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THE FEASIBLE METHODS FOR CYAN BACTERIA HARVESTING FROM THE WATER BODY SURFACE

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Purpose. The feasible methods for the cyan bacteria mechanical extraction from the eutrophic water bodies' surface layer during the algal bloom have been suggested and considered. **Methodology.** The visual observation method on a water body (namely, the Kremenchuk reservoir) during the time of the algal bloom (from June to September) to determine the places of the cyan bacteria most massive and regular assemblages have been applied. **Results**. By the visual observation method the typical places of the most massive and regular assemblages of cyan bacteria in the area of a water reservoir have been detected. A collector of original construction for the surface water layer pumping out of such places of the water body have been suggested. Methods for the cyan bacteria harvesting from the stationary coastal stations using a seine for the pulling biomass toward the collector, from the upper pool of hydroelectric dam and from the specially equipped vessels have been proposed. **Originality.** For the first time, it has been suggested a collector of original construction for the surface water layer pumping out of a water body. The detailed original methods for the cyan bacteria biomass harvesting from the eutrophic water reservoirs, using both the stationary coastal stations and the specially equipped vessels have been proposed. **Practical value.** The extraction of the cyan bacteria biomass sizable percent out of the water bodies (the Dnipro reservoirs in particular) during the algal bloom might allow to prevent the water body from being depleted of oxygen and, consequently, to prevent the aquatic fauna from being killed by asphyxia, significantly improving the ecological state of the water body and the coastal zone. Out of the harvested biomass, subjected to anaerobic digesting, biogas with high content of methane can be obtained. The rest of biomass can be used as an effective organic fertilizer. References 20, figures 6.

Key words: eutrophication, algal bloom, cyan bacteria, water reservoirs, harvesting methods.

МОЖЛИВІ СПОСОБИ ЗБИРАННЯ ЦІАНОБАКТЕРІЙ З ПОВЕРХНІ ВОДОЙМИ

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Проблема евтрофікації водойм становить значну екологічну проблему. Особливо гострою вона є для штучних водойм, які не мають природних механізмів самоочищення. Так в Україні каскад дніпровських водосховищ щороку дуже потерпає від цвітіння води. За неможливості вберегти ці водойми від потрапляння в них стоків, насичених живильними для ціанобактерій речовинами, дієвим способом покращення їх екологічного стану може бути механічне вилучення значних обсягів насиченої ціанобактеріями води. Доведено, що з ціанобактерій, підданих анаеробному бродінню, може бути одержаний біогаз з високим вмістом метану, а рештки біомаси можуть бути використані як ефективне органічне добриво, тому таке вилучення даватиме не лише екологічну, а й економічну користь. У цій роботі нами запропоновані різні можливі способи вилучення насиченого ціанобактеріями поверхневого шару води з евтрофікованих водойм під час цвітіння води. Розглянуто способи збирання як зі стаціонарних берегових станцій, так і зі спеціальних рухомих суден.

Ключові слова: евтрофікація, цвітіння води, ціанобактерії, водосховища, методи збирання.

PROBLEM STATEMENT. The matter of water bodies eutrophication is a significant ecological problem in the present time. [1–12] Eutrophication is caused by addition of superfluous nutrients, mainly phosphates, into a water body, which induces explosive growth of plants and algae. The decaying of them consumes oxygen from the water. As a result, the oxygen depletion in the water body kills aquatic animals. Eutrophication is almost always induced by the discharge of phosphate-containing detergents, fertilizers, or sewage, into an aquatic system [13].

Surveys show that 54 % of lakes in Asia are suffering from eutrophication; in Europe it takes 53 %; in North America 48 %; in South America 41 %; and in Africa 28 %.

For the artificial water reservoirs, which do not have the natural mechanisms for self-depuration, the problem of eutrophication is even more exacerbated than for the natural lakes.

The water reservoirs, formed by building of hydroelectric power stations, worldwide cover more than 600,000 km^2 (which is about the area of Ukraine). In 2005 there were more than 8 thousand of big hydroelectric dams (≥15 m height) used for hydropower generation, which provided 19% of the world's electricity supply [14].

The ever-increasing humans' demand for energy and tendency to use the renewable sources of energy lead to construction of new hydroelectric facilities, and so more and more water reservoirs are formed.

Typically, on the banks of those water reservoirs the intensive agriculture is done (for there is access to water for irrigation), the large-scale industrial plants demanding of much water or\and electrical energy are built (such as atomic power stations, chemistry plant, etc.), a large population of people live.

So in 20 century the threat of the Dnipro water reservoirs appeared in Ukraine. That turned the Dnipro – one of the largest rivers of Europe – into a system of the almost stagnant lakes, on the banks of which a significant amount (nearly 7 million) of people live and the intensive agricultural and industrial production is

performed. Excessive supply of nutrients from the sewage of factories and plants, and cities' water purification stations, as well as runoff from the fields rich with fertilizers is the main cause for eutrophication of these water bodies and for the algal bloom in their water every summer.

