ABSTRACT

Relevance of the topic: Regular analyses of water quality in Ukrainian water reservoirs show a tendency to its decrease with every passing year. The quality of water is defined basing on organoleptic parameters which have their limitations and basing on the particles and substances, dissolved in it. For now the indexes do not exceed the set maximum, but they get closer to the limit with every year.

The norms and standards for waste waters to be discharged into surface water reservoirs in our country are softer than the ones in Europe, Japan, United States of America, and several other countries. Most of their standards have the set limits of two times (or more) tougher than Ukrainian. For example, limit of Phosphate-ion in water in Europe is 0.4 mg/dm^3 while in Ukraine it is set to 3.5 mg/dm^3, which can lead to irreversible consequences. Another example is ammonium with European limit of 0.04 mg/dm^3 and Ukrainian 2.5 mg/dm^3. For this reason water quality in Europe is much higher than the Ukrainian. At the same time European legislation does not separate indexes of biological oxygen demand and chemical oxygen demand, and has only one value set for them both. This phenomenon can be explained by the interdependence of these two indicators, which are highly dependent on the growth of algae in water.

Every summer Ukrainian natural and artificial water reservoirs face the problem of algal bloom. In summer blue-green algae grow rapidly and this process is uncontrolled. This excessive algal growth leads to decrease of water quality because organoleptic parameters of water worsen. Due to rapid algal growth the concentration of dissolved oxygen in water is unstable, so all the aquatic organisms are affected by its changes.

The connection of the work with scientific programs, plans, and topics: The master's thesis has been completed at the Environmental Engineering Department according to "National target program for the development of water management and ecological improvement of the Dnipro river basin for the period up to year 2021 (Law of Ukraine of May 24, 2012 № 4836-VI) and Regional ecological program "Clean Dnipro" up to year 2021 (Decree of Regional Council of March 22, 2013 № 21-2/VI).

The aim of investigation is justification for implementation effectiveness of an installation for natural reservoirs cleaning.

The objectives:

- to perform analysis of Ukraine natural water reservoirs' state and water quality problems;
- to perform analysis of existing technologies and equipment for cleaning water from algae;
- to perform analysis of factors that influence algae growth in natural water reservoirs;
- to justify selection of certain method for cleaning water with development of installation project;
- to justify implementation effectiveness of an installation for natural reservoirs cleaning.

The object of investigation is the process of water reservoirs pollution with blue-green algae.

The subject of investigation are parameters of surface waters pollution with blue-green algae, equipment for cleaning water from algae, and measures and means for normalization of water reservoirs state.

The methods of investigation: in process of investigation were used information search methods, statistical analysis methods, and analytical method.

The scientific novelty of obtained results:

- the dependence of algae growth on indexes of water quality and temperature is proven;
- the implementation effectiveness of an installation for natural reservoirs cleaning is justified;
- the model of an installation for mechanical water reservoirs cleaning from algae is developed.

The practical value of obtained results:

- the implementation effectiveness of an installation for natural reservoirs cleaning is justified;
- the model of an installation for mechanical water reservoirs cleaning from algae is proposed.

The project contains: __ tables, __ figures, __ formulas.

MAIN CONTENT OF THE WORK

The **introduction** substantiates the relevance of the topic and shows the connection with scientific programs, also there are formulated the aim and main tasks of the investigations, scientific novelty and practical significance of the work are given.

The **first section** gives the analysis of general characteristics at Ukraine water resources and water reservoirs, analysis of water management in main Dnipro Basin reservoirs concerning the quality of water, analysis of the legislative documents, norms and standards of Ukraine and Council Directives of European Union regarding water quality and water protection. The problem of water quality in natural and artificial water sources and reservoirs is very important and serious. Analysis of the known methods and methodologies of estimating the water quality and methods of increasing the water quality in water reservoirs showed that this problem was dealt with by A. Yatsyk, A. Tomiltseva, M. Tomiltsev, Y. Hryshchenko, V. Shevchuk and others. They have investigated the processes of reservoirs self-cleaning, processes of reservoirs' pollution, and methods of water quality estimation.

The main factors that influence water quality in natural and artificial water reservoirs are sewage discharge and waste waters discharge from industrial sites and from municipal buildings. Together with water there are discharged heavy metals, organic matter, phosphates and nitrates. They all have a great influence on the water quality indexes. As a result, water gets more contaminated and less suitable for drinking and domestic uses. For that reason the problem of water quality increasing is so relevant.

Table 1 General characteristics of the Dnipro Basin water reservoirs

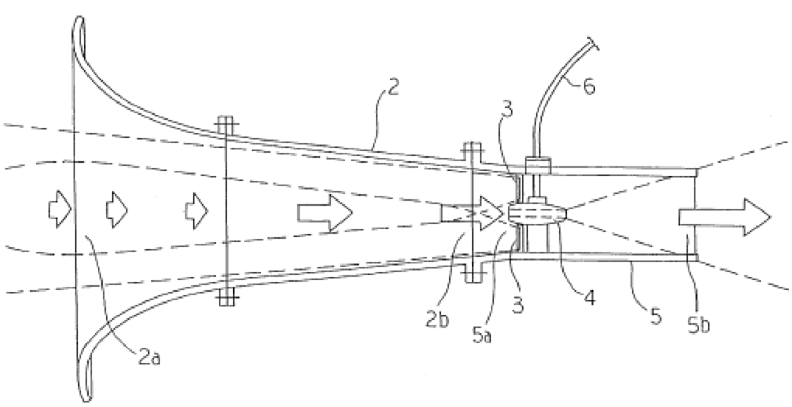
Oblasts	Area. thousand km^2	Long-time average annual resources of streamflow, km^3/year		Insurance with long-time average annual resources of streamflow, thousand km^3/year			
		local	total	Per 1 km^3		Per 1 person	
				local	total	local	total
Dnipropetrovsk Oblast	31,9	0,87	53,0	27,3	1661,4	0,2	16,3
Zaporihia Obast	27,2	0,62	53,0	22,8	1948,5	0,35	30,2
Kyiv Oblast	28,9	2,04	46,4	70,6	1605,5	0,44	10,0
Kirovohrad Oblast	24,6	0,95	50,2	38,6	2040,	0,98	51,6
Poltava Oblast	28,8	1,94	51,5	67,4	1788,2	1,35	35,8
Kherson Oblast	28,5	0,14	54,5	38,6	1908,8	0,13	51,2
Cherkasy Oblast	20,9	1,01	47,4	48,3	2267,9	0,81	38,1
Chernihiv Oblast	31,9	3,45	29,57	108,2	927,0	3,30	28,2

Table 1 shows the main characteristics of water intake from Dnipro River. Here included are sizes of oblasts and water usage, which somewhat determines their ability to self-cleaning.

To solve this problem it is required to have information on water quality throughout the year, data on excessive water contamination, data on rates of reservoirs' ability to self-cleaning. Analysis of the gathered data showed that there are sufficient methods of estimating the water quality experimentally and mathematically.

