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ENVIRONMENTAL ASSESSMENT OF SMALL RIVERS OF IRPIN RIVER BASIN BY EKOSYSTEM PRINCIPLE

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Abstract

The main objective *of this work is the study of the ecological state of small rivers in the Irpin river basin within the Kyiv region. The establishment of the main reasons for the unsatisfactory ecological state of the investigated objects, among which are Nyvka, Kozka and Unawa rivers.* ***Methods****: The study used an ecosystem-basin approach, statistical processing of own data and monitoring data of public institutions. The systematization was carried out and a data bank of hydrochemical indicators of the Irpin river for a ten-year period was formed.* ***Results****: According to the results of studies, in all tributaries the norms of maximum allowable concentrations of pollutants are exceeded, which is the main destabilizing factor for the Irpin hydroelectric system. Conclusions on the environmental condition of the Irpin river were performed on the basis of the dynamics change of the water quality index in eight control points. For the quantitative ecological characteristics of the load on the hydroelectric system of the Irpin river basin, the index of anthropogenic impact in the control sections was calculated.* ***Discussion****: The obtained results stipulate the necessity of further study of structural and functional peculiarities of the development of the Irpin hydroelectric system in space and time. An estimation of the influence of anthropogenic factors on the state of the hydroecosystem will allow the correction of environmental protection activities to improve the ecological status of the studied basin.*

Keywords: river basin; hydroecosystem; maximum allowable concentration; small rivers; anthropogenic impact

1. Introduction

In the early 80's, there was a problem of deterioration of the ecological status of small rivers, that is still relevant today. The water fund of Ukraine includes about 20 thousand small rivers, of which 15 thousand flows into the Dnipro River. Most of the rivers flow through the cities or near the enterprises that are direct contaminants of their waters, therefore exceeding the norms of maximum permissible concentrations (MPC) is inherent in almost all water systems of our state.

Topicality of the theme. Small rivers act as indicators of changes in the ecological (ecosystem or landscape) situation of plain areas [1]. Such rivers are often substantially polluted or subject to significant fluctuations in the values of water quality indicators, because, even relatively small, the load may exceed their ability to self-purify, and the widespread regulation of runoff leads to significant violations of the hydrological regime. The peculiarity of the formation of the flow of small rivers is their relationship with the landscape of the basin, which makes them vulnerable, that is, the degree of dependence of their inherent bioprocesses from the surrounding catchment is much higher than that of large rivers. The solution to this problem is only possible after regular large-scale environmental researches of small and medium-sized rivers. The research should be based on the ecosystem approach and the basin approach. The object for such research may be the ecosystem of the Irpin basin, with numerous small tributaries [2, 3]. This river basin, as well as many other basins of the middle rivers of Ukraine, failed to maintain its immutable hydrological regime and ecological status of the adjoining territories.

The aim of the article is assessment of the Irpin river basin ecological state and the establishment of the hydrological regime formation peculiarities.

Review of recent research. Methods of studying the ecological state of the small rivers basins are devoted to scientific works of Sovgir S.V., Goncharenko G. Ie., Goncharenko V.G., Berchak V.S. [1], Ladyka M.M., Udod V.M., Korh O.V. [5].

2. Presentation of the main material

Irpin river is the right tributary of the Dnieper river (Fig. 1). The length of the river – 162 km, the catchment area – 3340 km^2. It takes a start on the northern outskirts of the village Yaropovichi, Andrushiv region, Zhytomyr oblast'. The place of falling into the Kiev reservoir is located near Kozarovychi village. The river bed is winding unstable with the width 15 m, depth 1.2 m, flow rate within 0.3 m/s [6], it belongs to plain-type rivers with calm flow [7]. The river bed became noticeably narrowed and faded, compared to 100 years ago [5] the width of the river at the mouth was more than 100 m, and depth - from 2 to 5 m.

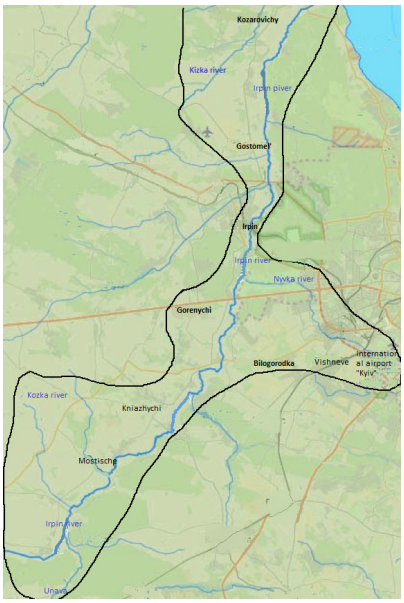

Fig. 1. Map of the area of research of the Irpin river basin with control hydrous solutions of Irpin river (Mostysche village, Kozarovychi village, Gorenychi village, Bilogorodka village, Gostomel' urban-type settlement, Kozarovychi village).

