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REDUCTION OF THE ENVIRONMENTAL THREAT FROM UNCONTROLLED DEVELOPMENT OF CYANOBACTERIA IN THE WATERS OF THE DNIEPER RESERVOIRS

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Abstract. We have analyzed the ecological hazard that has emerged as a result of the construction of hydropower plants on the Dnieper, which became the cause of uncontrolled development of cyanobacteria. The environmental risks that are caused by the uncontrolled development of cyanobacteria and their biodegradability were studied. The efficiency of application of the known methods of suppression of mass development of the blue-green algae was analyzed. The amount of biogas that can be synthesized from cyanobacteria biomass of Kremenchug reservoir was estimated. The strategy of avoiding the ecological disaster from the uncontrolled development of cyanobacteria and its negative impact on the environment was suggested.

Key words: ecological hazard, cyanobacteria, blue-green algae, biogas, biodegrading..

1. Introduction

In addition to the expected result – the production of cheap electricity, the construction of the hydroelectric complex on the Dnieper river has caused a threat to the ecological safety of Ukraine – a significant deterioration of the ecological state of the Dnieper river.

Such negative environmental effects were caused by two main reasons:

1. Flooding by the waters of newly created reservoirs the territories with settlements, agricultural lands, livestock farms, living space of the population.

2. Significant decrease in the speed of the Dnieper flow.

In general, the total area of the hydroelectric reservoirs of the Dnieper cascade is about 7000 km^2, and there is about 45 km3 of water in these reservoirs. If we consider that the annual flow of the Dnieper river is about 50 km^3 of water, it becomes clear that the amount of water that fills the artificial reservoir of the Dnieper river, close to its annual flow. Thanks to the advent of artificial reservoirs, the section of the river channel, which determines the rate of continuous flow, became much larger, so in the reservoirs (in particular, in Kremenchuk, which is the largest) the velocity of water is so small that it can be considered stagnant. On this basis it is fair to accept the current state of the Dnieper in the middle and lower channel not as a river but as a cascade of flowing ponds with large area and volume of water.

Based on the information above, it will be most methodologically correct to use the limnological approach to the study of the Dnieper river ecosystems. Huge areas of the farmland that are located under the waters of the newly created reservoirs caused saturation of the water with organic compounds. The amount of these compounds is increasing continuously and huge masses of municipal and industrial wastewater, contaminated rainwater and melted snow water run into the Dnieper. Coastal zone unlike reed beds of the Dnieper river historically was included into intense field technology, whereby the surface water (which later falls into the Dnieper) saturated with mineral and organic fertilizers. Such a radical change (a significant decrease of the Dnieper in large reservoirs up to an almost standing state, and the enrichment of organic contaminants) ultimately led to radical changes in the biota of the river. Creating a new interaction in a new biota as well as the creation of a new biotic hierarchy have resulted in a rapid uncontrolled development of blue-green algae that have invaded the newly created reservoirs of the Dnieper [1, 2]. Depending on hydrodynamic conditions, shape of the coastline, the strength and direction of the wind, blue-green algae concentrated in different parts of the Dnieper reservoirs. This led to a loss of the Dnieper river's ability to cleanse itself, which caused a progressive uncontrolled development of blue-green algae (Fig. 1).

Fig. 1. The Accumulation of blue-green algae near Kremenchug hydroelectric station

The nature of the biological cycle of life and death of blue-green algae causes a dominant role in the ecosystem of the Dnieper. Since blue-green algae do not need the soil environment, their quantities are not affected by the depth of the reservoir. Therefore, under the influence of the wind blue-green algae (Fig. 2), migrate along the reservoir, which creates conditions for their progressive reproduction.

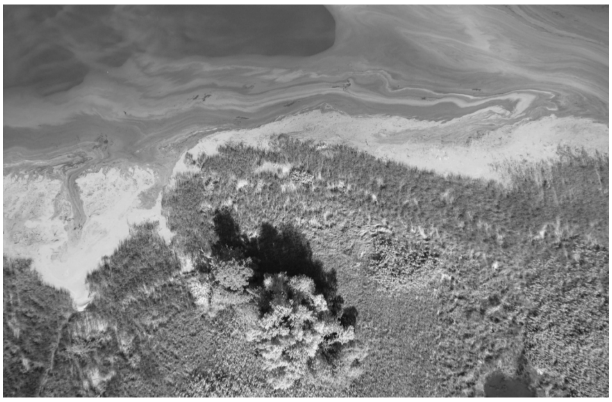

Fig. 2. Aerophotography of water "blooming", caused by the massive development of cyanobacteria

Density of cyanobacteria is somewhat less than the density of water, so even after a heavy storm they float to the surface quickly and keep developing rapidly, consuming solar energy. The dense surface layer of blue – green algae is formed in a short time, which reduces the reflectance of sunlight. This, in its turn, contributes to additional heating of the surface layer (where cyanobacteria is concentrated), and thus accelerates the development of algae – the process becomes auto-catalytic .This contributes to the uncontrolled development of cyanobacteria as well as to the absence of species for which it would appear as food.