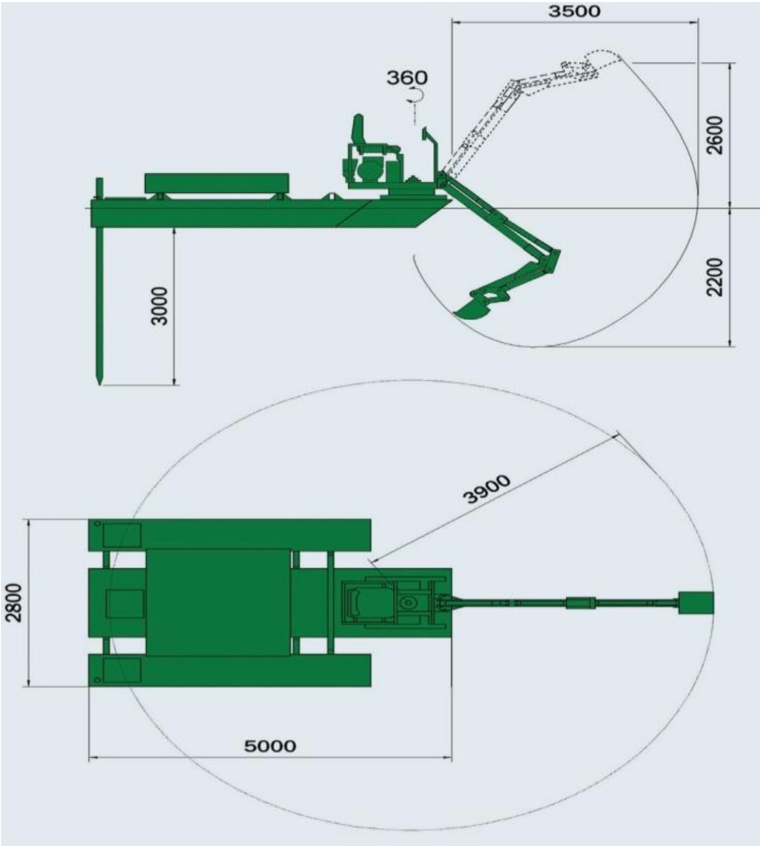
The analysis of Ukrainian legislation and comparison of it with Council Directives of European Union showed that although some norms in state legislation were tougher, they are now amended with new ones, not so strict. Most of European norms are a lot tougher. For that reason, a lot of European water resources have cleaner water.

The **second section** gives the analysis of mechanical water cleaning method and its properties, the analyses of existing equipment for water cleaning, including biological water cleaning. It describes different types of equipment with different approaches to the process of water cleaning.



The apparatus for purification of water area by irradiating it with ultraviolet light (Figure 1) differs from some other devises because it doesn't extract the algae from water. All it does is irradiates contaminated water with ultraviolet light and that's it. After irradiating, the algae are let out with dirty water.

Small self-moving water treatment device "Ros" for mechanical water treatment (Figure 2) has completely different approach to water cleaning. It can extract algae from water, but only in shallow ponds of reservoirs, because it literally extracts algae from water and from the bottom of reservoir. It can't extract the micro algae from water (the one that causes the algal bloom in summer). This device is most useful for cleaning shallow and small reservoirs and for deepening the ponds by getting the mud from the bottom of ponds.



There is also equipment for water treatment at the outflow of plants, which meant that they are static and cannot change the location of their cleaning processes, which makes the devices of this type inefficient for preventing algal bloom.

Another type of water cleaning techniques is to situate the cleaning device at the intake of, for example, pump station and to clean water directly before its intake to the further using. This approach can be useful only to decrease the wearing out of station equipment, and completely inefficient for improving water quality.

The **third section** shows the results of investigating the dependencies between temperature of water in water reservoirs and the main water quality indexes. The investigation was carried out in three stages. The first stage is analysis of water quality in Kremenchuk Water Reservoir. It proves the interconnection and interdependencies between the main water quality indexes and the temperature in both directions. The processes of reservoir's self-cleaning are slowed down because of building the water reservoir. The second stage is carrying out the regression analysis to prove dependencies between the considered parameters. The results of the analysis showed that mathematical calculation of such dependencies may be conducted with calculation errors approximately 15 %. The third stage was the analysis of environmental hazards that are caused by production complex area of the Kremenchuk water reservoir. The most influencing was considered the availability of organic matter in water.

The evaluation of each indexes' influence was conducted by building the equations of approximation and the graphs that show the changes in amounts of substances and rates of particulates concentration in water in time, depending on season. In other words the indexes change with changes in water temperature.

Table 2 shows the values of the main water quality indicators for the last four measured values for compliance with periodicity of the sampling.

Table 2 Main indexes of water quality are showed in Table2.

The values of the main water quality indicators	t,°C	Dissolved O_2, mgO_2/dm^3	Chromaticity, 0 PCS	NH^+_4, mg/dm^3	COD,mgO/dm^3	Iron mg/dm^3	Mn, mg/dm^3	Phosphate-ion, mg/dm^3
SRN №4630-88 (amended in 2017)		*≥4,0*	-	*2,5*	*15*	*0,3*	*0,1*	*3,5*
ESWO from 2012		-	-	1,29	50	-	-	2,15
January 2017	0,5	8,6	30	0,34	25,4	0,24	<0,05	-
July 2017	23	6,9	50	0,43	20,1	0,41	<0,05	0,34
October 2017	16	4,9	40	0,4	29,4	0,34	<0,05	0,52
January 2018	3	8,2	37	0,57	19,4	0,52	<0,05	0,57

The values of the parameters show the state of water in Kremenchuk water reservoir. Some of the values exceed the established norms, but the others seem to be within the limits allowed.

Using the equations of approximation it is easier to see the dependency of dissolved concentration from the temperature (Figure 3). The figure shows the changes of dissolved oxygen concentration in water in time. The values are taken from autumn indexes. The graph shows that from year 2013(number 1) to year 2017 (number 5) which indicates the worsening of situation with dissolved oxygen. If the concentration of dissolved oxygen falls lower than 4 mgO_2 / dm^3, there occurs mass fish death.

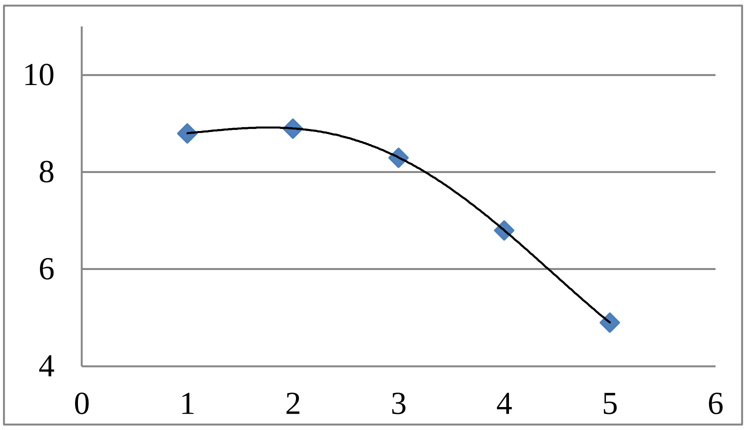


Table 3 Equations of approximation for the dissolved oxygen from 2013 to 2018.