There are additional factors, which induce eutrophication of the Dnipro water reservoirs.

Thus, the water erosion of the banks causes, in the first place, the nutrients to be put into the water directly and, in the second place, the relatively shallow water reservoirs to grow even shallower. As a result, during the summer ardor the reservoirs are more heated up, which fosters the growth of cyan bacteria.

The consequences of cyan bacteria domination in the Dnipro aquatic system are only negative. During the phase of their decaying, which lasts from the middle of July till the end of September, cyan bacteria turn the Dnipro water into a stinking and dirty liquid. That makes impossible to purify the water up to the drinking water standards at the initial water purification stations. Also it depletes the water of oxygen and repeatedly causes the fish kills. The dead fish comes up to the water surface and decays under the hot sun, making the air above the Dnipro even more nauseous.

The data [15] on the composition of the air above the Rybinsk water reservoir during the algal bloom in it also testify the depletion of oxygen in the water. Among the components, the authors found out methane. As is known, the latter one is formed in the process of anaerobic digesting. Hence, a conclusion can be made, that the depletion of oxygen in the water during the decaying of cyan bacteria is such significant, that in the surface layer the conditions for the anaerobic rotting are created.

The frequent water rising and subsiding in the lower pools of hydroelectric dams induces the banks to be flooded and the Dnipro water, teemed with cyan bacteria, to enter into the Dnipro's branches, old channels and ponds. Therefore, the excellent sandy beaches – the ornament to the Dnipro and favorite people's places for swimming and resting – are silted and virtually gone.

During the warm period, the Dnipro water turns into a source of dangerous bactericidal pollution [16–18].

If, for the present, we cannot eliminate the excessive supply of unwanted nutrients into the Dnipro water reservoirs, then only the annual extraction of the main bulk of cyan bacteria with all nutrients they have absorbed might improve the bad ecological state of the Dnipro.

The earlier investigation [19, 20], in which the authors of this paper took part, has proved that from the cyan bacteria, subjected to anaerobic digesting, a biogas with high content of methane can be obtained, and the rest of biomass can be used as an effective organic fertilizer.

Therefore, the extraction of the cyan bacteria from the Dnipro reservoirs can bring economic profit.

PURPOSE – to propose and consider the possible methods for the mechanical extraction of cyan bacteria from the surface layer of eutrophic water bodies during the algal bloom.

EXPERIMENTAL PART AND RESULTS OBTAINED. Surveys on the algal bloom in the Kremenchuk reservoir testify, that the mass of cyan bacteria drifts along the surface of the reservoir in the direction of wind and waves (fig. 1). In pacific days, along the banks, to which the wind have been blowing earlier, the surface water layer extremely teem with cyan bacteria is formed.

Figure 1 – View of the part of the Kremenchuk water reservoir and its dam from space.
The pale streaks across the water are masses of cyan bacteria driven by the wind and current

The localization of the biomass of cyan bacteria upon the reservoir surface allows suggesting effective methods for mechanical extraction of the surface water layer including cyan bacteria.

The issue of gathering and processing such quantities of water is not very complex technically. If we take the area of all the Dnipro water reservoirs and extract the 5-cm-thick surface layer with cyan bacteria out of them, the volume of extracted water will be 0,35 km^3, which is roughly equal to the volume of annual sewage from a big city. Thus, the volume of annual sewage from Kiev is about 0,44 km^3.

As the main construction element in pumping the surface layer out of water we see a drowned (up to 30-40 cm depth) platform, the function of which is to cut the surface layer up, so that only the water mass teemed with cyan bacteria could be taken into the pipe. Most basically the construction of such a platform is shown at fig. 2. The platform is equipped with a system of floats. Their function is 1) do not let the platform drown, and 2) to ensure that the platform is placed horizontally at the given depth under the water surface. The outline and size of the platform may vary according to the specific task. This construction element (the drowned platform + the sucking pipe) hereinafter in this paper referred to as the collector.

