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REGULARITY OF EFFECTS OF CLIMATIC CHANGES ON QUALITY INDICATORS OF SURFACE WATER OF THE DNIESTER BASIN

Purpose. To substantiate the regularities of the influence of climate change on the quality indicators of surface waters of the Dniester basin taking into account the influence of waste water of the oil and gas enterprise.

Methodology. The ecological assessment of the quality of surface waters affected by the discharge of waste water from the oil and gas enterprise of the Carpathian region was carried out by determining the integrated index of water objects quality potential. The statistical processing of the database of hydrochemical monitoring of surface water bodies of the Svicha river basin for the period of 2006–2015, databases of the meteorological data from the Dolyna meteorological station was conducted and followed by mathematical modeling and regression analysis using MatLab, TableCurve 2D programs.

Findings. The analysis of the state of hydroecosystems where the waste water was discharged was carried out. A three-dimensional model of air temperature changes in the Dolyna district in Ivano-Frankivsk region during 2006–2015 was obtained. Correlation-regression dependence of qualitative indicators of surface water taking into account climatic changes was established. As a result of the conducted research the authors obtained the following results: the dependences found for the Precarpathian rivers of the upper Dniester basin prove the hypothesis: within the range of average annual temperatures of reservoirs (8–11°C) and their increase by 1–2 °C during the last ten years with maintaining the trend in the future: global increase in the average annual air temperature leads to the intensification of the processes of self-cleaning of reservoirs. The indicator of biochemical oxygen consumption (BOD_5) was increasing at this time. The conducted regression analysis proves that there is a certain correlation between the quality of water on the basis of BOD_5 and the long-term changes in air temperature. The greater the pollution of the water object is, the more intense dependence gets.

Originality. For the first time the functional regularities of the change of the complex index of the quality potential of water objects according to the change in the average monthly temperature of air on the basis of statistical analysis were obtained. For the first time a connection between a separate indicator of the water quality of a natural reservoir (on the example of BOD_5) within the influence on the surface hydroecosystem of discharges of waste water from the oil and gas enterprise and the global increase of the temperature was found.

Practical value. The results of the study can be used for determining the priority problems of surface water, for further prediction of the impact of climate change on the water quality of the rivers Turianka, Sadzhava, Lushchava, which are within the influence zone of the oil and gas industry enterprises, and will promote the development of scientifically proved measures to ensure the environmental safety of surface water and prevention of emergency ecological situations in the Carpathian region. The tendency of intensification of self-purification processes in surface water bodies with increasing temperature will be the subject of our further more detailed research.

Keywords: *surface water, the index of potential water quality, air temperature, waste water, oil and gas industry*

Introduction. Every year there is a rapid growth in anthropogenic activity associated with the development of industry and the significant use of water resources. Climate change, which has occurred in recent decades, affects the water regime of the year of Ukraine, which determines the expediency of taking certain measures to preserve and restore water resources for water consumption and water use of the population. Today, the quality of natural watercourses in the Carpathian region is deteriorating as a result of excessive water use and discharging insufficiently treated return water. As a result, there appears pollution, clogging, depletion of water resources, degradation of river ecosystems. However, the quality of water is affected not only by anthropogenic load, but also by natural conditions. The signing of the UN Framework Convention on Climate Change by representatives of 175 countries suggests that climate change is a significant threat to the environment and economic development.

There is a large number of scientific works dedicated to the study of this problem, however, local tendencies may differ from global ones [1, 2]. An analysis of previous research makes it possible to ascertain the insufficient knowledge of long-term climate change and its consequences for the Carpathian region. Therefore, it is very relevant to determine the dependence of quality indicators of surface water on the influence of natural factors and their changes in time.

Analysis of the recent research. The analysis of literature has shown a significant number of works on the impact of climate change on the qualitative and quantitative characteristics of water resources [1, 3]. It is worth noting the works of Ukrainian scholars such as O. M. Adamenko, Ya. O. Adamenko, L. M. Arkhypova, V. M. Shmandiy, M. M. Prykhodko, M. V. Korchemlyuk and others who conducted research on the ecological state of the rivers of the Carpathian region.

For example, in the paper [4], the main parameters of air temperature and rainfall according to the data of all meteorological stations of the Ukrainian part of the Prut river basin for the years 1990–2016 are studied by the authors, and it is concluded that the average annual air temperature in the Prut river basin increased for the analyzed period by 0.5–1.1 °C compared with the norm. The least positive deviation of the average annual temperature of air from the norm (0.5 °C) belongs to the mountainous areas – the meteorological station Pozhyzhevska, and the maximum deviation (1.1 °C) belongs to the plain areas – a meteorological station Chernivtsi. The average perennial rainfall for the analyzed period increased from 21 to 95 mm in all meteorological stations compared to the norm, except for the meteorological station Chernivtsi, where the average annual rainfall decreased by 5 mm.