Period	
Winter	$y=0,0646x^4-1,0477x^3+6,0174x^2-14,299x+20,017$ $R^2=0,8975$
Summer	$y=-0.2792x^4+3.6083x^3-16.071x^2+27.642x-6.1$ $R^2=1$
Autumn	$y=0.0292x^4-0.325x^3+0.8708x^2-0.675x+8.9$ $R^2=1$

The graph and the table show dependency of dissolved oxygen concentration and temperature.

The same situation occurs with chromaticity and chemical oxygen demand indexes.

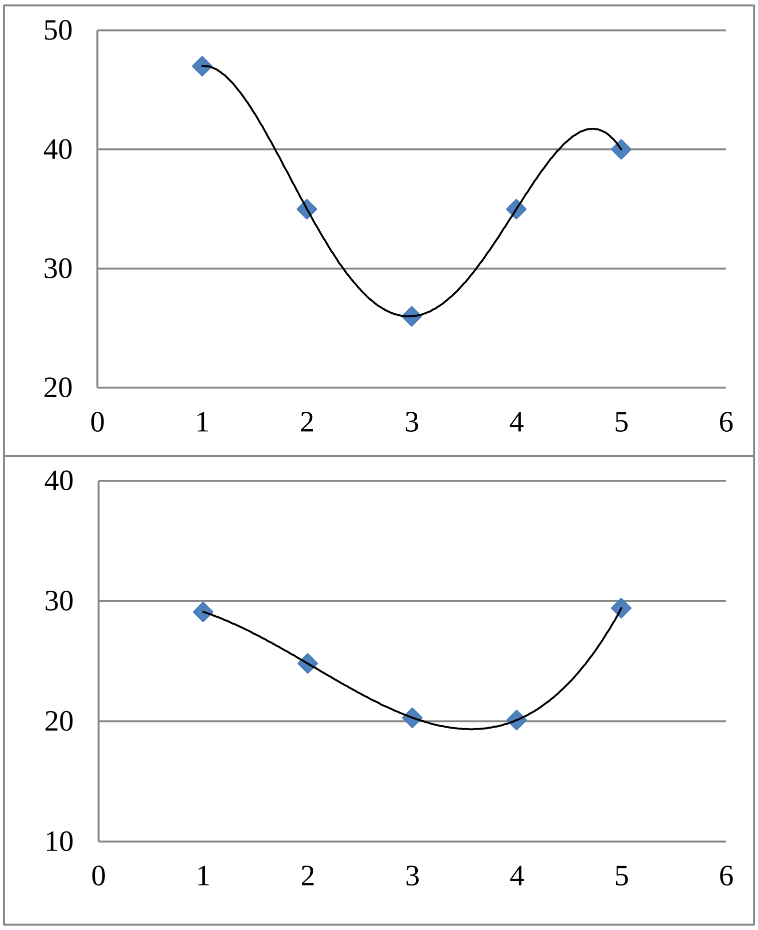


Figure 4 replicates in the graphs the changes in chromaticity level (upper graph) and chemical oxygen demand (lower graph) also for autumn period.

As it can be seen, the level of chromaticity has dropped in 2015 (number 3) and then increased in 2016 (number 4). The lowering of this index occurred due to cold weather that did not allow the algae to grow rapidly. In 2016 though, a lot of organic matter got into water because of flooding. This event led to algal overgrowth and rise of chromaticity level.

As the processes in water are interdependent, the changes in chromaticity level led to chemical oxygen demand leaps. The graph shows drop of this parameter at about same time as the previous one and with slight delay it increased after the chromaticity rose.

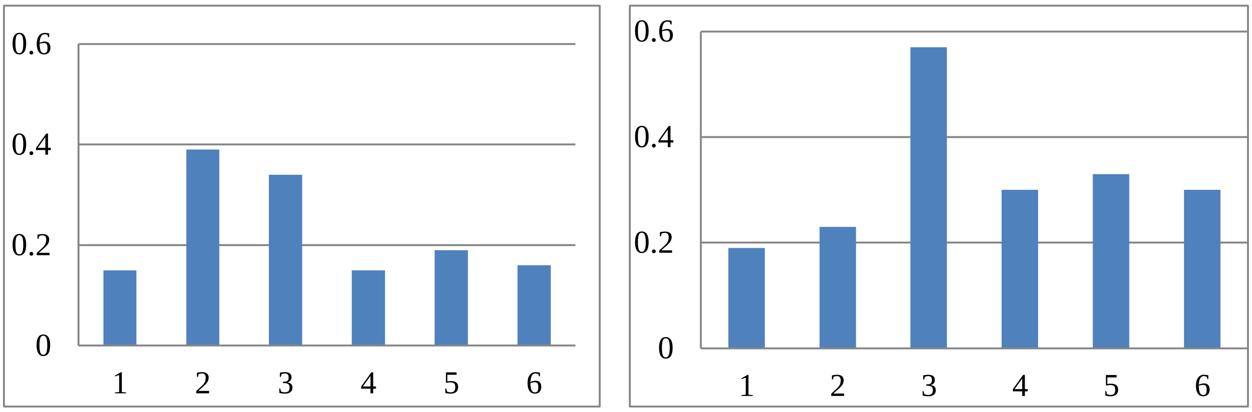


Figure 5 shows relatively new index of water quality for Ukraine – phosphate-ion. It was not until 2017 that this indicator was measured and considered. The numbers 1-6 represent reservoirs of Dnipro Basin. Left graph represents phosphate-ion level for July 2017 and right graph represents January 2018. From the start of measuring this substance only rose.

Kremenchuk water reservoir (number 3) shows the highest concentration of phosphate-ions in water. Although its concentration is still low, phosphate-ion has a dangerous property: when in low concentration it intensifies photosynthesis of algae, in high concentration it leads to eutrophication of the whole reservoir.

The next stage is regression analysis that shows results of calculations for each investigated substance. The calculations have an error of approximately 17% which allows the usage of this method for estimating future results.

Table 4 Calculated values of the free unit and the coefficient of regression for dissolved oxygen, water chromaticity, and chemical oxygen demand

	Dissolved oxygen	Chromaticity	Chemical oxygen demand
a_0	8,75014	32,2143	21,43577
a_1	-0,06088	0,45419	0,291998

The results show calculated coefficients for dissolved oxygen, chromaticity, and chemical oxygen demand. With these coefficients it is possible to calculate possible changes in concentration of the mentioned substances.

After the regression analysis goes analysis of environmental hazards.

