

## ENVIRONMENT PROTECTION

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Svitlana Madzhd<sup>1</sup>,  
Yana Kulynych<sup>2</sup>,  
Adrian Iavniuk<sup>3</sup>

## ECOLOGICAL ASSESSMENT OF THE HUMAN -TRANSFORMED SYSTEMS OF THE IRPIN RIVER

National Aviation University  
Kosmonavta Komarova Ave, 1, Kyiv, 03680, Ukraine  
E-mails : <sup>1</sup>madzhd@i.ua; <sup>2</sup>yanakulynych45@gmail.com; <sup>3</sup>a\_yavnyuk@ukr.net

### Abstract

**Purpose:** to learn the interaction of natural and anthropogenic factors and their consequences in the system “Natural environment (Irpin river) – human-transformed environment (Nyvka river)”. **Methods:** To assess the structural and functional changes of hydroecosystems, transformed under technogenic impact, hydrochemical, toxicological and biological techniques, as well as the methods of mathematical statistics for experimental data processing and summarization of obtained results, were applied. **Results:** it is proposed to determine the dynamics of the biotic self-regulation mechanism change under impact of the modifying (anthropogenic) factors, by the example of the two-component system – “Natural environment (Irpin River) – environment, transformed under technogenic impact (Nyvka River, the right-hand tributary of the Irpin River)”. It is proposed to extend additionally the opportunities of the ecological assessment due to application of the integrating index – the index of ecological conformity. **Discussion:** obtained results stipulate necessity of the further investigation of structural and functional patterns of the Irpin River ecosystem in space and time. Assessment of anthropogenic factors impact on hydroecosystem condition will make it possible to correct the nature guard activity concerning the improvement of the fishery object ecological condition and recreation essence of the Irpin River. Integration of the Nyvka and Irpin Rivers into a single system “Natural environment – environment, transformed under technogenic impact” will make it possible to obtain the objective assessment of technogenic changes in hydroecosystems. Implementation of the index of ecological conformity will make it possible to estimate completely the inner processes in the rivers.

**Keywords:** ecological conformity indices; ecological indices; features of ecological indices; hydroecosystem; mechanism of biotic self-regulation; structural and functional properties.

### 1. Introduction

Conservation of water resources as renewable natural water is important for the optimal biosphere condition, as well as for the creation of favorable conditions of social and economic development of regions. It means that natural waters constitute an integral part of the natural environment, participating in natural complexes formation, as an element of production forces of the system [1].

The role of small rivers is poorly estimated in Ukraine, however they “take part” in economic and social life of the state [2]. The small rivers formulate significant part of the total river runoff. At the same time, in recent years, technogenic impact on their condition increased, because most of them are the objects of the fishery or recreational purpose. And, that is why, to keep sustainable ecological development of these aquatic resources, regular environment assessment

of their condition should be carried out, to prevent the qualitative waters depletion.

## 2. Analysis of literature and problem definition

The basic principle of keeping safe functioning of hydroecosystems (HE) is the guarding of their biotic self-regulation [3, 4]. Because stability of HE development is connected with such factors of its existence, as non-uniformity of abiotic and anthropogenic parts of the water ecosystems in time and space [5], structural and functional changes of the aquatic environment self-regulation mechanism changes occur [6-10].

According to scientific and technical literature, these changes are connected with the discordance of HE development with the basic laws and principles of the common ecology. It leads to disorders of ecological capacity of the water ecosystems, and it is a push to the shifting of the dynamic equilibrium of their development [7].

The clarification of the changes of biotic self-regulation of the water systems, transformed under technogenic impact, was proposed to be carried out basing on the system “Natural environment – environment, transformed under technogenic impact”.

**The aim of the work:** to learn the interaction of natural and anthropogenic factors and their consequences in the system “Natural environment (Irpin river) – human-transformed environment (Nyvka river)”.

## 3. Materials and methods of research

To clarify the structural and functional changes and to estimate the mechanism of biotic self-regulation, the system “Natural environment – environment, transformed under technogenic impact” was analyzed.

The first component is the Irpin River system, hydroecosystem of which is under regular anthropogenic contamination from the Nyvka River (right-hand tributary).

