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Spis treści

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Ocena potencjału ekologicznego: poszukiwanie konstruktywnych podejść

Assessment of ecological potential: the search of constructive approaches

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Streszczenie

Ramowa dyrektywa wodna UE określa ocenę stanu ekologicznego obiektów naturalnych na podstawie podejścia porównawczego. Porównania dokonuje się z tak zwanymi warunkami referencyjnymi. Zaleca się również określenie potencjału ekologicznego (w rzeczywistości - także stanu ekologicznego) sztucznych i silnie zmodyfikowanych zbiorników wodnych na podstawie podejścia porównawczego. Ale jest całkowicie niejasne, co i jak wybrać jako punkt odniesienia dla porównania. Proponujemy ocenę potencjału ekologicznego na podstawie porównania z zestawem warunków akceptowalnych oraz środowiskowym i technicznym (ZWET). Stosowanie zasad RDW stawia kilka praktycznych pytań. Jaki zestaw warunków można traktować jako odniesienie dla różnych typów zbiorników? Ile parametrów trzeba ocenić? Jaki jest algorytm porównania? Autorzy starają się odpowiedzieć na te pytania i zaproponować praktyczne zalecenia.

Abstract

The EU Water Framework Directive prescribes an assessment of the ecological status of natural objects on the basis of a comparative approach. The comparison is made with the so-called reference conditions. It is also recommended to determine the ecological potential (in fact - also the ecological state) of artificial and heavily modified water bodies on the basis of a comparative approach, but it is completely unclear what and how to choose as a benchmark for comparison. We propose to assess the ecological potential on the basis of comparison with a set of Environmentally and Technically Acceptable Conditions (ETAC). Applying the principles of the WFD poses several practical questions. What set of conditions can be taken as a reference for different types of reservoirs? How many parameters do you need to have to evaluate? What is the comparison algorithm? The authors attempt to answer these questions and offer practical recommendations.

INTRODUCTION

At the end of the first half of the twentieth century, Vernadsky V. I. pointed out to several important aspects of human influence on the biosphere (Vernadsky, 2012). In the mid-1930s, the author of the ecosystem concept, A. Tansley (Tansley, 1935) believed that besides natural ecosystems, there are also anthropogenic ones. He considered them along with the natural as one of the elements of the face of the Earth. Now it becomes completely obvious that the further evolution of the biosphere will occur with a permanent replacement of natural ecosystems by anthropogenic, such as agro-, urbo- and technoecosystems (Protasov, 2016). Therefore development of principles and methods of assessment of the ecological status for not only natural, but also heavily modified, as well as artificial water bodies, technoecosystems is a need.

For sanitary and technical hydrobiology, the most important problems are not only assessment the ecological status of water bodies, but also developing measures for the conservation and restoration of water ecosystems, improving the quality of water resources, creating conditions for efficient and safe operation of water bodies (Oksiyuk and Davydov, 2013).

The concept of ecological potential in the WFD. The principles of bioindication that form the basis of the EU Water Framework Directive 2000/60 / EC (Directive, 2000) methodology, environmental quality assessments by biotic indicators have a long history and are widely used in practice. Some principles of bioindicative assessments, methodology and methodological techniques that have more than 150 years history (Abakumov, 1981) which are used in the Directive, were considered jointly by scientists from Eastern European and Western countries in the 1970s. (Winberg, 1981; Woodiwiss, 1977). In particular, the principle of priority of hydrobiological indicators in environmental assessments was developed. At the same time, it should be acknowledged that the issue of assessing the state of anthropo-dependent, artificial water bodies, their ecosystems in general, has not been sufficiently elaborated.

Purpose of this work was: to propose some approaches in creating methods of assessing the state of highly modified, artificial water bodies, their ecosystems, and also water bodies of technoecosystems, taking into account environmental and technical criteria.

Classification of water bodies. In carrying out regular observations, monitoring of the ecological state, environmental assessments The Directive proposes the use of a number of key concepts, in particular, related to the classification of water bodies. These concepts include: "natural water body" or a object of natural waters (river, lake), "heavily modified water body"and "artificial water body". Differentiation of the groups of water bodies, the definition of the boundaries between them becomes necessary, as further for assessments of their state require the use of two concepts – "ecological status" for the first and "ecological potential" for artificial. At the same time, however, a question coming from general environmental perceptions arises: can such groups of water bodies and their ecosystems always be distinguished as clearly separated from each other?