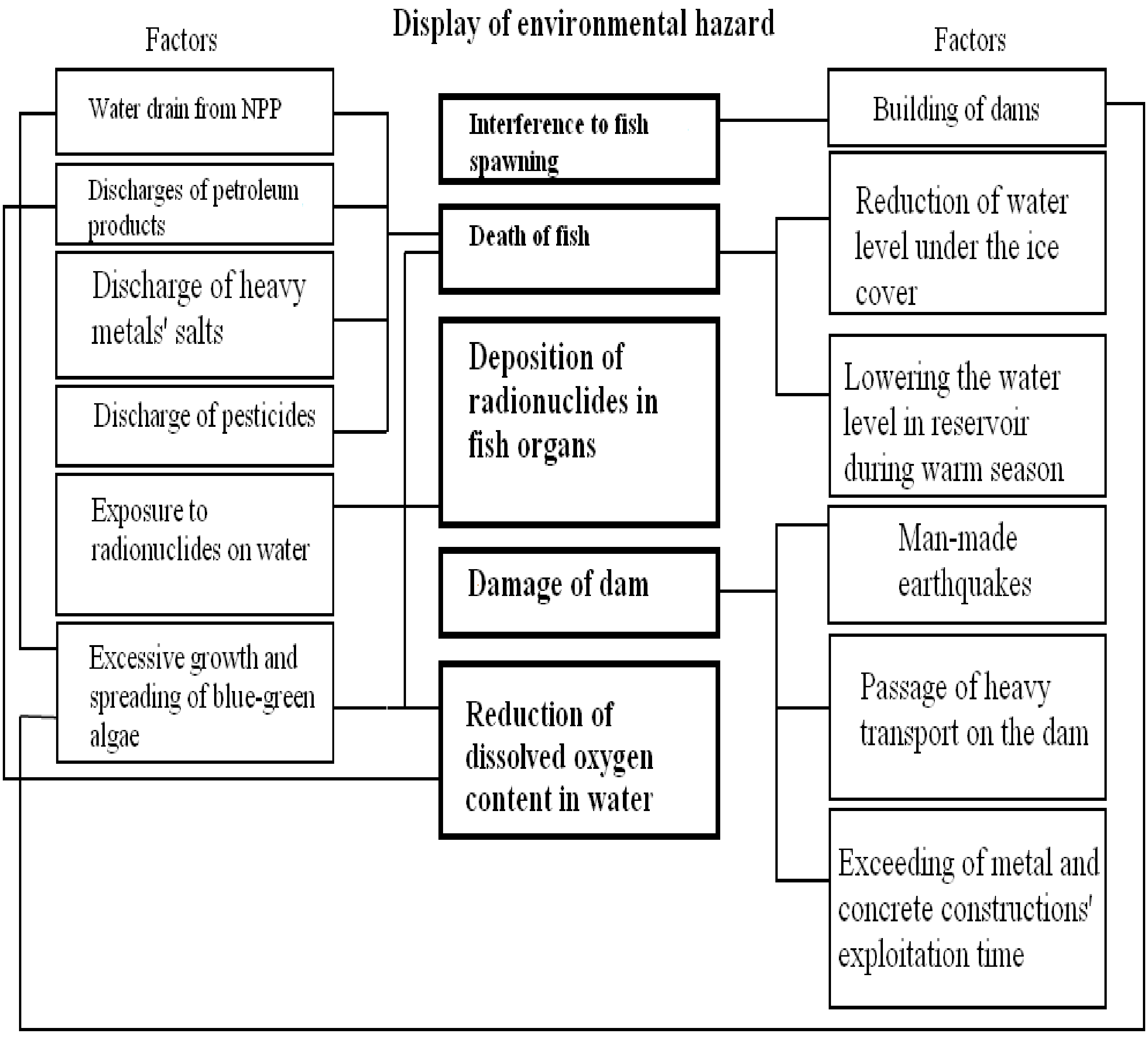


Figure 6 Factors of environmental hazards

Figure 6 displays the environmental hazards and the factors that cause them. On this scheme there are complex interconnections between the factors. For example, most of the factors influence the excessive algal growth and spreading of blue-green algae. The growth of algae in its turn influences the rates of environmental hazards like death of fish and reduction of dissolved oxygen content in water.

As the blue-green algae do not need a connection with bottom of the reservoir, they are not affected by the depth of reservoir. For that reason depending on wind direction, blue-green algae can change their placement which creates suitable conditions for their progressive reproduction. The density of cyanobacteria is slightly smaller than the density of water so the algae after storms quickly recover their position in surface layers of water, where they consume solar energy and grow intensively. With such conditions the blue-green algae rapidly create thick surface layer of algae and it lowers coefficient of sunlight. This phenomenon causes additional heating of the surface water layer, where the most of blue-green algae are concentrated, so the process of their development gets even faster.

For this reason there is a need to collect blue-green algae from water in order to prevent excessive algal bloom and to reduce the threat of situation worsening. As a result, here presented is the model of an installation for natural reservoir cleaning. Work title "**Swan**".

The installation for mechanical and biological water treatment can separate algae, dirt, and garbage directly from water. It is completely self-portable. This device collects blue-green microalgae continuously by using a water flow produced by a pump that works at the expense of diesel engine. The water with algae, dirt, and garbage is drawn into the filters that can intake 100 000 liters of water per hour each. The prototype has in its construction two of those filters. Optionally there could be three filters of this type or 4 smaller, which can operate with 50 000 liters of water per hour. But, depending on volume and size of filters size of the swan can variate as well.

When water flows into the filter, first obstacles in its way are ultraviolet light lamps that process the algae to disassemble it from harmful bacteria and to stop their operation. Next step is to separate water from disassembled algae, dirt, and garbage. This mission is accomplished by filtrating band, which can separate particles of size up to 1 micron. When the rate of water flow decrease because of too many algae particles the band cleans itself. The algae then are transported into the container to be further transported to biogas producing plant.

When the band is clean the water starts to flow again at high velocity. The operation of band cleaning takes about 10 seconds. After the band filter water gets into a compartment with useful bacteria. This process is needed to make water clean and suitable for aquatic organisms to live in. When water is exposed to ultraviolet lamps, all the bacteria there die, including not only harmful, but useful ones too. So, there is logic in inhabitance of water with new healthy useful bacteria. After bacteria saturation, water is let out back into water reservoir.

The device has a form of a swan so that it won't scare the birds off. The back of the swan can be easily opened to get the collected algae out of the container. This approach allows to extract the algae from the device is short time and with no need of putting it out of water. Due to the compact construction, the device can be easily moved from one location to other with the power of engine, situated in the body of the swan.

The beak of the swan can be used for garbage and macro algae collection from the water surface. In shallow water reservoirs like ponds of small lakes the swan's beak can be used for bottom cleaning, for extraction of algae from lower layer of water and from bottom, and for deepening the bottom of water reservoir. Also, the head of swan can be easily interchanged on variable head which does not perform any of those actions. It would be better used in large water reservoirs, where its service is not required due to great depth. Change of the head from one type to another should be held on land in order to prevent any kind of injuries and damage of the equipment.