Second component of the system “Natural environment – environment, transformed under technogenic impact”, is the Nyvka River. It is directly connected with the contamination source – aviation facility, reverse waters discharge of which, together with the surface runoff, transformed above mentioned system into environment, transformed under technogenic impact.

Both aquatic systems belong to the Dnieper basin, and the permanent trophic connection makes it possible to consider them as the conceptual majority of interconnected constituents in the system “Natural environment (Irpin river) –

human-transformed environment (Nyvka river)”. Such approach makes it possible to determine the limits of the human impact on Irpin HE.

Personally collected research data [11,12], complemented by the 10-year monitoring data [13], are processed in the work. Hydrochemical calculations were carried out with the use of the formulas [6].

To estimate the structural and functional changes of systems, transformed under technogenic impact, organoleptic, hydrochemical, toxicological and biological techniques were applied. The methods of mathematical statistics for experimental data processing and summarization of obtained results, were applied as well.

## 4. Research results

Nyvka river, as a source of thechnogenic contamination, significantly changes the qualitative indices of ecological situation of the the Irpin river, due to exceeding of the individual and summary limit acceptable concentration (LAC) sanitary and hygienic indices. Hydrochemical content of the aviation facility reverse waters, discharged into the Nyvka River, are represented in table 1.

Table 1

Hydrochemical content of the aviation facility reverse waters

Index	Concentration	Degree of LAC excess
Ph, units	$\frac{7.8}{7.6-7.9^*}$	Norm
ChOD, mg O <sub>2</sub> dm <sup>-3</sup>	$\frac{45}{43.6-46.4}$	3
BOD, mg O <sub>2</sub> dm <sup>-3</sup>	$\frac{35.4}{30.2-40.5}$	7
Ammonia Nitrogen, mg dm <sup>-3</sup>	$\frac{35.5}{27.5-40.5}$	144
Nitrite Nitrogen, mg dm <sup>-3</sup>	$\frac{0.96}{0.9-1.0}$	48
Nitrate Nitrogen, mg dm <sup>-3</sup>	$\frac{0.03}{0.02-0.04}$	Norm
Cu <sup>2+</sup> , mg dm <sup>-3</sup>	$\frac{0.03}{0.02-0.04}$	30
Cr <sup>6+</sup> , mg dm <sup>-3</sup>	$\frac{0.024}{0.01-0.14}$	24
Zn <sup>2+</sup> , mg dm <sup>-3</sup>	$\frac{0.04}{0.03-0.05}$	4
Oil products, mg dm <sup>-3</sup>	$\frac{65}{30-100}$	1300

Phenol, mg dm <sup>-3</sup>	$\frac{0.004}{0.002-0.006}$	4
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\*Note: in numerator: average value of the concentration / in denominator: (minimal concentration)-(maximal concentration)

Due to analysis of the table, it is made conclusion that intensive contamination of the Nyvka River occurs. It contributes to the formation of the human-transformed environment and, that is why, its water ecosystems may be classified as contamination origin of the Irpin River. The reason is the formation of secondary contamination zones because of ecological toxicity agents – heavy metal ions (HMI) – table 2.

Table 2

Distribution of HMI in hydroecosystems of the Nivka river

HMI	Surface water layer		Bottom water layer		Bottom sediments	
	mg dm <sup>-3</sup>	Degree of LAC excess	mg dm <sup>-3</sup>	Degree of LAC excess	mg dm <sup>-3</sup>	Degree of LAC excess
Zn <sup>2+</sup>	0.02	2	0.01	норма	0.86	86
Cr <sup>6+</sup>	0.31	31	0.48	48	0.86	86
Cu <sup>2+</sup>	0.02	20	0.03	30	0.3	300

The analysis of data in table 2 shows that suspended solid matter in water contribute to HMI sedimentation in certain places, by formation of the secondary contamination zones in the reservoir. Moreover, according to scientific and technical literature [15], it should be considered that HMI, due to their physical and chemical properties and biochemical influence on biota, may change their form of residence in hydroecosystems, however, it firstly occurs due to transition from one reservoir to another one [15].

At the same time, in most cases, structural and functional changes in hydroecosystem, may be estimated with the help of ecological indices and their features.