The result of the impact of uncontrolled development of cyanobacteria in artificial reservoirs of the Dnieper is the transformation of the river water during the period of decomposition of blue-green algae (from the second half of July to late September) into a dirty liquid with a strong unpleasant odor. This makes it impossible to purify the river water up to the requirements of the standards for drinking water at the stations of primary water purification intakes of coastal cities. The air is filled with a sickening smell of decay that causes numerous diseases of the respiratory tract. The decay of cyanobacteria in the Dnieper waters reduces oxygen, which causes suffocation of valuable fish species (perch, bream, chub, saber fish, etc.), causing considerable damage to fisheries of the country. The evidence of suffocation is a mass floating of dead fish on the surface and its decomposition, which creates an additional environmental threat to the ecosystem. Catastrophic reduction of oxygen content in the water is also confirmed by the analyses of the air above the waters of Rybinsk reservoir in the period of its algal bloom. Among the components the authors [3] have detected methane, which is formed during anaerobic fermentation. Thus, during the decomposition of blue-green algae the oxygen concentration reduction in the river water is so significant that in the surface layer oxygen-free fermentation takes place.

Due to fluctuations in the level of water in artificial reservoirs the coastal strips of the Dnieper are often flooded (marshes, lakes, sleeves and oxbows of the Dnieper) and cyanobacteria is getting spread. As a result of siltation many famous sandy Dnieper beaches, the places that used to be a pride and beauty of the Dnieper as well as well-known recreational areas, are disappearing. An unpleasant odor of decomposing algae significantly reduced the popularity and the quantity of boating tourism and in the summer the water becomes a dangerous source of microbiological contamination.

2. Analysis of recent researches and publications

There is a positive experience of the restoration of lake waters of Canada [4] – a significant reduction of estratest of Great lakes (lake Erie – 25,8 thousand km^2, 458 km^3, lake Ontario – 190 thousand km^2, 1638 km^3), which emerged in the 1960s and 1970s due to the growth of population and the consequent water pollution by nutrients, that led to the development of an undesirable flora, in particular cyanobacteria. During four decades (1930–1970) the pollution of Great lakes was increasing, which led to the formation of zones, poor in oxygen. Two important things should be noted: huge amounts of recovered, at least partially, drinking water – the object of restoration have been the reservoirs transformed by anthropogenic pollution of natural origin, i.e. the reservoirs, which have sufficiently powerful mechanisms of self-purification; the improvement of basins of Great lakes has been achieved through blocking the contamination sources, in particular, the elimination of phosphorus from the content of widely used detergents.

According to the results of our observations and analysis it can be stated that the cascade of the Dnieper reservoirs differ from the lakes of Canada as well as from powerful artificial wastewater treatment plants, and, therefore, it is not possible to directly use the experience to restore the quality of water accumulated in these projects [1, 5].

Statement of the problem. The aim of the research was to establish the degree of ecological danger from uncontrolled development of cyanobacteria, the extent of their negative impact on the environment and assessment of the prospects of using cyanobacteria collected for energy production.

3. Results and Discussion

To suppress mass development of blue-green algae, the following methods should be considered: mechanical, physical, chemical, ecological and biological methods (Fig. 3).

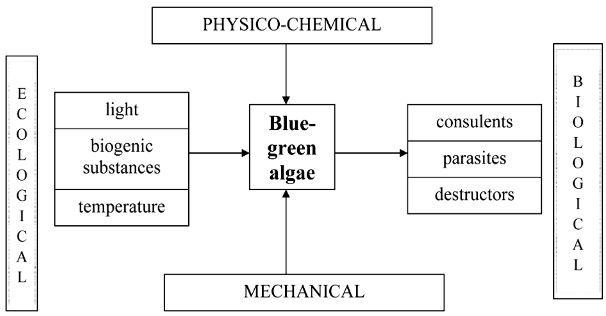

Fig. 3. Methods of suppression of mass development of the blue-green algae

The most effective physico-chemical methods include aeration of water and application of algaecides. Even though the application of these methods leads to a dramatic reduction in a number of cyanobacteria, but they have significant drawbacks. Aeration of large amounts of water air is uneconomical (65–90 kopecks/m^3), and the use of algaecides is possible only in bodies of water that is not intended for drinking or fishing as well as in the reverse water supply systems.