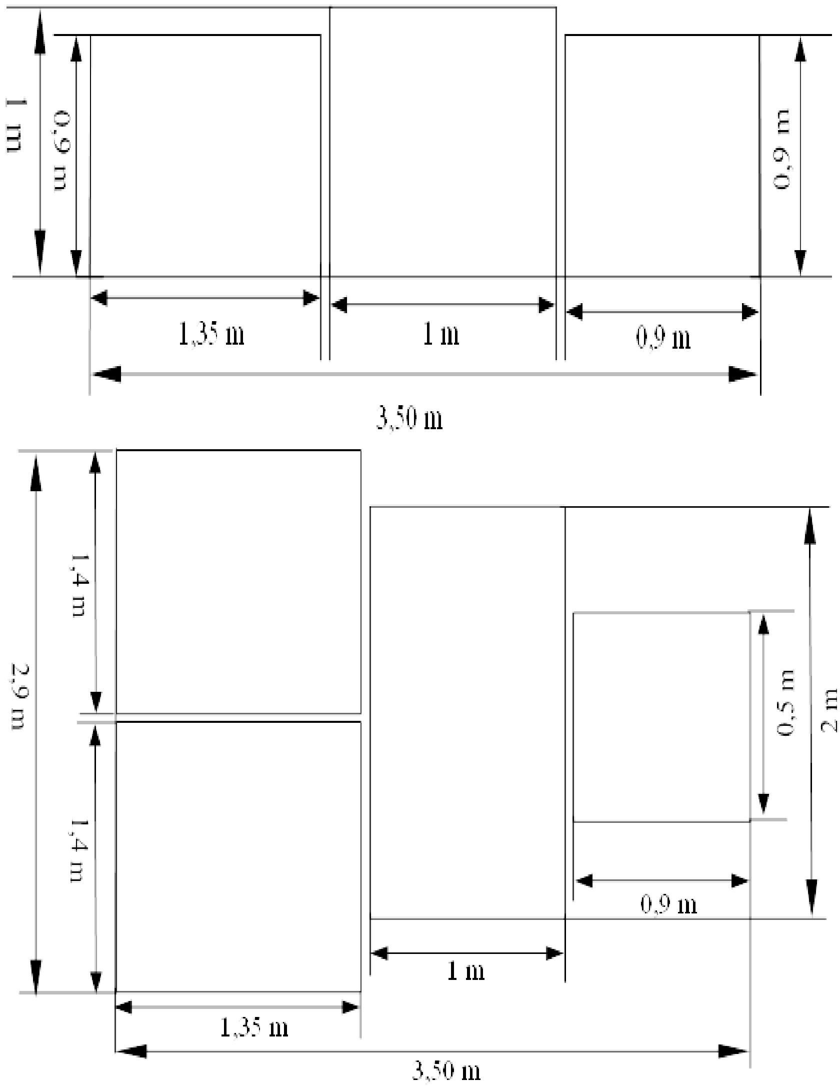
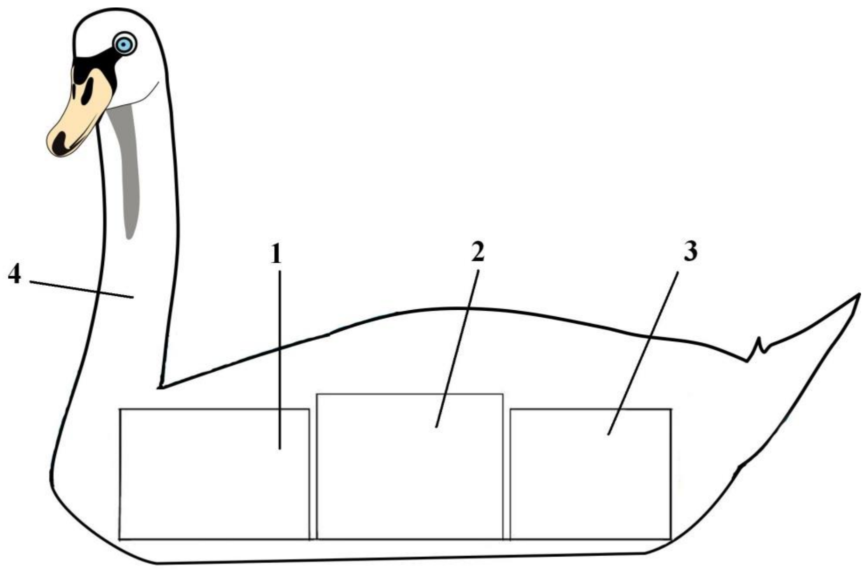


Figure 7 shows scheme of installation from the inside, without its covering hull from top view and side view. From the inside the device looks at it is shown in the figure. The disposition of the swan's insides from head to tail is as follows: head with a beak (in one or another variation), the body of swan starts with two filters situated side by side with water intake from front part, right behind them lays the container for algae collection, made out of plastic to increase its buoyancy, and then follows the engine that performs several functions (it makes the "swan" move, it triggers the pump to life, enables the head and ladle's movement). Figure 8 shows the "Swan" with its covering hull.

It is clear that between filters and the container there are connecting pipes and between the engine and the pumps (in the filters) also connecting accessories, and when the functioning head of the swan is attached, it is also connected to the engine via appliances. The connections are secured and protected from mechanical damage and wearing out. The space between the parts of the apparatus has to be filled in with superlight material, but it doesn't have to be some specific material. The only requirement is that it should not cause rust of the metal parts.



There can also be constructed smaller swans for specific needs for example, only with container and engine (in this case the engine would be smaller because there would be no need in the whole construction). It can be used for collecting the gathered algae from the bigger swan to displace it to the shore, where the algae can be transported to plant for biogas production (or some other needs).

There are different areas of microalgae usage. For example a biogas production can be one of them. There are facilities that process the algae under anaerobic conditions, but they need to grow the algae in specific ponds while natural water reservoirs are tormented with suitable algae for biogas production. The scientists from Kremenchuk Mykhailo Ostrohradskyi National University have already developed a station that produces biogas from algae. As an option, collected algae can be used for further research in universities. Also, they can be used for experiments and study of new professions of the industry.

The algae as well can be used as fertilizers. Algae are full of nutrients, so they are perfect fertilizers and they are completely organic and don't pollute soils with chemical compounds. Another way of using algae is supplements for immunity improvement and in cosmetology to improve state of skin and hair. Ukrainian concern Naturalissimo produces pills and dry powder of Chlorella and Spirulina as a source of vitamins, antioxidants and lots of other useful nutrients for health and beauty. In this way the effect from the "Swan" increases.

The **fourth section** contains development of methodology for determining measures to improve water quality.

In order to designate the measures for improving the quality of water in reservoirs, here is proposed the method of "choosing the best alternative". This method allows execution of a comparative analysis of alternative measures using enumeration which includes technological parameters and organizational measures, provided with norms. The best one is such alternative value that has the highest validity coefficient ($W_j \geq 0$ if $\sum_{j=1}^{n} W_j = 1$).

The algorithm of such task includes number of steps:

1) The next conditions for construction of alternative selection function which:

$$\mu_{\mathrm{Ri}}(x_{i,}x_j) = \begin{cases} 1, x_i > x_j, x_i \approx x \\ 0 \end{cases}; \qquad (1)$$

with $\mu_{\mathrm{Ri}}(x_{i,}x_j)$ as alternative selection function R_i (characteristic function, which has values from 0 to 1);

0 – the criteria does not have value;

1 – the criteria does have value.

