Determination of the Ecological Risk of Deterioration in the Water Flow of the Udy River Basin of Kharkiv Region, Ukraine

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Abstract
The new method for assessment of the ecological risk of deterioration of a surface waters condition was presented. The methodology for assessment of the risk of the water ecosystem well-being disruption is based on the determination of all parameters of the state of quality of surface waters that exceed the ecological standards using the probit-regression model. The process of determining the ecological risk for watercourses of the Udy river basin in Kharkiv region showed a high level of danger to the well-being of the water ecosystem. Ranking of the observation posts for the quality status of the Udy river in terms of the ecological risk makes it possible to identify the most polluted river sections.

Keywords
Ecological risk; river basin; rational use of water; water protection measures; surface waters; Kharkiv region; Udy river

INTRODUCTION

The current state of surface waters requires the development of new scientific tools to prioritize the implementation of environmental protection measures. One of the most effective methods for determining the level of environmental hazard is an ecological risk assessment.

Method of assessment the ecological risk for disturbing the well-being of an aquatic ecosystem, presented in this paper, is based on the determination of ecological standards. The necessity of scientific substantiation of the permissible limit of anthropogenic impact on the qualitative condition of surface waters determines the relevance of this development. The implementation of the method for assessing the ecological risk of disturbing the well-being of an aquatic ecosystem is performed on determining the excess of ecological standards. The purpose of development of this method is to increase ecological safety and rational use of natural resources.

The Udy River basin has a transboundary significance and flows through the territory of a large industrial center of Ukraine. The region in general characterized by high anthropogenic pressures in many components of the environment. This is confirmed in different research papers (Vasenko et al., 2006; Vystavna et al., 2018; Vystavna et al., 2019), where the contamination of Udy river is affected on even groundwater and urban springs. Therefore, determination of implementation of environmental measures prioritization based on the assessment of such ecological risk is a very relevant task in Kharkiv region.

ANALYSIS OF RECENT STUDIES

Many scientific studies are devoted to determination of surface waters pollution level, in particular in the field of ecological risk assessment. (Hofmann et al., 2015; Keese, 2010; Gov.uk, 2011; Tsybulskiy, 2015; Levenets et al., 2017).

Generalized ecological risk comes down to two types:
– the risk of contravention sustainability of ecosystems as a result of actual or potential environmental pollution;
– the risk to public health is the probability of adverse health effects on human (Vasenko et al., 2015).

Currently, there is a large number of well-known methods for assessing the risk to public health, but in the majority of cases, they are based on sanitary and hygienic standards, limit (safe) values (Epa.gov, 2016).

The approaches to assessment of water bodies' quality based on the determination of Threshold Limit Value (TLV) or Maximum Permissible Concentrations (MPC) do not adequately reflect the state of the aquatic ecosystem. Therefore, the using of such limit values in the calculations of ecological risk is not correct. Although the measurement units of the level of environmental safety can be indicators, what characterizes the state of human health. There is the problem in determination of the deterioration risk of aquatic ecosystems.

The method for assessing ecological risks appeared from the impact of pollution sources on water bodies (Oehha.ca.gov, 2016) is based on the processing of data collected using a specially developed express scheme of field studies based primarily on biological data. The expert analysis of the characteristics of receptors and risk indicators, the size of anthropogenic pressure and possible threats to the aquatic ecosystem is applied at the level of detailed risk assessment. There are well known methods for assessment of the ecological risk for water bodies, based on the biological sensitivity and the response of certain organisms (Salem et al., 2016), as well as methods for the probable distribution of the species sensitivity (SSD) (Afanasyev and Grodzinskiy, 2004; Romanenko et al., 2009).

Ecological risk assessment using SSD reflects the probability that observed concentrations will exceed critical ones for organisms. Research (Afanasyev and Grodzinskiy, 2004; Romanenkoet al., 2009) was showed that probable results reflect empirical information well enough, so this method is valuable as an addition to more traditional approaches for calculating risks(EPA, 1994;Gottschalk and Nowack, 2012).

The disadvantage of the above mentioned methodological approaches is laboriousness, unequal conditions in aquatic ecosystems and the reaction of organisms, as well as the need toper form the additional hydrobiological studies with the involvement of leading experts.

In Directive 2000/60 / EC (EU WFD, 2006) it was proposed to carry out the risk assessment of priority substances, identified in accordance with Article 16 (2) and listed in Annex X. Currently, not all substances including those listed in Annex X are controlled and can be provided by official data of monitoring studies.This indicates the need to implement the risk assessment systems that will be provided by the existing monitoring system and statistical reporting.