It seems that concept of continuity of the basic properties of objects of surface waters not enough in the composition of the general provisions of the WFD. Water bodies may occupy a particular places in a continuous series of water ecosystems. Its can be only conditionally divided into zones of ecological continuum – from natural, not transformed by man to completely artificial.

The concept of the ecosystem continuum and anthropogenic impacts gradient. In the ecosystem continuum model (Fig. 1. a), ecosystems (№№ 1–6) we are intuitively located between the poles A (natural ecosystems, almost no human influence) and B – artificial water bodies, technoecosystems, where the influence is maximal

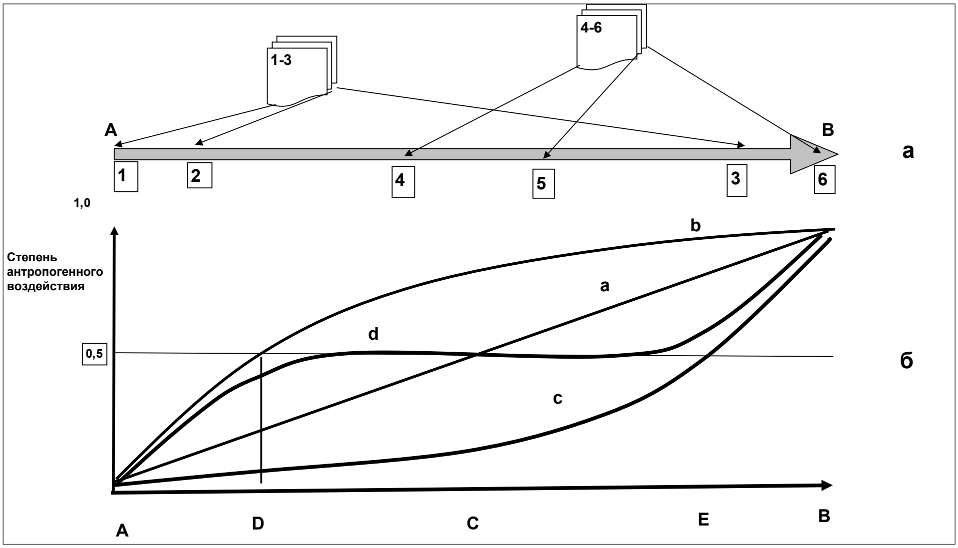

Fig. 1. Model of the ecosystem continuum, in which water bodies and their ecosystems (№№ 1–6 1–6) are located between poles A and B from natural to techno-ecosystems (according Protasov, 2018)

The degree of anthropogenic impact has a gradient nature, but the properties of this gradient are different (see Fig. 1. b). Location of a specific ecosystem in a certain part of the continuum is possible only with the conditionally determining the degree of impact. In our model, we represent it in the form of increasing from 0 to 1 (Y-axis). The value 0.5 corresponds conditional boundary between few and heavily modified until artificial water bodies (where the value is 1). Nature of the separation of the continuum into zones will depend on nature of the increase of impact degree in it. It is possible to propose several variants of dependencies (Fig. 1. b). In principle, a large number of variants of the graphic model are possible, but the presented 4 ones describe a substantial part of the variants.

The first option (a) shows only the general trend of changes in the model. The second option (curve b), as a whole, reflects the situation in many regions and even vast areas in the world with a developed system of use of water bodies. The curve c is typical for administrative and ecological regions with a much smaller pressure of anthropogenic impact. Curve d, probably describes the real situation today in many regions: the presence of a small number of undisturbed ecosystems, a large number with an average level of disturbances and a relatively small number of artificial water bodies.

For ecosystems of surface waters, WFD declares commitment to implementation the model c, although the distribution of ecosystems by type d or close to it can actually be achieved. One of the criteria for establishing the localization of ecosystems in this gradient can be a transition from two-component to three-component ecosystems: the biotic elements and natural abiotic, also include anthropogenic elements.

Assessment of the status of real natural water bodies, in fact, is a procedure for establishing their place in the ecosystem gradient, identifying a kind of "distance" from the reference ecosystem to the study one.