Observations in the mouth of the Irpin river were conducted since 1972 by the hydrometeorological service, and since 1987 also by the Department of Ecology of Small Rivers of the Institute of Hydrobiology of the National Academy of Sciences of Ukraine. The Irpin river is powered by numerous sources and tributaries, these are small rivers, 10-20 km in length, 37 small waters system fall into it. The biggest ones are presented in the Table 1.

Table 1

Characteristics of the biggest small rivers of the Irpin river basin

Left tributary	Length, km	The catchmentarea, km^2	Right tributary	Length, Km	The catchment area, km^2
Vid'manka	7,0	24,3	Kryv'ianka	15,0	59,7
Lupa	14,0	82,0	Bilka	9,6	33,4
Kudelia	13,0	57,3	Unava	87,0	680,0
Bucha	34,0	301,0	Gorenka	20,0	56,0
Svunoryika	20,0	69,5	Liubka	9,0	30,8
Syvka	17,0	80,2	Moshchun	10,0	54,0
Rokach	15,0	160,0	Nyvka	23,0	94,0
Kozka	28,0	177,0	Bobritsia	13,5	49,1

The territory of the basin consists of agricultural lands, including dehydrated and irrigated, forest arrays, water surfaces of rivers, artificial reservoirs and canals, settlements, and also excessively moistened, marshy and eroded lands [8]. So, in accordance with Irpin IWM data, in the Irpin river basin, there are functioning 14 hydrometeorological systems with a total area of agricultural land 19273.2 ha [9]. In the river basin, there are 6 reservoirs (the biggest one – Lisne) and 265 pounds with total capacity of 48.4 million m^3 [10]. There are small drainage and drainage-humidifying systems (Buchans'ka, Tarnovs'ka, Shpytkivs'ka and others) and big Irpin' drainage-humidifying reclamation system (DHRS) with an area of 8.2 thousand ha, that is the first bilateral action system in Ukraine. On the 131 km range, the Irpin river is a trunk channel of Irpin DHRS, that regulates surface runoff and groundwater level [5, 10]. The total length of the regulated riverbed is about 110 km. In 1969, the riverbed of Irpin river was expanded and deepened to a cross-section area of about 25-40 m, that was provided a pass of average annual water consumption by 10% of security and faultless operation of side drainage, overpass and prefabricated channels [7].

Nowadays the river runoff is pumped to the Kiev reservoir by the Irpin pump station [10]. The canals are laid along the floodplain through 120-400 m in the lower section and 200 m in the upper part. Within 71 km from the Rakovka village to the Unawa river, artificially deformed the channel, making it parabolic [11].

The reason for the land reclamation work was a significant water logging floodplain, and the inability to use these lands for agricultural purposes. As the result of the interaction of a reclamation system with natural geosystems, an integral natural-technical system is created and functioning, in which the state and changes of technical and natural components are interconnected [12].

The results of research. To achieve the goal of research, it was supposed to solve the following tasks:

1) determination of main anthropogenic factors, that have influence on formation of the technogenically-modified ecosystem structure of the Irpin river basin;

2) the study of the ecological state of the Irpin river basin and the factors of its formation.

During the period of the phytoplankton studying of the Irpin river, 103 species of algae were discovered, presented by the 111 intraspecific taxa, among them the main ones are *Euglenophyta, Chlorophyta, Chrysophyta, Dinophyta*. Generic coefficient, calculated for the Irpin river, is 2.23 [11]. The estimate of species diversity was made according to the Shannon index (indicates species diversity), calculated by the biomass (2.36±0.05 bit/ex) and by the number of phytoplankton (1.74±0.05 bit/ex):

$$H = -\sum_{i=1}^{n} p_i \log_2 p_i , \qquad (1)$$

where $p_i = \frac{x_i}{\sum_{i=1}^{n} x_i}$ and relates to number of characteristics (for example, individuals) of a particular object (such as specie) in sample (for example, in biocenosis).