The aim of this research is determination in prioritization of environmental measures implementation based on the assessment of the ecological risk of the aquatic ecosystems deterioration with consideration of established environmental standards.

RESEARCH METHODS

The paper (Rybalovaand Artemiev, 2017) is proposed the method of the ecological risk assessment of the aquatic ecosystem deterioration based on the determination of environmental standards with consideration of the landscape and geographical features of river basins.

In case of absence of environmental standards in the work, it is proposed to use the upper limit of the 3 categories of surface water quality classification as a threshold value. This corresponds to class II in good condition according to the procedure. It is believed that if the ecological standard is exceeded, there is a risk of disturbing the well-being of the aquatic ecosystem. (Vasenko et al., 2016). Our article is proposed to use the methodology of ecological assessment of surface water quality for the relevant categories (Romanenko et al., 1998; Korobkova, 2016).

The value of the ecological index of water quality is determined by the following formula(Romanenko et al., 1998; Korobkova, 2016):

$$I_e = \frac{(I_1 + I_2 + I_3)}{3}, \qquad (1)$$

where I_1 – contamination index of salt components; I_2 – trophic-saprobiological index (ecological sanitation) indicators; I_3 – index of specific indicators of toxic and radiation exposure.

At the second stage, ecological standards are determined according to the method presented in the article (Vasenko et al., 2016).

During developing ecological standards, it is necessary to apply a landscape-ecological approach, taking into account the geographical location, the dynamics of the formation and functioning of natural systems, their diversity and at the same time individual uniqueness, sustainability to climatic changes, natural and anthropogenic impacts (Vasenko et al., 2016).

Ecological standards can be individual (for specific and unique objects) and typical; promising and potentially possible (taking into account the latest technologies and trends), relatively stable (long-lasting) and operational (taking into account situational changes), acceptable and optimal (targeted).Ecological standards are scientifically based values of indicators (hydromorphological, hydrophysical, hydrochemical, hydrobiological, microbiological, radiation) of aquatic ecosystems, which reflect a good ecological condition of a water body. Ecological standards are established on a basis of analysis of the results of processing materials from previous hydrological, hydrochemical, hydrobiological, ecological toxicological and radioecological expeditionary research and regime observations. This is the fundamental difference between ecological standards for surface water quality and water use safety standards (threshold limit value (TLV)) for certain hazardous substances (Vasenko et al., 2017).

The risk of the well-being disturbing of an aquatic ecosystem (ER) is estimated by determining probits based on the following equation (Rybalova et al., 2018):

$$\mathrm{Pr}ob = -2{,}3 + 2{,}21 \lg \sum \left(\frac{C_i}{C_{EHi}} \right), \qquad (2)$$

where C_i – concentration of i-th substance in the water body, mg/dm^3; C_{EHi} – ecological standard for the i-th substance in water body, mg/dm^3.

Table 1. Normal-probabilistic distribution with interconnection of probits and risk

Prob	ER	Prob	ER
–3.0	0.001	0.1	0.540
–2.5	0.006	0.2	0.579
–2.0	0.023	0.3	0.618
–1.9	0.029	0.4	0.655
–1.8	0.036	0.5	0.692
–1.7	0.045	0.6	0.726
–1.6	0.055	0.7	0.758
–1.5	0.067	0.8	0.788
–1.4	0.081	0.9	0.816
–1.3	0.097	1.0	0.841
–1.2	0.115	1.1	0.864
–1.1	0.136	1.2	0.885
–1.0	0.157	1.3	0.903
–0.9	0.184	1.4	0.919
–0.8	0.212	1.5	0.933
–0.7	0.242	1.6	0.945
–0.6	0.274	1.7	0.955
–0.5	0.309	1.8	0.964
–0.4	0.345	1.9	0.971
–0.3	0.382	2.0	0.977
–0.2	0.421	2.5	0.994
–0.1	0.460	3.0	0.999
0.0	0.50	–	–

At the third stage, in accordance with a principle of the normal-probabilistic distribution, for value of Prob, the corresponding value of the ecological risk of deterioration of water bodies is established.

At the fourth stage, the total ecological risk of water bodies deterioration is determined by the formula (Vasenko et al., 2015):

$$ER = 1 - (1 - ER_1) \times (1 - ER_2) \times ...(1 - ER_n), \quad (3)$$

where ER – summarized ecological risk of deterioration of water bodies; ER_1,..., ER_n – ecological risk of each pollutant substances.