Another method that can give some good results is the collection of cyanobacteria and its subsequent disposal (production of biogas, lipids and fertilizers). Among the existing technologies of cyanobacteria processing we would like to concentrate on the option of building a biological station for the production of biogas, fertilizer and other valuable for industry and agriculture products.

The basis for the biogas production is the method of purification surface waters from blue-green algae owing to collection and use of its concentrated biomass as a substrate for the biogas production through biotechnology methane "fermentation" and ensuring the desired level of water quality in reservoirs cascade under the condition of energy savings. The outcome of the biogas mixture at +28°C per 1 day was 200 ml of 1 dm^3 of the substrate. Analysis of the biogas flame spectrum makes it possible to conclude that the percentage of methane in the studied gas mixture was dominating [6]. Economical and ecological efficiency in the use of cyanobacteria for the production of biogas (on the example of the Kremenchug reservoir with water surface area of 2250 km^2) is estimated as follows: assuming the collection of seston in the amount up to 50 kg/m3 [1] from 828 million m^3 of water from shallow waters its biomass will be 4,14.107t during the growing season. While fermenting this biomass in the process of methane "fermentation" one can receive up to 30 million m^3 of biogas (18,8 million m^3 of methane), which is equivalent to 20 tons of oil or 17 thousand tons of diesel fuel.

Without the use of pretreatment only a small portion of the energy contained in biomass can be taken out. Cavitation, which yet has not found a wide application in industrial technologies, is an effective method of hydro-mechanical intensification of chemical-engineering, food, pharmaceutical, biological and other processes. The effectiveness of cavitation process is stipulated by cavitation crashing of the solid phase, turbulance of the boundary diffusion layer of the liquid by cavitation bubbles, emergence of mass transfer aspects, which are characterized by high values of mass transfer coefficients.

Processing of biological objects in a cavitation field can be used as an independent process and ensure an inactivation and extinction of microorganisms or as cyanobacteria pre-treatment stage with the aim of increasing the mass transfer surface for the following extraction or biochemical processes. The results of microscopic analysis showed that for certain modes of processing liquid substances in the cavitation field, the decrease of contrast cells is observed as well as damage to the cell membrane, reducing the clarity of contours, cell shape change, aggregation and mechanical damage. Experimental studies [8] have established that in case of hydrodynamic cavitation to increase the effectiveness of the process of obtaining energy from cyanobacterial biomass, a degree of lipid extraction increases by 54,3 % and the amount of synthesized biogas increases by 28,3 %. In the cyanobacterial biomass treated in a hydrodynamic cavitation field.

The use of cyanobacteria has the below environmental effects:

– The use of ecologically safe, without significant energy costs, method of seston collection.
– The fulfillment of conditions of the Kyoto Protocol to the UN Framework Convention on Climate Change (Rio de Janeiro, 1992).

– Accession to the Directive 2000/60 / EC of the European Parliament and of the Council “establishing a framework for Community action in the field of water policy" from October 23, 2000.
– Recovery of the broken structural-functional organization of the littoral ecosystems of the Dnieper cascade reservoirs (gas balance, hydro-chemical regime, reducing the toxicity of water and spawning fish fauna etc.).
– Rehabilitation of the environment and the population by improving the quality of natural as well as drinking water.
– The use of manufactured products as organic mineral fertilizers in agriculture and forestry;
– The use of social and financial effect for sustainable ecological and economic development of the Dnieper regions.

Utilization of cyanobacteria has the below energy resources and energy-saving effects:

– Free use of raw materials as substrate for fermentation;
– Introduction of low-cost production of biogas and its transformation into electricity;

Based on the analysis of the research data [8] there was developed a strategy of avoiding ecological hazard from uncontrolled development of cyanobacteria and their negative impact on the environment, which includes the consistent implementation of the following stages: collection of cyanobacteria and transporting them to biological stations $\Rightarrow$ processing of biomass into a hydrodynamic cavitation field $\Rightarrow$ concentration of biomass $\Rightarrow$ extraction of lipids from biomass $\Rightarrow$ biomass biodegradation with biogas extraction $\Rightarrow$ use of waste biomass as a fertilizer.

4. Conclusions

Based on the analysis of the sources of ecological hazard in the waters of the Dnieper reservoirs of Kremenchug territorial-production complex it was concluded that one of its determining factors is the uncontrolled development of blue-green algae and their negative impact on the environment. The feasibility of producing biogas from the biomass of blue-green algae was scientifically proved. The efficiency of pre-treatment of the biomass of cyanobacteria in the field of hydrodynamic cavitation in order to increase the completeness of the biomass decomposition was established.

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