The complex ecological assessment of the water contamination, expressed as the index of contaminated waters (ICW), is considered as the normative index. This fact was taken into account when generalized ecological assessment of condition of the Nyvka River, which is of 7,8 category and of IV class of water contamination (dirty).

In that follows, the dynamics of the changes (averaged indices) of the Irpin River ecological

condition, influenced by technogenically transformed waters of the Nyvka River, was investigated primarily. To do it, ICW, as a unique state normative criterion for water quality class determination, was used. According to the given standard, water quality class is determined by the following environmental components: salt content indices, indices of trophic and saprobiological content, indices of specific toxic ingredients. To calculate the ICW, hydrochemical water content data of three section lines of Mostysheshe village, Hostomil urban settlement, Kozarovychi village of 2009-2014 period, were used [11]. Fig. 1 shows the values of ICW for three section lines. (Fig. 1).

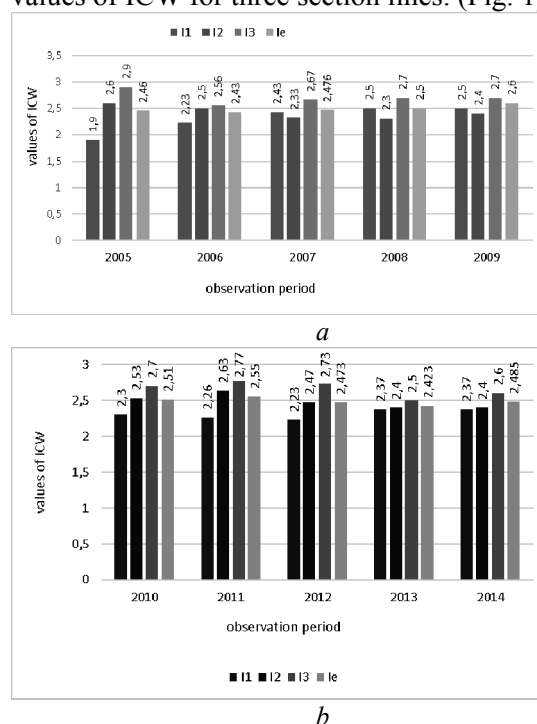


Fig.1. Dynamics of the water contamination indices change a) observation period 2005-2009 years; b) observation period 2010-2014 years

- I<sub>1</sub> – village Mostysheshe section line data
- I<sub>2</sub> – urban settlement Hostomil section line data
- I<sub>3</sub> – village Kozarovychi section line data
- I<sub>e</sub> – generalized water contamination index for three section lines

Hence it follows that:

- first, due to up-to-date approaches concerning determination of the indices of HMI content for ecological norming in the water of reservoirs [6], total ecological index dynamics was possible to be investigated;
- second, authors [6] use up-to-date technique of the atomic-absorption spectroscopy. Errors in this case do

not exceed 46-60% for  $\text{Cr}^{6+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Zn}^{2+}$ . It meets norming requirements of the water quality control;

- third, qualitative condition of the Irpin river waters for 2010-2014 year, is characterized as dirty.

To extend the opportunities (boundary level of ecological impacts) of this normative index, we made additional proposal. We proposed to determine the index of ecological conformity of structural and functional opportunities of HE simultaneously.

This index (Ie.c) is the averaged integral criterion characterizing intensity of internal processes in the river. To derive the calculation formula of the proposed index, following parameters are used: qualitative content of HE, level of biotic HE structure simplification, level of the water body self-purification:

$$Ie.c. = \sum_{i=1}^n \varphi_1 \sum_{j=1}^m \varphi_2 \sum_{k=1}^l \varphi_3 \quad (1)$$

where  $\varphi_1$  is the dependence of HEs functioning on their qualitative content, taking into account generalization of the ecological index;

$\varphi_2$  is the dependence of HE functioning on level of their biological structure simplification;

$\varphi_3$  is the dependence of HE functioning on level of the water body self-purification ability.

The calculation results of the proposed ecological conformity index, are represented in the table 3.