At the fifth stage, the characteristic of the ecological risk of water bodies' deterioration is given. In the interpretation of the obtained values of ecological risk it is proposed to use the following rank scale.

The classification of water bodies according to the ecological risk (Table 2) allows determining their suitability for water use. This is an important for the implementation of an iterative approach to the management of water protection activities.

Table 2. Characteristics of surface water quality by the value of the ecological risk

Water quality class	The value of ecological risk indicator (ER)	Qualitative assessment of the ecological risk of aquatic ecosystems deterioration	Trophism
I Excellent	0.01–0.19	Minor risk	Oligotrophic
II Good	0.20–0.39	Increased risk	Mesotrophic
III Satisfactory	0.40–0.59	Significant risk	Eutrophic
IV Unsatisfactory	0.60–0.79	High risk	Polytrophic
V Bad	0.80–1.00	Critical risk	Hypertrophic

The assessment of the ecological risk of disturbing the well-being of the aquatic ecosystem was performed for the watercourses of the Udy River basin in the Kharkiv region. The Udy River basin is one of the largest tributaries of the Seversky Donets River and has a transboundary disposition. Total river length – 164 km, from them 127 km are flowed through the territory of the Kharkiv region. Total catchment area – 3894 km^2, from them 3460 km^2 are situated in Kharkiv region.

At the first stage, the degree of pollution of the Udy river watercourses is determined according to the method of ecological assessment of the quality of surface waters by the relevant (Romanenko et al., 1998; Korobkova, 2016).

The assessment of the ecological condition of the Udy River by the values of the ecological index showed the deterioration in the long-term period. The qualitative condition of the Udy River in the Kharkiv region is deteriorating from the border with Russia (Urban-type settlement (uts) Okop) to the mouth (uts. Eshar).

The ranking of monitoring posts for the qualitative condition of the Udy River in the Kharkiv region by the value of the ecological index showed that the most polluted area is in uts. Eshar (Figure 1).

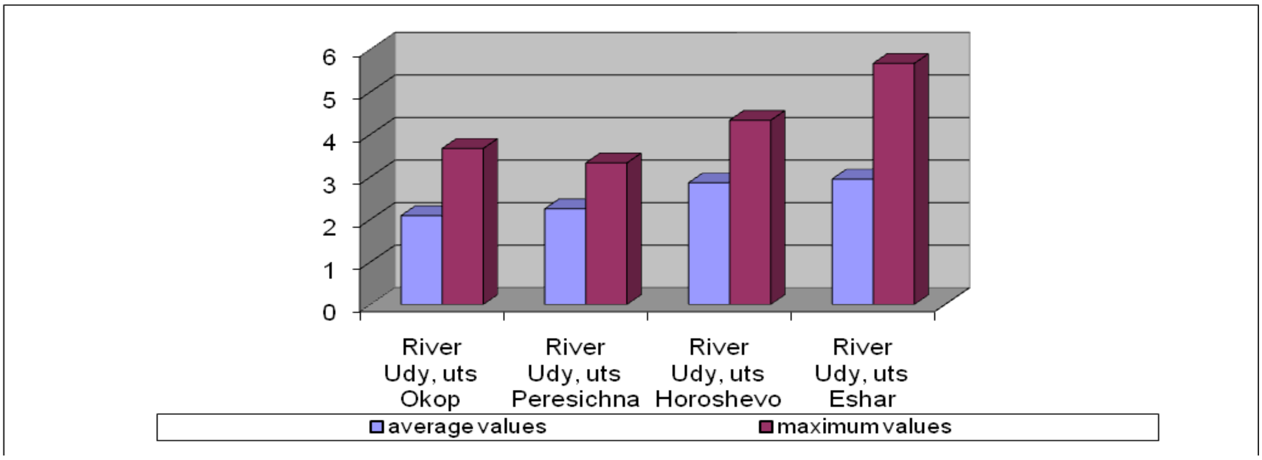

Figure 1. Ranking of monitoring posts for the qualitative condition of the Udy River in the Kharkiv region by the value of the ecological index

The ecological standards for the Udy River basin within the Kharkiv region were determined (Table 3).