Ecological status and ecological potential. Returning to the proposed continuum model (in terms of model) water ecosystems of "high" (status) occupy a position near point A. Accordingly, the objects of the good and moderate status occupy some areas in the continuum, more or less distant from point A. However, and, it should be emphasized they always remain in the area of the continuum AD (model b) or AE (model c). Outside these areas, it is not ecological status that is being assessed, but ecological potential. It should be noted that the WFD does not offer quantitative estimates.

Depending on which option of the gradient of anthropogenic impact model we can apply the distribution in the zones of continuum are different (Fig. 2–4). In the first model (curve b, Fig. 2.) ecosystems 1 and 2 are located in the area of natural water bodies and the procedure of assessing of their status consists in assessing of their similarity with the ecosystem R, located as close as possible to the point A of the continuum (reference ecosystem, reference conditions, "distance" in the continuum r_1). Ecosystems 4 and 5 are located in the area of moderately and heavily modified water bodies. Ecosystem 5 can be as a "reference" for ecosystem 3 ("distance" in the continuum p_1). As for ecosystem 6, the comparison looks unreasonable ("distance" in the continuum p_2), because this ecosystem is in the area of heavily modified or artificial ecosystems.

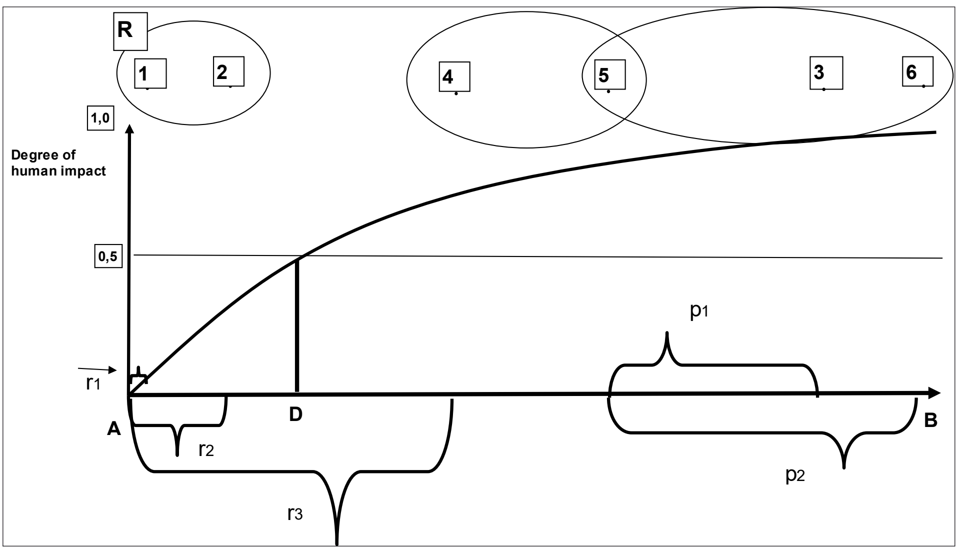

Fig. 2. The distribution of ecosystems 1–6 in the gradient of anthropogenic impact by the type b of model of the ecosystem continuum (explained in the text)

One of the documents accompanying the WFD (Common…, 2003) the algorithm for determining both the status/state and environmental potential are given. Maximum Ecological Potential (MEP) associated with values typical for the most similar type of natural water bodies.