Table 3

**Generalized characteristics of the water systems of the Irpin river according to various criteria**

Investigation term	River waters quality			Changes of the mechanism of HE biotic self-regulation
	Irpin river contamination level by Water Contamination Index	Water quality class	I e. c.	
2010	3.51 (dirty)	IV	5.13	Self-regulation disturbance
2011	3.95 (dirty)	IV	5.9	Self-regulation disturbance
2012	2.6 (dirty)	IV	8.1	Achieving the limit of compensation abilities of HE
2013	2.83 (dirty)	IV	7.1	Achieving the limit of compensation abilities of HE
2014	3.55 (dirty)	IV	5.4	Self-regulation disturbance

Generalized ecological assessment of condition of the Irpin river is of IV class of water contamination (dirty), Ie.c. – 5,13-8,1, and the mechanism of HE biotic self-regulation is

disturbance or achieving the limit of compensation abilities.

#### 4. Results Discussions

At such level of technogenic factors impact, partial exhaustion of natural resources occurs, due to changes of the structural and functional features of the water ecosystems. Simultaneously, the period of the Irpin river hydroecosystems development (2012-2013), was observed. These ones are characterized by ecological situation improvement, the index of ecological conformity increased significantly. That is why, obtained results stipulate necessity of the further investigation of the Irpin River water quality in time and space, up to river mouth (Kyiv reservoir).

At the same time, on the base of the Ie.c. investigation database, it may be forecasted that the functioning of the integral system, with the consideration of Le Chatelier-Broun principle, results in dynamic HE equilibrium shifting to the least technogenic impacts. As a result, the mechanism of adaptive reactions of biota develops, as well as homeostasis sustainability.

Thus, obtained results stipulate necessity of the further investigation of structural and functional features of the Irpin River HE development in time and space, up to river mouth (Kyiv reservoir). Assessment of anthropogenic factors impact on HE condition will make it possible to modify the environment guarding activity concerning improvement of ecological condition of the Irpin River, which is of high fishery and recreational value.

#### 5. Conclusions

1. Methodological approaches of the Irpin River ecological condition assessment in context of the guarding of its sustainable development, are discussed.

2. It is proposed to consider and implement the ecological assessment of the Irpin river HE, as integration of two components: “Natural environment (Irpin river) – environment, transformed under technogenic impact” (Nyvka river)” into a single system.

3. It is estimated that existing interrelations and interactions in HE of such trophic level, provide the

functional coincidence of the Irpin river development (qualitative condition) with the basic laws and principles of the common ecology.

4. It is found that the normative indices (water contamination index), as well as the indices of response on modifying anthropogenic factors, are lower for the Irpin River in comparison with the Nyvka river. The water system of the Irpin River is classified as one of the IV water quality class (dirty).

5. Ecological indices and their parameters (indices of impact and conformity) determine the intensity of biotic waters self-regulation intensity (index of biotic HE simplification, coefficient of waters self-purification).

6. Obtained results stipulate the necessity of the further investigation of the Irpin River water quality in time and space up to the river mouth. It is aimed for estimation of the biotic self-regulation mechanism changes (fundamentals of the water bodies functioning).

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С.М. Маджд<sup>1</sup>, Я.І. Кулинич<sup>2</sup>, А.А. Явнюк<sup>3</sup>

Екологічна оцінка антропогенно-змінених систем р. Ірпінь

Національний авіаційний університет, пр. Космонавта Комарова, 1, Київ, 03680, Україна

E-mails : <sup>1</sup>madzhd@i.ua; <sup>2</sup>yanakulynych45@gmail.com; <sup>3</sup>a\_yavnyuk@ukr.net

**Мета:** вивчення взаємодії природних та антропогенних факторів та їхніх наслідків у системі «природне середовище (р. Ірпінь) – антропогенно-змінене середовище (р. Нивка)». **Методи:** для визначення структурно-функціональних змін техногенно забруднених гідроєкосистем були застосовані гідрохімічні, токсикологічні та біологічні методи, а також методи математичної статистики для обробки та узагальнення отриманих експериментальних даних. **Результати:** запропоновано визначати динаміку змін механізму біотичної саморегуляції під впливом модифікуючих (антропогенних) факторів, на прикладі системи із двох складових – «природне середовище (р. Ірпінь) – антропогенно змінене середовище (р. Нивка, права притока р. Ірпінь)». Запропоновано додатково розширити можливості екологічної оцінки за рахунок впровадження інтегрального показника – індекса екологічної відповідності. **Обговорення:** отримані результати обумовлюють необхідність подальшого дослідження структурно-функціональних особливостей розвитку гідроєкосистеми р. Ірпінь у