The obtained data indicate a predominance of oligodominant structure of phytoplankton [13].

The main technogenic pollutants of the Irpin rivers average long-term surface runoff from urbanized areas [14], agricultural waste water, activity of numerous industrial enterprises and utilities enterprises, and also discharged polluted waters of numerous tributaries.

According to the data, that are presented in «Ecological passport of Kyiv region for 2015», main water users-pollutants of Irpin river and its tributaries during 2013-2015 were MHMC, urban-type settlement Hlevakha – 430.8 thousand m³ (average value for 2013−2015), in 2016 – 0.42 mln. m^3. Main water pollutants: NO_3 with excess of the MPC in 1.1 times, NO_2 – in 1.1, sulfates– in 1.0, chlorides– in 1.2. «Bakalia Trade» ltd. discharged 4.58 thous. m³ of water (2014). ME «Boyarkavodokanal» discharged into river 1,381 mln. m^3 with excess of the MPC of NH_4 – in 1,1times. And in hydrous of Kozarovychi village, in contradistinction to urban-type settlement Gostomel', the presence of a radioactive isotope ^{90}Sr is noted. However dynamic of its presence does not exceed the MPC and tends to decrease from 1,12 mg/dm^3 in 2011-2013 to 0,03 in 2017. Also from January 2012, in Irpin river water was noted presence of such pollutants as: surfactants, Fe, Mn, Cu, Ni, Pb, Cr^{+6}, Zn, petroleum products, phenols, that were not noted by monitoring data in previous years.

In accordance with statistical data of Dnipro basin management, in selected samples of water in 2015 from 2 hydrous (urban-type settlement Gostomel', Kozarovychi village) was found multiplicity exceeding MPC on indicators: BOD5–5; COD–9; Fe– 2; Mn – 3, and due to the data of Central Geophysical Observatory at one control point(Mostysche village) exceedance of the MPC was recorded: for BOD_5–in 1 time, NH_4 – in 1 time, NO_2 – in 5 times, Fe – in 5 times, Cu – in 6 times, Zn – in 4 times, Cr – in 7 times, Mn – in 7 times. According to the set of hydrobiological indicators, the state of water quality in the Irpin river in 2016 was related to the III class–moderately polluted water.

To assess the level of water pollution, we used method of hydrochemical parameters comparison with the limits of maximum permissible concentration (MPC) [8]. Environmental assessment of water quality is carried out, according to «Methodology of environmental assessment of surface water quality for the respective categories», which includes 3 blocks of indicators:

- block of saline composition;
- block of tropho-saprobiological (ecological and sanitary) indicators;
- block of specific substances of toxic action.

The research was carried out during 2015-2017 on the territory of the Kyiv oblast'. Water samples from the Irpin river and its tributaries were sampled and analyzed. Also, for factor analysis of the surface water quality formation of the studied basin were used ecological monitoring data from state enterprises: Central Geophysical Observatory, Dnipro basin management, annual Regional reports data of Kyiv oblast' about environmental state, and also National report about environmental state.

Next stage of research was carrying out of environmental characteristics of Irpin river state within Kyiv oblast by monitoring data of state hydrous of Mostysche village, Kniazhychi village, Kozarovychi village (Fig. 1). Obtained data were analyzed, systemized, summarized and presented in Table 2.

In accordance with the methodology, characteristic of water pollution degree of Irpin river basin was done by the ecological index I_E, the value of which is equal to the arithmetic mean of the block indexes:

$$I_E = (I_1 + I_2 + I_3)/3, \quad (2)$$

where: I_1 – block of saline composition, which includes the mineralization of water, the content of sulfates and chlorides; tropho-saprobiological;

I_2 – block of ecological-sanitary characteristics, which includes the contents of suspended solids, COD, BOD_5, dissolved oxygen, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, phosphates, biomass of phytoplankton, index of saprobity;

I_3 – block of specific characteristics of toxic and radiation action: Cu, Cr, Hg, Zn, phenols, Ni, etc.

Results of calculation of water pollution degree are presented in Fig. 2.