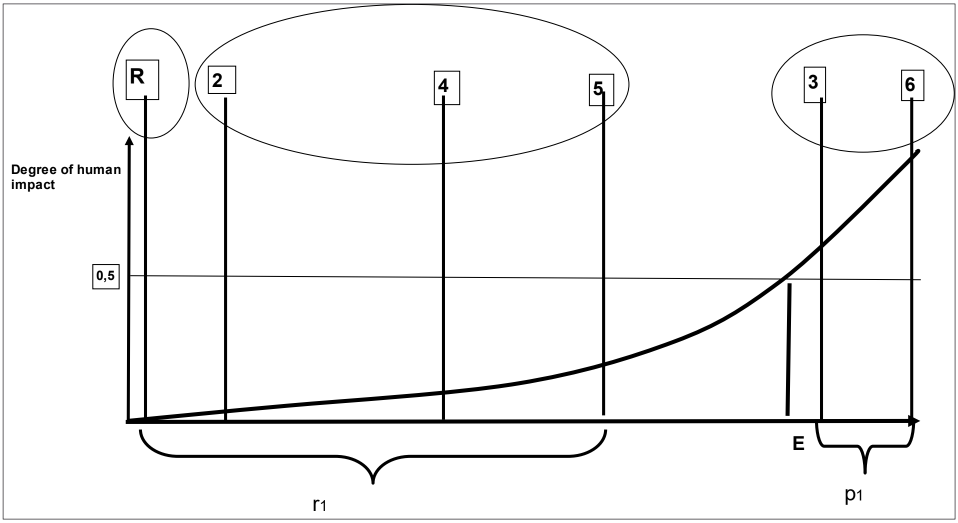

Fig. 3. The distribution of ecosystems 1–6 in the gradient of anthropogenic impact by the type c of model of the ecosystem continuum (explained in the text)

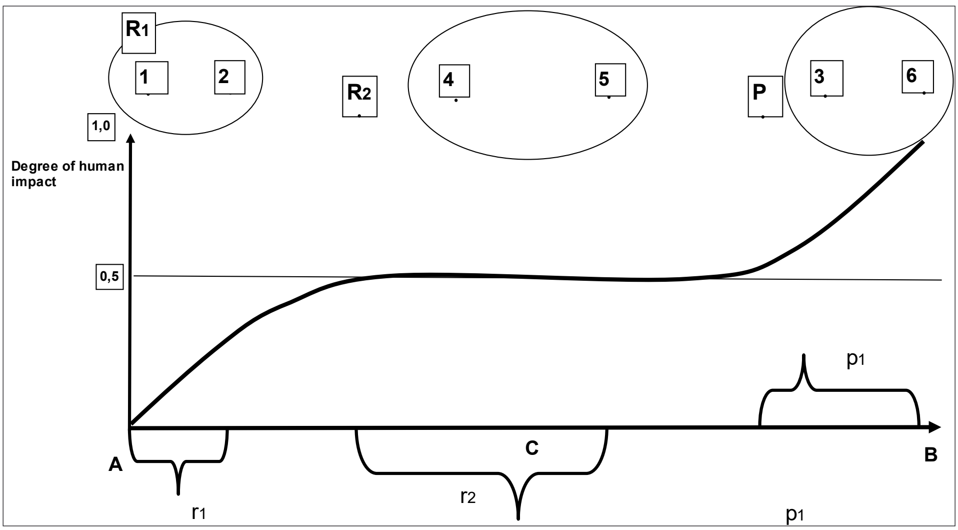

Fig. 4. Distribution of ecosystems 1–6 in the gradient of anthropogenic impact by the type d of model of the ecosystem continuum (explained in the text)

The algorithm given in (Common…, 2003) has no quantitative assessment criteria, which makes its use ineffective. The lack of quantitative assessment criteria is considered as an important feature of the classification of the ecological status of water bodies (Zhukinsky, 2006), assessments are based on comparisons with ecosystems that are considered reference.

Fundamentally, the choice of systems for comparison in assessing modified ecosystems can occur by two ways. The first is similar to the choice of reference conditions. It may consist in the choice of some technoecosystem. (but, by no means, "not similar in natural water body").

With a huge variety of natural hydroecosystems, their basic structure is quite typical, biotopic structure, biotic relationships are fairly predictable. At the same time, with the increase of the proportion of anthropogenic elements of biotopes, anthropogenic changes of the structure of biotic communities, the predictability of conditions is significantly reduced, ecosystems are becoming more and more individual, atypical, which is vividly expressed in techno-ecosystems (Protasov, 2013; 2014).