просторі і часі. Оцінка впливу антропогенних факторів на стан гідроекосистеми дозволить скорегувати природоохоронну діяльність стосовно покращення екологічного стану об'єкта рибогосподарського і рекреаційного призначення р.Ірпінь. Об'єднання р. Нивка та р. Ірпінь в єдину систему «природне середовище-антропогенно змінене середовище» дозволить отримати об'єктивну оцінку антропогенних змін в гідроекосистемах. Введення індексу екологічної відповідності дозволить в повній мірі охарактеризувати інтенсивність внутрішньоводоймних процесів у річках.

**Ключові слова:** гідроекосистема; індикатор екологічної відповідності; механізм біотичної саморегуляції; структурно-функціональні зміни.

**С.М. Маджд<sup>1</sup>, Я.І. Кулинич<sup>2</sup>, А.А. Явнюк<sup>3</sup>**

**Экологическая оценка антропогенно-измененных систем р. ирпень**

Национальный авиационный университет, пр. Космонавта Комарова, 1, 03680, Киев, Украина

E-mails : <sup>1</sup>madzhd@i.ua; <sup>2</sup>yanakulynych45@gmail.com; <sup>3</sup>a\_yavnyuk@ukr.net

**Цель:** изучение взаимодействия природных и антропогенных факторов, а также их последствий в системе «природная среда (р.Ирпень) – антропогенно-измененная среда (р.Нивка)». **Методы:** для определения структурно-функциональных изменений техногенно-загрязненных гидроэкосистем были применены гидрохимические, токсикологические и биологические методы, а также методы математической статистики для обработки и обобщения полученных экспериментальных данных. **Результаты:** предложено определять динамику изменений механизма биотической саморегуляции под влиянием модифицирующих (антропогенных) факторов, на примере системы из двух составляющих – «природная среда (р.Ирпень) – антропогенно измененая среда (р.Нивка, правый приток р.Ирпень)». Предложено дополнительно расширить возможности экологической оценки за счет внедрения интегрального показателя – индекса экологического соответствия. **Обсуждение:** полученные результаты обуславливают необходимость дальнейшего исследования структурно-функциональных особенностей развития гидроэкосистемы р.Ирпень в пространстве и времени. Оценка влияния антропогенных факторов на состояние гидроэкосистемы позволит скорректировать природоохранную деятельность по улучшению экологического состояния объекта рыбохозяйственного и рекреационного назначения р.Ирпень. Объединение р.Нивка и р.Ирпень в единую систему «природная среда - антропогенно измененная среда» позволит получать объективную оценку антропогенные изменения в гидроэкосистемах. Введение индекса экологического соответствия позволит в полной мере охарактеризовать интенсивность внутриводоемных процессов в реках.

**Ключевые слова:** гидроэкосистемы; индикаторы экологического соответствия; механизм биотической саморегуляции; структурно-функциональные свойства.

**Svitlana Madzhd** (1976). Ph. D. in Tech. Sc.

National Aviation University, Kyiv, Ukraine.

Education: National Pedagogical Dragomanov University, Kiev, Ukraine (2002), National Aviation University (2011).

Research area: improving environmental monitoring in the technosphere zone of influence of civil aviation, methods of improving the ecological state of the environment near airlines.

Publications: 80.

E-mail : madzhd@i.ua

**Yana Kulynych** (1994). Ph. D. Stud.

Education: Kiev national university of construction and architecture (2015)

Research area: small and medium rivers, influence of civil aviation on hydrosphere.

Publications: 4.

E-mail : yanakulynych45@gmail.com

**Adrian Iavniuk** (1988). Lecturer.

National Aviation University, Kyiv, Ukraine.

Education: National Aviation University, Kyiv, Ukraine. (2011).

Research area: radioecology, radiobiology, radiobiological effects.

Publications: 8.

E-mail: a\_yavnyuk@ukr.net