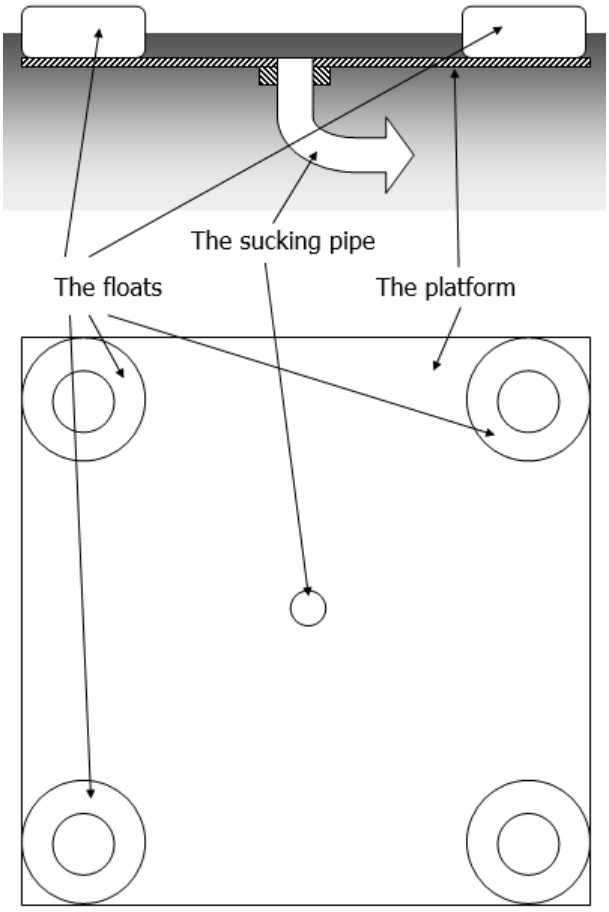

Figure 2 – The collector

Overall, the possible gathering methods may be divided in two groups: 1) harvesting cyan bacteria from stationary coastal stations and 2) harvesting them from specially equipped vessels. Let's consider them.

1. Harvesting cyan bacteria from stationary coastal stations.

It is rational to establish stationary coastal stations for harvesting cyan bacteria only at those places, where they often gather in abundant during the algal bloom. Surveys we made on the Kremenchuk reservoir have shown that such assemblages occur at the following places:

1) in natural bays, especially narrow and elongated, as, for example, the bay near Svitlovodsk (fig. 3), where we harvested 2 m^3 of cyan bacteria biomass for the experiments this year.

2) in the upper pool of hydroelectric dam, immediately before the turbines.

Figure 3 – The long and narrow natural bay in the Kremenchuk water reservoir near Svitlovodsk

When harvesting cyan bacteria from bays, the following method can be used for pulling the biomass toward the collector. The coastal section of the water is surrounded by a 0,5-meter-high seine (fig. 4), the top edge of which is floated on the water, supported by floats. The collector is drowned near the bank inside the area encircled by the seine. During the pumping the biomass out into the collector, the seine is being slowly dragged out, so the biomass is being pulled toward the collector.

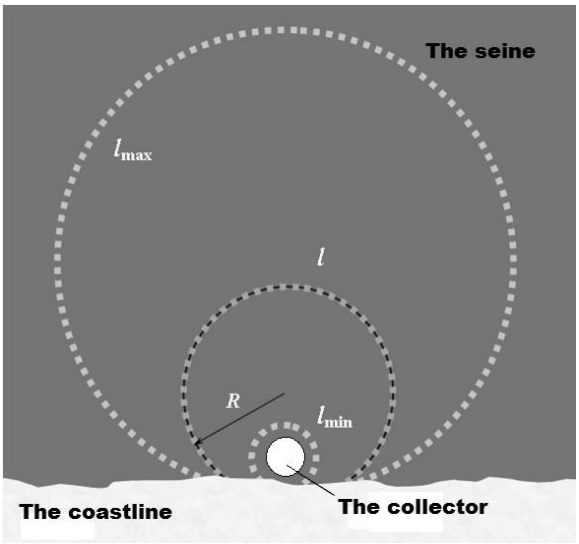

Figure 4 – Harvesting cyan bacteria from off the coastline using a seine for pulling them toward the collector

One of the most effective places for the establishing a stationary station for harvesting cyan bacteria from a water reservoir is the place directly before the hydroelectric station's turbines, where the cyan bacteria are pulled by the current. It is there where the stationary collector should be placed. The gradient of height between the upper pool and the lower one allows the concentrating column to be established on the lower pool's bank down the dam, so the collector is higher than it is, and the biomass can flow into the column simply by gravity (fig. 5).