Complex acceptable ecological and technical conditions. Creating a reference complex of environmentally and technically acceptable conditions (ETAC) for techno-ecosystems, artificial and highly modified reservoirs can be a solution for assessing if it is impossible to determine natural reference conditions. Obviously, for techno-ecosystems, especially such large as HPP reservoirs, environmentally dangerous as the techno-ecosystems of nuclear power plants ETAC should be developed individually

Principles of determining ETAC. A good ecological potential will be in the ecosystem that is as close as possible in its properties and characteristics to the ETAC. The characteristics of these conditions should include three interrelated units: hydrophysical, hydrochemical, hydrobiological. For different techno-ecosystems, their priority may be different. In the first block, such hydrophysical indicators as water transparency, temperature, nature and intensity of internal and external water exchange, hydrodynamic processes are important. The second block includes pH indicators, dissolved oxygen content, the content of biogenic substances (nitrogen and phosphorus compounds), and organic substances. In some cases, the content of specific chemical compounds may be added. The third block includes biotic indicators. There is reason to believe that from ecotopic groups of hydrobionts for environmental assessments it is advisable to give preference to contour – benthos and periphyton. On the one hand, many systems of bioindication assessment are built on the organisms of these groups, on the other hand – exactly contour-bionts most often create major biological hindrances in the operation of water supply systems.

We propose for heavily modified water bodies and artificial water bodies, in particular for the water bodies of techno-ecosystems of power plants to change and modify the concept of ecological potential. According to the WFD "status", the state of natural water bodies is similar to the same concept of "ecological potential" for "unnatural". We propose a modified comparative potential assessment principle.

Definition of state indicators. The complex (matrix) of indicators proposed by us (Table 1.) includes 28 indicators in four blocks: hydrophysical, hydrochemical, biological, technical. In certain cases, as proposed and when environmental regulations are created (Romanenko et al., 2000; Methodology…, 2001), The matrix can be supplemented by a special block of indicators of specific substances of toxic and other effect. This matrix of indicators (as example) was compiled on the basis of the research experience from one water techno-ecosystem in Ukraine (cooling pond of NPP). For other objects it is necessary to make certain additions and adjustments both in the number of indicators, and in their range of values. Such a need is associated with both regional and structural-operational features.

The choice of 7 gradations is due to the need of sufficient sensitivity, as well as the practical possibility of choosing of the state variants. As can be seen from the table, a change of indicators in the direction of gradations 1–7 occurs towards a conditional "degradation" of the state, that is, the rightmost column of values describes the worst case combination of values.

Table 1. Hydrophysical and hydromorphological, hydrochemical, hydrobiological and technical indicators for assessing the ecological potential of the water techno-ecosystem (according Protasov O. O., 2018)

Gradations		1	2	3	4	5	6	7
Hydrophysical and hydromorphological indicators	Dimension							
Secchi transparency	m	≥2,55	2,50-1,55	1,50-1,35	1,30-0,95	0,90-0,55	0,50-0,25	≤ 0,20
Water exchange	V consumption per month / V water body	3,00	2,99-2,00	1,99-1,50	1,49-1,00	0,99-0,50	0,49-0,25	≤ 0,24
Temperature regime, summer	°C	Average value in the water body higher than the background value at 1-2°C	Average value in the water body higher than the background value at 3-5°C	Average value in the water body higher than the background value at 6 °C and locally < 27°C	27-29°C on ≥ 50% of water area	≥ 30°C locally	≥ 30°C in most parts of the water area	Locally ≥ 40°C
Water level fluctuations	m	≤ 0,10	0,11-0,20	0,21-0,40	0,41-0,80	0,81-1,60	1,61-3,00	≥ 3,01
Hydrochemical indicators								
Mineralization	mg/dm³	300	301-500	501-700	701-900	901-1200	1201-1500	≥ 1500
pH		≤ 7	7,1-7,2	7,3-7,5	7,6-8,0	8,1-8,5	8,6-9,0	≥ 9,1
Amonium Nitrogen	mg N/dm³	≤ 0,09	0,10-0,20	0,21-0,30	0,31-0,50	0,51-1,00	1,01-2,50	≥ 2,51
Nitrate nitrogen	mg N/dm³	≤ 0,20	0,21-0,30	0,31-0,50	0,51-0,70	0,71-1,00	1,01-2,50	≥ 2,51
Phosphorus phosphate	mg P /dm³	≤0,015	0,016-0,030	0,031-0,050	0,051-0,100	0,101-0,200	0,201-0,300	≥ 0,300
Dissolved oxygen	mg/dm³	≥ 9,0	8,9-8,0	7,9-7,0	6,9-6,0	5,9-5,0	4,9-4,0	≤ 3,9
Oxygen saturation (surface)	%	100-96	95-91	90-81	80-71	70-61	60-41	≥ 40
Permanganate oxidability	mg O/dm³	≤ 3,0	3,1-5,0	5,1-8,0	8,1-10,0	10,1-15,0	15,1-20,0	≥ 20,1
Hydrobiological indicators								
Phytoplankton biomass	mg/dm³	≤ 0,5	0,6-2,0	2,1-5,0	5,1-10,0	10,1-50,0	50,1-100,0	≥ 100,1
Filamentous algae biomass	g/m²	≤ 10	11-50	51-100	101-500	501-1000	1001-3000	≥ 3001
Zooperiphyton biomass / mobile	g/m²	≤ 200,0	199,9-100,0	99,9-50,0	49,9-20,0	19,9-5,0	4,9-2,0	≤ 1,9