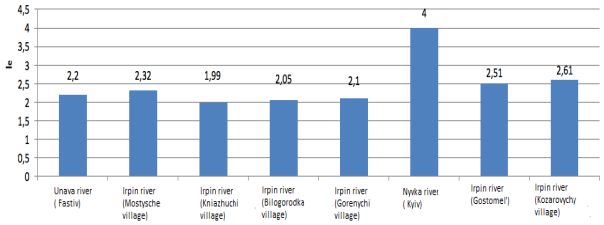

Fig. 2. Indicator of the ecological index of water quality in the Irpin river basin

Calculations of pollution index with saline composition components (I_1), of ecological-sanitary index (I_2) and specific toxicity indicators index(I3) were carried out by the formula:

$$I_i = \frac{1}{n}\sum_1^n N_i, \quad (3)$$

where I_i – index; N_i – quality category; n – numbers of indicators.

Table 2

Indicators of water quality indixes in the Irpin river

Water quality index	Sampling points					
	Mostysche village	Kniazhychi village	Bilogorodka village	Gorenychi village	urban-type settlement Gostomel'	Kozarovychi village
I_1	2,00	1,83	1,67	1,67	2,00	2,3)
I_2	3,96	3,00	3,35	3,50	4,26	4,5)
I_3	1,00	1,13	1,13	1,25	1,00	1,00

The result of the main components analysis within the subsystem "use of river runoff" [5] indicates: the rate of actual use of the river runoff Irpin river is:

- 54% – high;
- irreversible water consumption of river runoff 48% – veryhigh;
- discharge of water into the river network 60% – higher than normal;
- discharge of contaminated waste water into the river network 3.2% – low.

The state of the basin, according to the indicators, is characterized as "bad".

For the quantitative environmental characteristics, the load on the hydroelectric system of the Irpin river basin, was calculated by previously developed, index of anthropogenic impact, according to the formula:

$$I_{anthr.impact} = \frac{C_{pollutants}}{MAC_{pollutants}} \cdot K_{self-clean}, \quad (4)$$

where $C_{pollutants}$ – concentration of pollutants; $MAC_{pollutants}$ – maximum allowable concentration of pollutant; $K_{self\text{-}clean}$ –coefficient of speed of self-cleaning of river water from pollutants.

The results of the corresponding calculations are presented in Fig. 3.

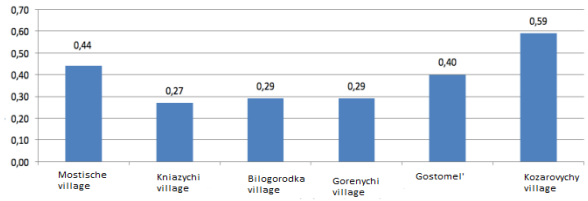

Fig. 3. Dynamics of technogenic load on the Irpin river by the index of anthropogenic impact

As can be seen from the diagram in Fig. 2, the most anthropogenic impactis done by the water of the Nyvka river. The Nyvka river flows in the Kyiv city, mainly in the collector, occasionally coming out on the surface with a narrow stream, or in the form of ponds in the Goloseevsky district, and then flows in the reservoir. Nature protection band width of 25 m, due to the Water Code of Ukraine, in the coastal area of the river is not given, although its banks placed about 60 businesses, and communities that have no centralized sewer systems. The largest enterprises in the river basin: Borschagovsky chemical factory, furniture complex "Rosa", PJSC " 20 CA", AGK Beryzka-3, horse stables, SE "Zavod 410 CA", international airport «Kyiv». Several collectors are opened in the river to provide drainage of the western outskirts of Kiev and drainage of the territory of residential areas.

Value of wastewater to natural 2:1. The water quality class of the river, according to the general ecological index, corresponds to the IV class of quality (dirty). The river has a weak self-purification

capacity, an index of catchment urbanization 10.3%, $I_{anthr.impact}=0.65$. Concentration of petroleum products along the river 0.03 mg/dm^3, at the mouth of the river 0.17 mg/dm^3, phenols respectively 31.17 mkg/dm^3 and 106.20 mkg/dm^3 [15].

According to the data [14], waste water of the Irpin river in the area of Kozarovychi village carry out an anthropogenic impact on the coastal zone of the Kiev reservoir. The reason is the polluted water of the Kozka river. Kozka river is water receiver of the drainage system. Inthepast (2005–2011) Kozka river of ten violated the quality of water in the mouth of the Irpin river, as a result of discharges of poorly treated sewage from poultry farm OJSC "Complex Agromars" (Gavrylivka village, Vyshgorod region), water pollution has been recorded continuously, exceeding the normative values in 2–3 times. During 2012, the waste water of JSC "Complex Agromars" did not exceed the MAD, due to the launch of a new purification system. Also, riveris polluted by sewage from MHMC of urban-type settlement Glevaha. According to the laboratory-analytical studies of discharges, there was an excess of concentration of NO_3 content in 1.9 times and NO_2 in 1.1 times [11].