2) Construction of obscure relation Q_1, which is a crossing of incoming alternatives (first convolution)

$$\mu_{Q_1}(x_{i,}x_j) = \min(\mu_{R_1}(x_{i,}x_j),..,\mu_{Rm}(x_{i,}x_j)); \qquad (2)$$

3) Definition of strong advantage Q_1^s, which is a degree, according to which the alternative x_i is better than x_j and the function of belonging:

$$\mu_{Q^s_1}(x_{i,}x_j) = \max(0, \mu_{Q_1}(x_{i,}x_j),..,\mu_{Qi}(x_{i,}x_j)); \qquad (3)$$

4) Definition of the set of non-dominant alternatives for the first convolution $\mu^{нд}{}_{Q_1}$:

$$\mu^{нд}{}_{Q_1}(x_i) = 1 - \max \mu_{Q_1^s}(x_i, x_j); \qquad (4)$$

5) Definition of second convolution:

$$\mu Q_2 = \sum_{j=1}^{n} W_j R_j, \qquad (5)$$

and the function of dependency is constructed:

$$\mu_{Q_2}(x_i, x_j) = \sum_{j=1}^{n} W_j \mu_{Rj}(x_i, x_j); \qquad (6)$$

6) Similarly, non-dominant alternatives are defined by the second convolution $\mu^{нд}{}_{Q_2}(x_i)$ and the function of dependency is constructed;

7) Non-dominant alternatives are defined by the second convolution;

8) Non-dominant alternatives are defined by the two of convolutions and the cross of first and second convolution is taken;

9) The best is such alternative *x_0*, for which the degree of non-domination by the two of convolutions is maximal:

$$\mu_{Q^{íä}}(\mathrm{x}_0) = \max \mu_{Q^{íä}}(\mathrm{x}). \qquad (7)$$

The solution of multi-criteria task via the method of choosing the best alternative, in the condition of lack of information allows numeral estimation for the probability of enormous uncontrolled algal growth appearance because of one or another reason and according to that, recommend the best available measures or means to increase the water quality.

Table 5 Criteria and alternatives for the reasons of water quality lowering in water reservoirs

Criteria	
R_1	Water quality decrease
R_2	Uncontrolled algal growth

R_3	High concentration of organic matter in water
R_4	Violation of self-purification processes
R_5	Intentional lowering of water level during warm season
	Alternatives
x_1	Better treatment of discharged sewage
x_2	Population of herbivorous fish
x_3	Use of algae cleaning apparatus
x_4	Increase of saprobiont population
x_5	Control of water level during warm season

Table 5 lists criteria and alternatives for the reasons of water quality lowering in water reservoirs. The criteria of choice are marked with *R* and according number. The alternatives are marked with *x* and according number

One of the main stages of this method is construction of advantages of the first convolution. For the first criterion R_1 relation of advantages by alternatives can be described as follows: the most influence it has on sewage quality, population of herbivorous fish, and on saprobiont population. Other alternatives have less influence (Table 6). This relation can be written as follows:

$$\boldsymbol{R_1: x_1 \sim x_2 \sim x_4 > x_3 \sim x_5} \quad (8)$$

Table 6 Matrix for criterion R_1

x_1/x_j	x_1	x_2	x_3	x_4	x_5
x_1	1	1	1	1	1
x_2	1	1	1	0	0
x_3	1	1	1	1	1
x_4	1	1	1	1	1
x_5	0	0	0	0	1

With the formula 5 for the definition of the strict alternatives and the set of small-scale alternatives for the first convolution $\mu_{Q1}(x_i, x_j)$ are defined.

Basing on the received data there were determined the dependency of dominant alternatives, constructed of dependency function, and determined the set of non-dominant alternatives.

Table 7 First convolution $\mu_{Q1}(x_i, x_j)$

x_1/x_j	x_1	x_2	x_3	x_4	x_5
x_1	1	0	0	0	0
x_2	0	1	0	0	0
x_3	0	0	1	0	0
x_4	0	0	0	1	0
x_5	0	0	0	0	1

The next stage defines dominant advantages of the alternatives (measures for improving the water quality) and sets the load of non-dominant alternatives from the first convolution $\mu_{Q2}(x_i, x_j)$

The set of non-dominant alternatives is defined along with the function of dependency. After that the set of non-dominant alternatives is determined on basis of two convolutions and function μQ_{ND}

Table 8 Matrix for determination of non-dominant alternatives μQ_{ND}

x_i/x_j	x_1	x_2	x_3	x_4	x_5
x_1	0	0	0	0,7	0,9
x_2	0,75	0	0	0,8	0,6
x_3	0	0	0	0,85	0
x_4	0	0,75	0	0	0,75
x_5	0	0	0	0,5	0
μQ_{2ND}	0,25	0,25	1	0,25	0,25
μQ_{1ND}	1	1	1	1	1
μQ_{ND}	0,25	0,25	0,85	0,25	0,25

Table 8 and Figure 8 show that received results of alternatives characterize the index of viability for the reasons of water quality decrease. The best out of them is x_3 use of an apparatus for removing the algae from water, because it has the highest coefficients of viability $fQ_{н.д.}$. This means that if using the apparatus for algae removal from water, better result can be achieved.

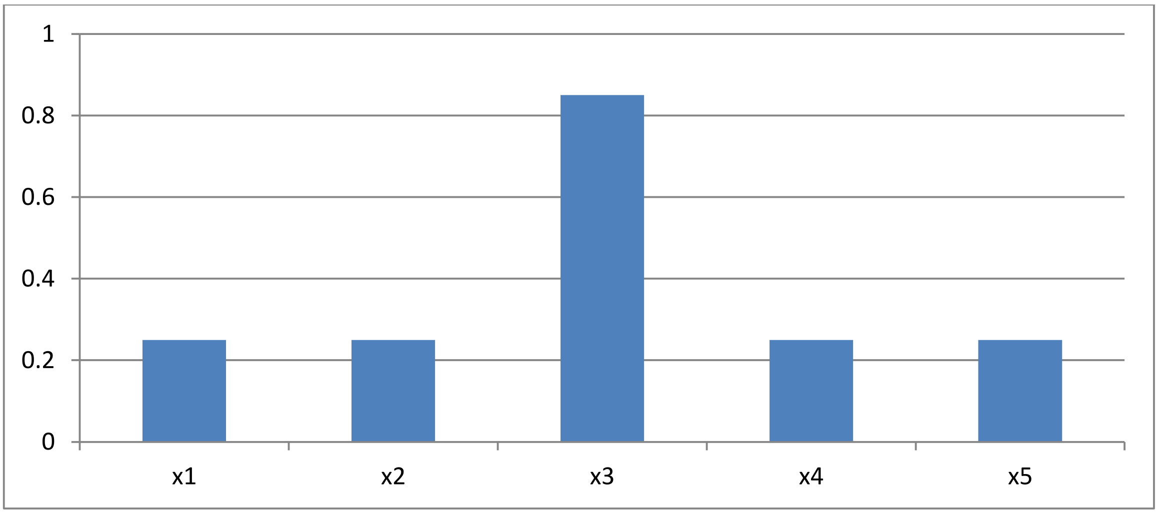


Figure 9 Function value according to all the alternatives: x_1 – sewage treatment, x_2 – population of herbivorous fish, x_3 – use of algae cleaning apparatus, x_4 – population of saprobionts, x_5 – control of water level lowering during warm season

So, in order to choose and justify the measures that will ensure increasing of water quality in natural water reservoirs, there was carried out comparative analysis to determine the viability of alternative suggestions using a list of parameters and measures to search the best alternatives.

Economic effectiveness of modelled measures is calculated with the indicator of the overall economic efficiency of environmental protection expenses. This indicator is used when justified structure and volumes of environmental protection measures (including construction of environmental protection objects) and amount of capital investments of environmental protection purposes.