Gradations		1	2	3	4	5	6	7
Zooperiphyton biomass / attached	g/m²	≤ 100	101-500	501-1000	1001-3000	3001-5000	5001-10000	≥ 10001
Number zooperiphyton groups		≥15	10-14	8-9	6-7	4-5	2-3	1
Soft zoobenthos biomass	г/м²	≥ 20,0	19,9-15,0	14,9-10,0	9,9-5,0	4,9-2,0	1,9-1,0	≤ 0,9
Number zoobenthos groups		≥ 15	10-14	8-9	6-7	4-5	2-3	1
Saprobity of phytoplankton		≤ 1,0	1,1-1,5	1,6-2,0	2,1-2,5	2,6-3,0	3,1-3,5	3,6-4,0
Saprobity of zooplankton		≤ 1,0	1,1-1,5	1,6-2,0	2,1-2,5	2,6-3,0	3,1-3,5	3,6-4,0
Saprobity of zoobenthos		≤ 1,0	1,1-1,5	1,6-2,0	2,1-2,5	2,6-3,0	3,1-3,5	3,6-4,0
Overgrowth by higher water plants (HWP)		Individual plants	Individual clusters	Clusters of plants, open water dominate	Overgr--owth of littoral 50%	Dominance of thickets over open water space on littoral	Separate areas of open water	Complete overgrowth of the littoral zone
Technical indicators								
Hindrances from invertebrates		Insignificant practically = 0	Noticeable	Low	Moderate	Strong	Emergency	Catastrophic
Hindrances from HWP		Insignificant practically = 0	Noticeable	Low	Moderate	Strong	Emergency	Catastrophic
Hindrances from filamentous algae		Insignificant practically = 0	Noticeable	Low	Moderate	Strong	Emergency	Catastrophic
Specific pollutants								
Cuprum	mg/dm³	< 1,0	1	1-2	3-10	11-25	26-50	> 50
Sulfates	mg/dm³	≤ 50	51-75	76-100	101-150	151-200	201-300	≥ 300

The composition of the blocks. Four indicators are taken from hydrophysical and hydromorphological ones. Secchi transparency is an important indicator; it is definitely related to the indicator biomass of plankton (Protasov and Novoselova, 2015) and the content of inorganic suspensions. Water exchange is one of the most important factors of the formation of water. In cooling ponds, in addition to external water exchange, internal is also of great importance, which is associated with the operation of the circulation cooling system. It is necessary to take into account the features of the relationship between indicators of temperature and water exchange: the absence of technogenic circulation is a consequence of the absence of heated discharges, which leads to a decrease of temperature. In addition, circulation flows create a peculiar heterogeneity of conditions in cooling ponds (Protasov et al., 2019).

Temperature indicator should be entered to assess the state of thermal power plants (TPP) and nuclear power plants (NPP) techno-ecosystems, but when assessing objects without technogenic thermal discharges, this indicator may be unnecessary. An increase of the temperature level above 40°C at the discharge of heated water leads to the death of most hydrobionts.

Hydrochemical indicators mainly related to the content of nutrients, as well as such an important factor as the oxygen content. Biotic indicators cover both the contour parts and the pelagic one of the ecosystem. Indicators of phytoplankton development for technical water bodies are important rather in the functional aspect: high biomass also indicates high production (to a lesser extent – low consumption by consuments). This has to do with pH change, since during intensive photosynthesis the pH values shift towards to an alkaline reaction.