Table3. Ecological quality standards for surface waters of the Udy River basin

No.	Indicator	uts Okop	uts Peresichna	uts Horoshevo	uts Eshar
1.	Mineralization, mg/dm^3	548	603	739	658
2.	Sulfates, mg/dm^3	28.7	104	165	185
3.	Chlorides, mg/dm^3	114	36.5	86.3	81.7
4.	Ammonium nitrogen, mg/dm	0.434	0.39	2.52	3.71
5.	Nitrite nitrogen, mgN/dm^3	0.065	0.02	0.189	0.293
6.	Nitrogen nitrate, mgN/dm^3	2.39	0.54	2.79	2.62
7.	Phosphorus Phosphates, mgP/dm^3	0.61	0.92	9.0	1.13
8.	Suspended solids, mg/dm^3	8.99	17.4	19.5	38.8
9.	Dissolved oxygen, mgO/ dm^3	7.72	9.02	7.3	8.36
10.	BOD-5, mgO/dm^3	3.19	3.47	5.2	4.8
11.	COD, mgO/dm^3	29.6	26.5	0.01	29.4
12.	pH	7.86	7.82	7.71	7.62
13.	Surfactant, mg/dm^3	0.015	0.018	0.023	0.16
14.	Petroleum products, mg/dm^3	0.07	0.12	0.15	0.16
15.	Iron total, mg/dm^3	0.15	0.25	0.24	0.13
16.	Manganese, mg/dm^3	-	-	0.022	0.04
17.	Cuprum, mg/dm^3	0.003	0.003	0.004	0.01
18.	Zinc, mg/dm^3	0.007	0.011	0.015	0.07

It should be noted that the maximum ecological index value for establishing the permissible ecological standard in uts. Horoshevo and uts. Eshar corresponds to category 6, class 4 (bad condition), and the average ecological index value in uts. Eshar - category 5, class 3 (unsatisfactory condition).

Table 4. Characteristics of the Udy river basin in the Kharkiv region for the ecological risk of deterioration of the status of aquatic ecosystems

River's title, post observation	ER	Class	Qualitative ecological risk assessment
River Udy, uts Horoshevo	0.64	4	High risk
River Udy, uts Peresichna	0.63	4	High risk
River Udy, uts Eshar	0.60	4	High risk
River Udy, uts Okop	0.39	2	Increased risk

For determination of complex of environmental measures, it is necessary to identify the influence of natural and anthropogenic factors on the ecological condition of this river and analyze the rationality of the economic use of the drainage basin of the river.

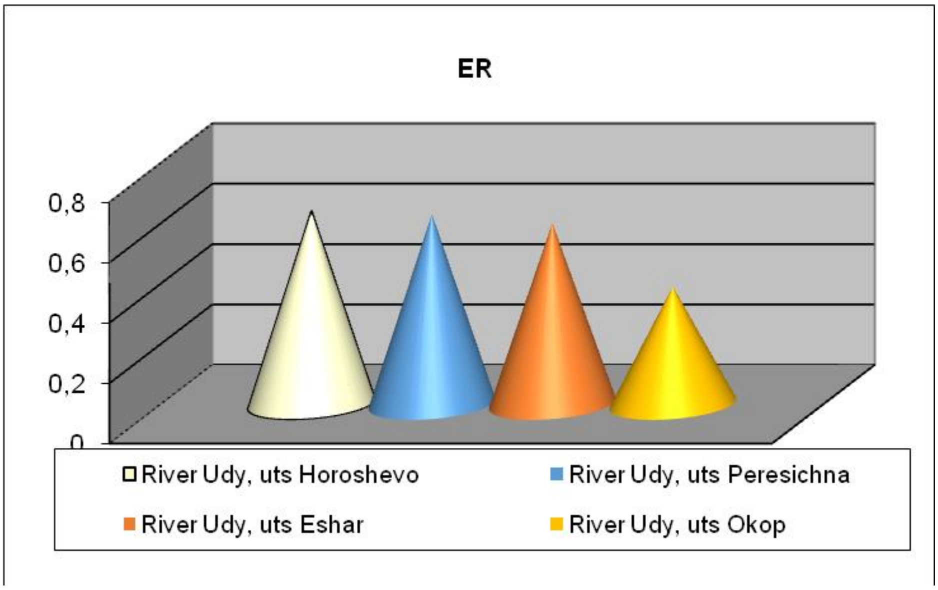

Figure 2. Ranking of watercourses of the Udy River Basin in the Kharkiv region by the value of the ecological risk of deterioration of aquatic ecosystems

CONCLUSIONS

For the first time, the assessment of ecological risk disturbance of well-being of the aquatic ecosystem was made for the watercourses of the Udy River basin in the Kharkiv region based on the determination of ecological standards. This assessment showed that the risk value for watercourses situated in Kharkiv corresponds to the 4th class (high risk). Thereby, these rivers are required the priority implementation of environmental protection measures.

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