brewery wastewater has the highest content of phosphorus compounds – 19 ml/l.→ 1045000 kg (1045 *t*) of phosphorus is released annually. Microalgae will delay 869 tons, i.e. reduce emissions by 6 times. From 1 ton of phosphates – 2 tons of fertilizers. One ton of phosphate fertilizers costs 25 000UAH. Profit per year – 43,450 000 UAH = 1,448,333 EUR.

Economic benefit from the biomass utilization as biofuel production
The average annual productivity of the growth of microalgae by biomass, when cultivated in a photobioreactor in the weather conditions of Ukraine, can accept 11.5 kg/m^2 of the surface of the photobio-reactive zone (culture medium). In this case, the average lipid productivity will be 4.1 kg/m^2.

Provided that the waste water is in the working area of the photobioreactor as a medium for an average of 3 days, the total volume of photobioreactor working areas for cleaning the effluent of the urban population of Ukraine will be: $5.8 \times 10^9 \times 3 = 17.4 \times 10^9$ l, or $17,4 \times 10^6$ m^3.

If the thickness of the layer of effluents as a culture medium in the photobioreactor zone does not exceed 0.2 m, then the total area of all photobioreactors should be:

$$\sum S_{bioreactor} = \frac{17,7 \times 10^6}{0,2} = 87 \times 10^6 m^2 \qquad (1)$$

Thus, the annual growth of biomass of algae can be: $M_{biomass} = 87 \times 10^6 \times 11.5 = 1000.5 \times 10^6$ kg (2). The annual growth of

lipids in this will be: $M_{lipid} = 87 \times 10^6 \times 4.1 = 356.7 \times 10^6$ kg (3).

Under real conditions, with the effective removal of algae biomass from wastewater 90% (data for centrifugation), the efficiency of separating lipids from biomass of algae by 90%, as well as the energy efficiency of processing lipids in biofuels, 90% of the annual mass of biofuel produced can be:

$$M_{biofuel} = 356.7 \times 10^6 \times 0.9 \times 0.9 \times 0.9 = 260.0 \times 10^6 \quad \text{kg} \qquad (4)$$

Given that the density of biodiesel is 0.86 kg/l, the volumetric amount of biodiesel produced will be:

$$W_{biofuel} = \frac{260.0 \times 10^6}{0.86} = 302.4 \times 10^6 \text{ liters.} \qquad (5)$$

Accepting the price of one liter of biodiesel at the level of UAH 28, the total annual profit from the sale of biodiesel will be:

$$\Pi_{biofuel} = 302.4 \times 10^6 \times 28 = 8466.2 \times 10^6$$

$$\text{UAH} = 282.2 \times 10^6 \text{EUR} \qquad (6)$$

After this calculation we can conclude that the positive benefit after applying the chances are better than even. Diagram 1 presents the economic benefit from the biomass usage (Figure 2).

As we can see, there are many positive effects of microalgae application. Microalgae is very promising way from the commercial, energy and environmental points of view. That is why they are so attractive for many scientists in the world. In the case of environmental safety, microalgae can be used for protection of all components of the biosphere (Figure 3).

Conclusion

As a result of experimental studies the concentrations of nitrogen and phosphorus compounds in waste water were decreased: NO_2 – by 5.75 times; NO_3 – by 4.65; PO_4 – by 1.45 times.

Insufficient waste water treatment by municipal facilities leads to phosphates lost. The urban population in Ukraine uses 5.8×10^9 l per 24 h. Thus, in Ukraine in a day irreversibly 37.7

Figure 2 Economic benefit from biofuel and biofertilizer production
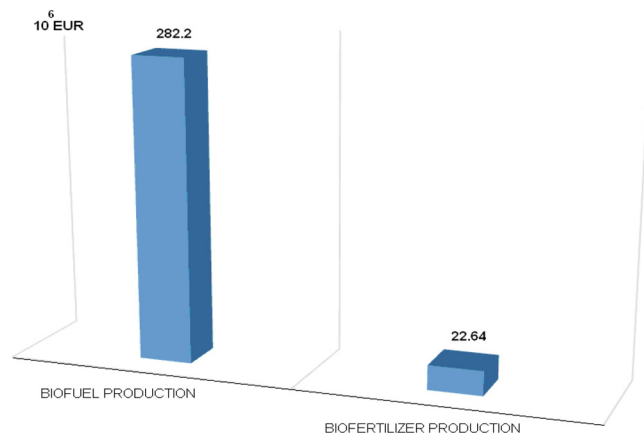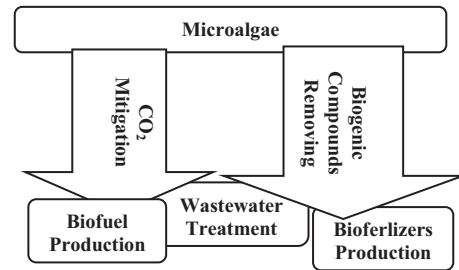

Figure 3 Microalgae application

tons of phosphates, causing irreparable damage to the environment, this year 3,760 t. It means from 13,760 tons of phosphates we get 27,520 tons of fertilizer (profit – $22\,640 \times 10^6$ EUR).

As was shown water consumption in Ukrainian breweries is 55 million m^3 per year. It means $1045\ t$ of phosphorus is released annually, microalgae will delay 869 tons, i.e. reduce emissions by 6 times. From 1 ton of phosphates – 2 tons of fertilizers (profit – 1,448,333 EUR).

Due to calculations we can concluded that the annual mass of biofuel production (in the weather conditions of Ukraine) is 260×10^6 kg (profit – 282.2×10^6 EUR). The studying of microalgae, improvement of methods for their production, search for new ways of their processing, and thinking on new possibilities of how to use products made out of them form one of the most actively developing research directions in modern science. However, wastewater treatment by microalgae with further extraction for biofuel production demands the further investigations to improve existing technologies.

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