The biomass index of filamentous algae is also related to the technical aspects of water body exploitation. In certain cases, during a significant development of filaments and a decrease of the phytoplankton abundance, during the period of contourization, filamentous algae can be of great importance in the overall production process.

Indicators of zooperiphyton and zoobenthos are important in two aspects: bioindication and technical. The WFD considers macroinvertebrates as important elements of bioindication of water quality and the state of ecosystems, albeit without their separation into benthic and periphytonic organisms. In addition, exactly periphyton invertebrates and benthos create significant biological hindrances in water supply systems.

The block of technical indicators takes into account the degree of biological hindrances caused by invertebrates and macrophytes. The range of indicators may be expanded in the case of the presence of a special kind of biological hindrances.

A block of specific pollutants should be formed taking into account the conditions of this techno-ecosystem, the operating conditions of this technical object.

The complex of indicators and their gradations obviously cannot be universal for different types of techno-ecosystems, anthropogenically modified ecosystems; it may have regional features.

The choice of values from the spectrum of gradations (in fact, the choice of values of ETAC for a given object) may be made on the basis of the principles of ecological desirability, on the basis of the project standards of the object, directive standards for example by environmental authorities, and also as a choice of typical indicators for a given region, type of objects, a given object or its part.

The choice of gradations for ETAC (Table 2) as an example based on the results of long-term data obtained during the study of the one techno-ecosystem of cooling pond.

Table 2. Gradations of indicators and assessment of the ecological potential of techno-ecosystem based of two years on a comparison of gradations of indicators with ETAC. (As example, some part of the indicators from Table 1 are taken)

Indicators	ETAC	values	1998	values	2006	values
Secchi transparency, m	3	1,50-1,35	4	1,30-0,95	3	1,50-1,35
pH	5	8,1-8,5	5	8,1-8,5	6	8,6-9,0
Nitrate nitrogen, mg/dm^3	2	0,21-0,30	1	≤ 0,20	1	≤ 0,20
Phosphorus phosphate, mg/dm^3	2	0,016-0,030	1	≤0,015	2	0,016-0,030

Indicators	ETAC	values	1998	values	2006	values
Permanganate oxidability mg O/dm^3	3	5,1-8,0	5	10,1-15,0	3	5,1-8,0
Filamentous algae biomass, g/m^2	3	51-100	5	501-1000	5	501-1000
Zooperiphyton biomass / attached, g/m^2	2	101-500	1	≤ 100	6	5001-10000
Overgrowth by higher water plants (HWP)	4	Overgr-owth of littoral 50%	2	Individual clusters	3	Clusters of plants, open water dominate
Hindrances from invertebrates	3	low	1	practically = 0	7	catastrophic
Hindrances from HWP	2	noticeable	1	practically = 0	1	practically = 0
Hindrances from filamentous algae	2	noticeable	1	practically = 0	5	strong
Value gradations 7	0		-		1	
Value gradations 7 and 6	0		0		2	
The sum of the estimated values of indicators (gradations)	31		27		42	
Average indicator	2,82		2,45		3,85	
Assessment of the potential regarding ETAC	1,00		1,15		0,74	
Assessment taking into account the gradations 7			1,15		0,66	
Assessment taking into account the gradations 7, 6			1,15		0,59	

As can be seen from the results of the assessment, in the first observation period (1989), the ecological potential was formally even better than the reference state for the selected indicators. In the second observation period (2006), the ecological potential significantly decreased, the state of the techno-ecosystem deteriorated. It is important to note that such an assessment was made on the basis of "bad" indicators in the technical block.

The sum of the gradations depends on their number, such comparison is correct only in case of complete coincidence of the number of indicators. Therefore, for further comparison, it is necessary to determinate the average gradation (sum of gradations / number of indicators). For a quantitative assessment and comparison with ETAC, the ratio of the average indicator for the investigated water body to the average indicator of ETAC should be calculated.