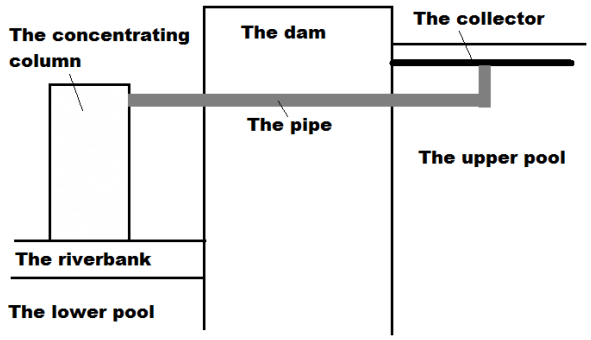

Figure 5 – Harvesting cyan bacteria from the upper pool of a hydroelectric dam

2. Harvesting cyan bacteria from specially equipped vessels.

Depending on weather conditions, the great assemblages of cyan bacteria may be formed in very different parts of water reservoir. In such a case, specially equipped vessels can be used for harvesting them. Besides the collector, such a vessel must be equipped with tanks for the harvested cyan bacteria. After the tanks are filled with cyan bacteria, the vessel delivers them to a coastal station, where they are pumped into the concentrating column. Actually, the concentrating column may be established on board the vessel, in order to deliver to the coastal station as less waste water as possible. But in such case the process of harvesting will be significantly slowed down, because the vessel is to stop and wait till the waste water in the concentrating column settle and precipitate.

Such a harvesting vessel may be designed specifically, or it may be made as a floating system, depicted on fig. 6, which is to be driven by an ordinary tugboat.

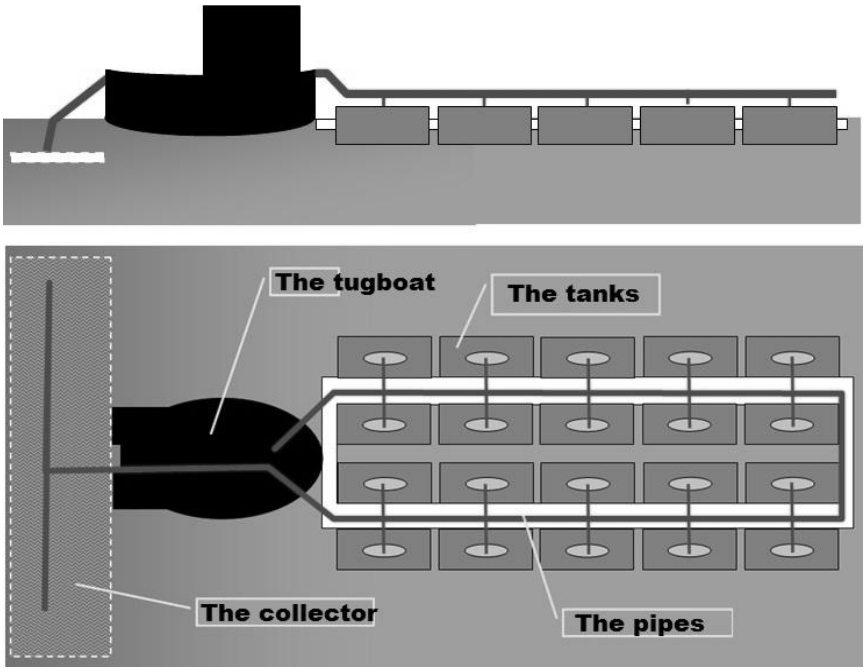

Figure 6 – A floating harvesting system, driven by a tugboat

CONCLUSIONS. The feasible methods for the mechanical extracting the surface water layer teemed with cyan bacteria from out the eutrophic water bodies during the algal bloom are considered in the paper. The methods for harvesting cyan bacteria from both the stationary coastal stations and the specially equipped vessels are proposed. Subsequently, the waste water is removed in the concentrating column, the harvested biomass can be subjected to an anaerobic digesting, and a biogas and organic fertilizer of high quality can be obtained. In the future, the proposed methods are to be tested in the Kremenchuk water reservoir to determine their efficiency experimentally.

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ВОЗМОЖНЫЕ СПОСОБЫ СБОРА ЦИАНОБАКТЕРИЙ С ПОВЕРХНОСТИ ВОДОЕМА

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Значительной экологической проблемой в настоящее время является проблема эвтрофикации водоемов. Особенно остро она стоит в случае искусственных водоемов, не имеющих естественных механизмов самоочистки. Так в Украине каскад днепровских водохранилищ ежегодно сильно страдает от цветения воды. При невозможности уберечь эти водоемы от попадания в них стоков, насыщенных питательными для цианобактерий веществами, действенным способом улучшения их экологического состояния может быть механическое изъятие значительных объемов насыщенной цианобактериями воды. Доказано, что из цианобактерий, подвергнутых анаэробному брожению, может быть получен биогаз с высоким содержанием метана, а остатки биомассы могут быть использованы как эффективное органическое удобрение, поэтому такое изъятие будет приносить не только экологическую, но и экономическую пользу. В этой работе нами предложены различные способы изъятия насыщенного цианобактериями поверхностного слоя воды эвтрофированных водоемов во время цветения воды. Рассмотрены способы сбора как со стационарных береговых станций, так и со специальных движущихся суден.

Ключевые слова: эвтрофикация, цветение воды, цианобактерии, водохранилища, методы сбора.

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