On the river Unava, the Fastiv reservoir was created. The river water is used for the needs of technical water supply, irrigation and fish farming. By the enterprise ME KOC "Fastivvodokanal" in 2016 in the river was thrown in sufficiently treated waters – 0.95 million m^3, which contained pollutants: 1 release of Fe – exceeding the norms MPC in 1.6 times, 2 release of Fe – in 3.2 times. JSC "Fakel" dumped in sufficiently treated water volume of 0.07 million m^3 contaminated NO_3 – in 1.1 times exceeded the MAC.

3. Conclusions

The problem of unsatisfactory ecological condition of small rivers in the Irpin basin is significant, and therefore requires the involvement of measures to solve it, because, according to the results of the calculations, each of them is polluted and has exceeded the MAC standards. The calculations confirmed that the Irpin river is under a negative influence because of its tributaries - directly because of the Nyvka ($I_{anthr.impact}$ in a place of confluence 0.65) and Kozka rivers ($I_{anthr.impact}$ in a place of confluence 0.59), in particular in the Kozkariver, the concentration of NO_3 content is exceeded – in 1.9 times and NO2 – in 1.1 times; in Unawa river – 1 release of Fe – in 1.6, and 2 release of Fe – in 3.2. This is the result of significant anthropogenic pressure on their catchment areas.

According to the final integral index (I_e) on the basis of the corresponding block indexes (I_1, I_2, I_3) the quality of the investigated river waters varied within 1.99–2.61.

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Екологічна оцінка стану малих річкок басейну річки Ірпінь за екосистемним принципом

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Основна мета даної роботи: Дослідження екологічного стану малих річок басейну р. Ірпінь в межах Київської області. Встановлення основних причин незадовільного екологічного стану досліджуваних об'єктів, серед яких р. Нивка, р.Козка та р.Унава. **Методи:** При дослідженні застосовувався екосистемно-басейновий підхід, статистична обробка власних даних та даних моніторингу державних установ. Здійснено систематизацію та сформовано банк даних гідрохімічних показників р. Ірпінь за десятирічний період. **Результати:** За результатами досліджень, у всіх притоках відмічено перевищення норм гранично допустимих концентрацій забруднюючих речовин, що є основним дестабілізуючим фактором для гідроекосистеми р. Ірпінь. Висновки про екологічний стан р. Ірпінь було виконано на основі динаміки зміни індексу якості води у восьми контрольних точках. Для кількісної екологічної характеристики навантаження на гідроекосистему басейну р. Ірпінь було розраховано індекс техногенного впливу в контрольних створах. **Обговорення:** Отримані результати обумовлюють необхідність подальшого дослідження структурно-функціональних особливостей розвитку гідроекосистеми р. Ірпінь у просторі і часі. Оцінка впливу антропогенних факторів на стан гідроекосистеми дозволить скорегувати природоохоронну діяльність стосовно покращення екологічного стану досліджуваного басейну.

Ключові слова: басейн річки; гідроекосистема; гранично допустима концентрація; малі річки; техногенний вплив

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Экологическая оценка состояния малых рек басейна реки Ирпень по экосистемному принципу

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Основная цель данной работы: Исследование экологического состояния малых рек бассейна р. Ирпень в пределах Киевской области. Установление основных причин неудовлетворительного экологического состояния исследуемых объектов, среди которых р. Нива, р. Козка и р. Унава. **Методы:** При исследовании применялся экосистемных-бассейновый подход, статистическая обработка собственных данных и данных мониторинга государственных учреждений. Осуществлена систематизация и сформирован банк данных гидрохимических показателей р. Ирпень за десятилетний период. **Результаты:** По результатам исследований, во всех притоках отмечено превышение норм предельно допустимых концентраций загрязняющих веществ, что является

основным дестабилизирующим фактором для гидроэкосистемы р. Ирпень. Выводы об экологическом состоянии р. Ирпень было выполнено на основе динамики изменения индекса качества воды в восьми контрольных точках. Для количественной экологической характеристики нагрузки на гидроекосистему бассейна р. Ирпень было рассчитано индекс техногенного воздействия в контрольных створах. **Обсуждение:** Полученные результаты обусловливают 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 исследуемого бассейна.

Ключевые слова: бассейн реки; гидроэкосистема; предельно допустимая концентрація; малые реки; техногенное воздействие

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