It should be noted that the indicators in their gradations are rather unequal. So, for the indicator "biohindrances", the transition from gradation 6 to gradation 7 corresponds to the transition from "emergency" bio-hindrances to "catastrophic", which is very significant, while the transition from 1 to 2 gradations ("hardly noticeable" – "noticeable") is difficult to grasp in practice. The same is applied to hydrochemical and hydrophysical indicators. Thus, temperature changes in the range up to 26-27°C are much less physiologically significant than the transition temperature to 29-30°C and more. Considering some differentiation of indicators, we propose to reduce ("degrade") the potential values by 10% if there is one gradation 7, if there are two gradations 7 - by 20%, etc. And if the one gradation 6 presence, reduce the potential values by 5%, in the presence of two gradations 6 - by 10%, etc. Thus, the assessment acquires three degrees of "optimism": without taking into account the significance of the gradations and taking into account two of them.

A graphical comparison of potentials of two years and ETAC (Fig. 5.) shows exactly which indicators go beyond the limits of ETAC.

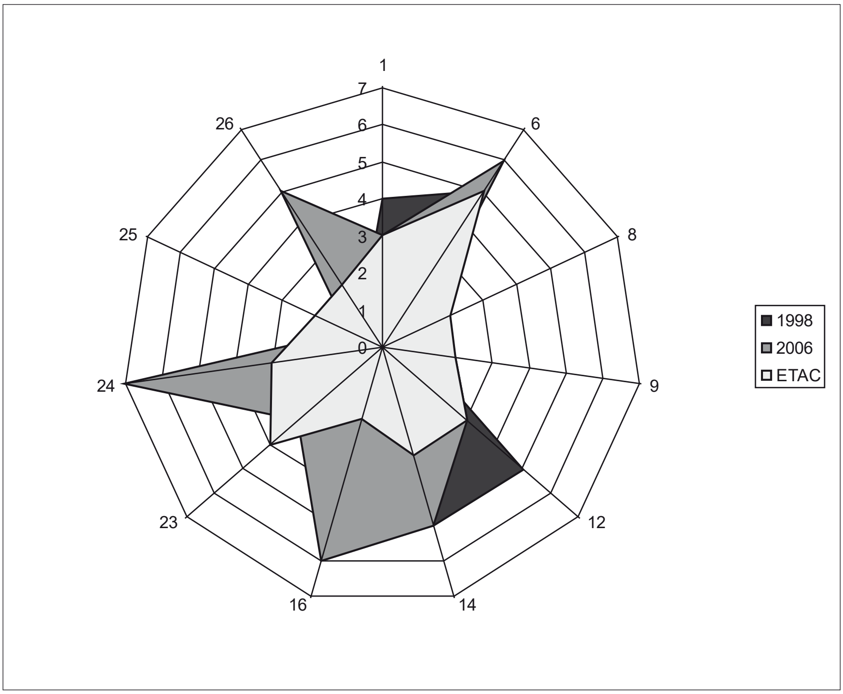

Fig. 5. Diagrams of comparison of ETAC and assessment of potential of Khmelnitsky NPP technoecosystem in different years. 1–7 are gradations of indicators, 1–26 are numbers of indicators in table 1

Any obtained quantitative values of the potential will always be part of a certain continuous series, so for classification purposes and verbal assessments, a special scale is needed. Proposed scale of estimates of potential contains 5 levels (Table. 3.).

Table 3. The assessment scale of the ecological potential of heavily modified, artificial water bodies and techno-ecosystems

Verbal designation of ecological potential assessment	Color for visualization, mapping	The range of potential	Step between levels
High	Blue	0,95—1,00	0,05
Good	Green	0,85—0,94	0,09
Moderate	Yellow	0,70—0,84	0,14
Bad	Orange	0,45—69	0,23
Low	Red	0—0,44	0,44

It should be noted that the scale is uneven. The range of one level (step) varies from 5 to 44, it means the assessment is generally shifted to lower values and the entire rating system is more sensitive to negative phenomena. Obtaining an assessment of "high potential" is possible only if the real state almost coincides with the ETAC.

Thus, in this example, in the first observation period, the ecological potential was "high", in the second period, the first level of assessment was "Moderate", and the third was "bad"

CONCLUSION

Assessment (evaluation) of the ecological potential of techno-ecosystems, heavily modified water bodies can be based only on a certain set of indicators, which may come close to the typical standing of a given object or be oriented towards to the desired ones. The complex of ecological and technically acceptable conditions (ETAC) should include several mandatory blocks: hydrophysical and hydromorphological, hydrochemical, hydrobiological, technical, as well as a block of special substances and / or factors.

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