The main value of this indicator and also pure economic effect of environmental protection measures have for substantiation of project decision and for object of given type and capacity.

The effectiveness of the expenses is determined basing on the environmental protection substantiation stages and in process of results estimation for environmental protection program tasks and regional usage of natural resources on certain territory. There are three approaches to determining the economic effectiveness of environmental expenses:

a) Basing on expenses minimization of determined expenses;

b) By comparison of the expenses with normal state of environment;

By comparison of the expenses with the valuation of distorted economic losses (calculation of total economic efficiency);

Due to lack of ecological standards' scientific development and to high practical cost of their achievement this approach hasn't got widening, though it is the most suitable for environmental protection activities aims from ecological point of view.

The most widespread approach is the one that allows fully enough take into account social and economic consequences of contamination by the way of comparison the expenses for environmental protection measures and its results, it allows to study deeper the expenses and losses and in such way estimate the economic effectiveness of environmental protection activity. This approach enables taking into account the expenses for reimbursement of ecological harm as inevitable production expenses.

Pure economic effect of environmental protection measures is determined aiming the justification of technical and economic choice of the best alternatives which differ among themselves by influence on environment and by influence of production results of the industries and subject of economic activity. The determination of environmental protection measures' pure ecological effect bases on comparing the expenses for their implementation to achieved result through these measures.

But because of the situation, where for calculation of ecological and economic effect there is a need in operating installation which is impossible at this stage of investigations. This is why considered above approaches are unavailable.

But there is a way to calculate the ecological and economic effect of the developed model of the installation. The formula of economic effect should be used. The empirical formula of economic effect looks as follows:

$$\mathbf{E=a_1*x_1+a_2*x_2+\ldots+a_i*x_i+a_n*x_n} \quad (9)$$

With:

a_i – average cost of yearly deposit (of the implemented measure) in *i* direction of measure completion, i.e. the average increase of pure income per year provided by this measure (using method of expert evaluation);

x_i – amount of possible in *i* direction.

Table 9 shows approximate change of water quality indexes for pessimistic scenario and for optimistic scenario.

Table 9 Change of water quality indexes for pessimistic scenario

Place	**Date of probe**	**t,°C**	**Factual main indexes of water quality**			**Values of main water quality indexes at 10%**		
			Dissol-ved O_2, mgO_2/dm^3	**Chromaticity, ° PCS**	**COD, mgO/dm^3**	**Dissol-ved O_2, mgO_2/dm^3**	**Chromaticity, ° PCS**	**COD, mgO/dm^3**
Norm	SRN №4630-88		***≥4,0***	***-***	***15***	***≥4,0***	***-***	***15***
	ESWO from 2012		***-***	***-***	***50***	***-***	***-***	***50***
Ros	*07.2017*	***23***	***7,7***	***12,6***	***25,2***	8,47	11,34	22,68
	08.2017	***27***	***5,6***	***18,5***	***36,4***	6,16	16,65	32,76
Ros	*07.2017*	***23,2***	***7,1***	***14,7***	***24,8***	7,81	13,23	22,32
	08.2017	***27***	***5,4***	***17,2***	***40,5***	5,94	15,48	36,45
Ros	*07.2017*	***24***	***5,4***	***32***	***39***	5,94	28,8	35,1
	08.2017	***24,5***	***3,9***	***39***	***41***	4,29	35,1	36,9
Sokyrne w.	*07.2017*	***23***	***6,9***	***50***	***20,1***	7,59	45	18,09
	08.2017	***25***	***4,4***	***55***	***30,6***	4,84	49,5	27,54
Svitlo-vodsk	*07.2017*	***23***	***7,2***	***50***	***29,1***	7,92	45	26,19
	08.2017	***25***	***5,8***	***54***	***34***	6,38	48,6	30,6
Kremen chuk w/i	*07.2017*	***22***	***6,56***	***40***	***39,5***	7,216	36	35,55
	08.2017	***25,3***	***6,7***	***59***	***36***	7,37	53,1	32,4

On the table we can observe calculated results of installation operations. Basing on it we can theoretically estimate operation of the installation. Before getting any income, there is a need of constructing the installation from the existing parts. For construction of the "Swan" we need 2 filters SmartPondFilter EBF-1200G ($900m^3$), one diesel engine Кентавр 4L22BT (35 HP), container, and hull (Table 4.16).

Table 10 Expenses on the installation construction

№	*Nomination*	*Model*	*Cost, UAH.*
1	Filter	**SmartPondFilter EBF-1200G (900m³)**	801,590
2		**SmartPondFilter EBF-1200G (900m³)**	801,590
3	Engine	Кентавр 4L22BT (35 HP)	51,424
4	Hull	(average cost of the sized hull)	520,000
5	Construction of the installation	20% from total cost of the components	330,920.8
6	Total		2,505,524.8

All the constituents chosen are the best alternatives between the offered on the market by few parameters: volume (amount of water let through the filter per hour), its physical parameters (length, width, and height), the presence of an ultraviolet lamp, whether the pump is built-in or not, and the price of the filter). The comparison was held out between 3 models of filters that were the most suitable for using in the installation. Namely there were: Smartpond Filter EBF 1200G, Smartpondfilter EBF-500G, and Pondtech Filter 130i. The comparison of the different filters is shown at the Table 11.

Table 11 Comparison of different types of filters

Model	**Smartpond Filter EBF 1200G**	**Smartpondfilter EBF-500G**	**Pondtech Filter 130i**
Volume l/h	100,000	30,000	25,000
Dimensions, (L x W x H) mm	1350 x 1400 x 890	1350 x 720 x 890	1150 x 760 x 740
UV lamp	+	+	+
Built-in pump	+	+	-
Price, *UAH*	801,590	559,300	66,419

From the table it is clear that the optimal option at this stage is the Smartpond Filter EBF 1200G filter, because its technical characteristics are the best out of the considered models and the maintenance of this filter is included in its price.

CONCLUSIONS

1. The main problems of hazardous situation in Dnipro reservoirs are: discharges of under treated industrial sewage, household sewage water, increase of organic matter amounts, lowering the water level of reservoir during warm season, active uncontrolled growth of blue-green algae.
2. The solution of multi-criteria task via the method of choosing the best alternative in the condition of information lack allows numerical estimation for the probability of enormous uncontrolled algal growth appearance. Because of one or another reason and according to that, recommend the best available measures or means to increase the water quality.
3. The proposed method allows identification of the process or parameter that can cause hazardous situation in water reservoir. The minus of this method is there is need to determine weighing factor for every specific point. On the other side this helps to estimate more precisely the reasons of possible hazards' appearance of lowering the water quality occurrence, and accordingly fitting measures to solve the problem.
4. The expert valuation method showed two scenarios for installation implementation – pessimistic and optimistic. In case of pessimistic outcome the

effectiveness will be 10%. In case of optimistic scenario it will gain 17% effectiveness.

5. Water resources of Ukraine consist of surface and groundwater. Surface waters cover 24, 1 thousand sq. km or 4% of Ukraine's territory. These reservoirs include rivers, lakes, reservoirs, canals, rates, etc. The most important water objects are rivers. Ukraine has 63119 rivers, including 9 large, 87 medium and 63029 small rivers.

6. The main water users on the Dnipro are: industry and utility, power engineering, water transport, agriculture (irrigation), fish farming, medical and preventive facilities of health care. All the branches put their requirements to the reservoirs' work regimes, which often are opposite one to another. All the users contribute to water pollution by discharging their wastes into the water.

7. The Ukrainian legislation has a large number of laws regarding water protection and regulations of water quality. The water quality is regulated by a number of State Laws, but most of them have less rigid than European ones.

8. Alignment on Ukrainian water legislation and European Union laws and directives require undertaking some serious steps like development of the Amendments to the Water Code of Ukraine aimed at direct action norms in the Code an taking into account advanced regulatory provisions of the EC legislation, development of specific Laws and Regulations, and some others.

9. 5. To start making difference in water quality in Ukraine it is not enough to make laws. Today's state of water resources of Ukraine is unpleasant. So, to make some difference there is a need in mechanical water treatment in order to purify water from already existing pollutants, garbage, and algae that contaminate water.

10. Mechanical cleaning of water is a type of water treatment used for filtrating wastewater, sewage or algae-polluted water. Mechanical cleaning means that in order to make water clean no chemical or biological substances are used. There are three basic types of mechanical cleaning of liquids: sedimentation, floatation and filtration.

11. . Certain type of water treatment devices perform mechanical water cleaning only in shallow ponds or reservoirs. The other ones can collect garbage and algae from the surface only. The third group of such devices can perform irradiation of algae in water via ultraviolet light to disassemble it from harmful bacteria and algae. There is also a group of devices that filter the algae from water.

12. There are great numbers of such devices, but none of them can combine filtration of the algae to prevent water from the algal bloom, ultraviolet irradiation of bacteria and collection of surface garbage at once and to contain it in the process of the apparatus' work. This is why it is vital to consider such installation.

13. The official data shows negative tendency of water condition in general. This means that water in Ukraine is not getting cleaner. In fact it is opposite to pure. State standards cannot control all the pollutants that industries discharge into rivers, because a lot of them are not specified in these standards. Apart from that the standards that are indeed list some of the pollutants have too high threshold discharge limit. All the European countries have more strict limitations and standards. Ukrainian waters are too polluted to clean themselves.

14. Hydro-chemical analysis of the surface waters state showed that factors that influence hydro-chemical water state are: anomalous temperature conditions; lack of snow and heavy precipitations; lack of floods. Such situation did not contribute to the processes of passing and finishing self-cleaning water, reducing its increased pollution from last year reducing the intensity of processes that affect the qualitative state of water and seasonal changes and seasonal fluctuations of quality indicators.

15. Excessive and uncontrolled growth of algae or other aquatic plants may provide very high concentration of dissolved oxygen, it is so-called supersaturation. On the other hand, oxygen deficiencies can occur when plant respiration depletes oxygen beyond the atmospheric diffusion rate. This can occur especially during the winter ice cover period and when intense decomposition of organic matter in the reservoir bottom sediment occurs during the summer.

16. The ability of the reservoir to self-cleaning is a lot lower than it should be. For that reason water in Kremenchuk reservoir can be considered as ditch water, which means that the flow of water is so low, that it can't provide the reservoir with strong enough flow to help it accelerate the process of self-cleaning. For that reason there is a need to help nature with restoration of good water quality. There are quite a few different methods of water treatment, but not all of them are suitable to be applied in natural water reservoir.

17. Water in the Kremenchuk water reservoir needs immediate interference because of its state. With every year water only gets worse, which causes serious diseases of people and aquatic organisms. It can cause even death of valuable fish species.

18. The usage of an installation for reservoir cleaning will improve the ability of the reservoir to self-cleaning. If the installation is implemented before the period of algal bloom starts, significant changes in water quality can be achieved even after one year of operation, which will be enlarged with every year after.

The extracted algae can be further used for biogas production, for cosmetology and health care, in food industry, and as a source of nutrients in agriculture, not to mention benefit of algae removal from water for fish and other aquatic organisms.

SUMMARY

O. Tymoshchuk. Justification for implementation effectiveness of an installation for natural reservoir cleaning. – Manuscript.

Thesis for obtaining the Degree of Master in specialty 101 - «Ecology» - National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute» MES of Ukraine, Kyiv, 2018.

Master's thesis is devoted to investigation of the water reservoirs contamination processes and justification for implementation effectiveness of an installation for natural reservoirs cleaning, and to development the water reservoirs cleaning device model.

In this work there were carried out analysis of Ukraine natural water reservoirs' state and water quality problems, analysis of existing technologies and equipment for cleaning water from algae, analysis of factors that influence algae growth in natural

water reservoirs, justification for selection of certain method for cleaning water with development of installation project, justification for implementation effectiveness of an installation for natural reservoirs cleaning.

There were established dependence of blue-green algae growth on the main indexes of water quality (chromaticity, chemical oxygen demand, phosphate-ions, and dissolved oxygen) and temperature. The equation for calculation the effect from the installation has been received, and basing on it the effectiveness of installation operation received varies from 10 to 17%. The implementation effectiveness of an installation for natural reservoirs cleaning is justified as a result of scientific research. The model of an installation for mechanical water reservoirs cleaning from algae is developed with taking into account the results of analyses and research. Approximate cost of the installation is 2,5 million hryvnias.

Key words: water quality indexes, water reservoirs, water treatment, equipment for water treatment, blue-green algae, surface waters, environment, water pollution, water quality, water.

АНОТАЦІЯ

Тимощук О.С. Обґрунтування ефективності впровадження установки для очищення природних водойм. – Рукопис.

Дисертація на здобуття освітньо-кваліфікаційного рівня магістра за спеціальністю 101 – «Екологія» – Національний технічний університет України «Київський політехнічний інститут ім. І. Сікорського» МОН України, Київ, 2018.

Магістерська дисертація присвячена дослідженню процесів забруднення водойм, обґрунтуванню ефективності впровадження установки для очищення природних водойм та розробці моделі пристрою для очищення водойм.

В роботі проведено аналіз стану та проблем якості води у водоймах України, аналіз наявних технологій та обладнання для очищення водойм від водоростей, аналіз факторів, які впливають на ріст водоростей у водоймах, обґрунтовано вибір конкретного методу очистки вод з розробкою проекту установки, обґрунтовано ефективність впровадження установки для очищення природних водойм.

Встановлено залежності росту синьо-зелених водоростей від основних показників якості води (кольоровості, хімічного споживання кисню, фосфат-іонів, та розчиненого кисню) та температури. Отримано рівняння для обчислення ефективності установки, і на його основі отримано результат, що ефективність впровадження установки коливається від 10 до 17%. Ефективність впровадження установки для очищення природних водойм обґрунтовано. Модель установки для механічного очищення водосховищ (водойм) від водоростей розроблено. Орієнтовна ціна установки складає приблизно 2,5 мільйона гривень.

Ключові слова: показники якості води, водосховища, очищення води, обладнання для очистки води, синьо-зелені водорості, поверхневі води, навколишнє середовище, забруднення води, якість води, вода.