The peculiarities of spatio-temporal distribution of temperature and precipitation over the Ukrainian part of the Prut river basin are established including steady growth of the positive deviation of the average annual temperature from the average-long-term norm; an increase in the average perennial rainfall, closer to the source of the river Prut; the prevailing trend of increasing precipitation in mountainous and flat areas; an increasing trend of temperature rise compared with the average-long-term norm in the direction from the north-west to the south-east and from the mountains to the plain areas; an increasing trend in the number of rainfalls compared to the average-long-term norm in the direction of south-east to north-west and from the plains to the mountains [4].

However, the identification of spatio-temporal regularities of the distribution of quality indicators of surface water in conditions of climate change for the researched area of the Carpathian region was not carried out.

Objectives of the article. The goal is to reveal the laws of the influence of climate change on the quality indicators of surface water on the example of the watercourses of the Dniester basin.

The natural watercourses of the Carpathian region are selected for the research objects, namely: the rivers Turianka, Sadzhava, Lushchava, which are in the zone of sewage pollutions of Dolyna oil and gas extracting enterprise.

To achieve this goal we need to solve the following tasks:

- to define a complex index of the quality potential of selected water objects;
- to research climate change in the Dolyna district of Ivano-Frankivsk region within the years 2006–2015;
- to conduct correlation-regression analysis of the complex index of the quality potential of water and its individual components with changes in air temperature.

Presentation of the main research. The ecological assessment of surface water quality is the basis for determining the trends of its change in time and space, determining the impact of anthropogenic load on the ecosystem of water bodies, assessing changes in the state of water resources.

Dolyna oil and gas extracting enterprise has an impact on the ecological state of the rivers Turianka, Sadzhava, Lushchava (right tributaries of the river Svicha), as it drains its waste water after purification into the water objects under research.

The method, used to assess the water quality in the given natural watercourses, is based on the determination of the complex potential quality index of water objects [4]. The author's method for assessing the quality of surface water includes sampling water, conducting analyzes, further generalization with obtaining a complex quality potential index (CIPQ), finding its spatial patterns of distribution for background natural objects, norms of quality potential at any point of an object. The obtained patterns are used for contaminated water object-analogues, assessing the level of quality potential on the developed scale. The proposed model can be used for the estimation of quantitative self-purification indexes of the year. This indicator is calculated by the formula

$$CIPQ = \frac{1}{n}\sum_{i=1}^{n} x_i;$$

$$x_i = \begin{cases} \dfrac{QS_i}{C_i}, & \text{if } \dfrac{QS_i}{C_i} > 1 \\ -\dfrac{C_i}{QS_i}, & \text{if } \dfrac{QS_i}{C_i} < 1 \end{cases},$$

where QS_i is water quality standard for the i^{th} indicator – limit values (permissible) indicators of water status and their properties, which meet the requirements of different consumers; C_i is the actual value of water quality for the ith indicator; n is the number of indicators.

In the calculations of the CIPQ, the so-called coefficients of the reserves of indicators (relative capacity of reserve power) are summed up, calculated as the excess of the permissible values over the actual ones (concentrations, units, points, and the number of deducted coefficients of the deficit of the indicators) (the relative value of the lack of reserves), calculated as excess concentrations (or other measurements) above the permissible values (in the same units). The result is divided by the number of used indicators.

Various indicators such as organoleptic, physical, chemical, biological, toxicological, sanitary conditions should be taken into account in the calculations of the CIPQ. The number of indicators taken for the calculation of the CIPQ should be at least 10–15, regardless of whether they exceed the acceptable values of quality indicators or not, but it must include indexes of hydrochemical, trophic and probiotic and toxicological groups: dissolved oxygen, COD (Chemical Oxygen Demand), pH, mineralization and biochemical oxygen consumption (BOD_5). In addition, all indicators of these groups, whose values exceed optimal, background or normative, must be included. From the calculations it is necessary to exclude indicators of pollutions which are not in the water in its natural state, if the concentration of pollution is far from the MPC (maximum permissible concentration), taking into account the effects of sumation, given that the potential of natural water quality can not characterize the amount of lack of pollutants that are not characteristic to natural water.

We also consider both the lower and the upper limits as a safe interval of physiological value of water in the calculations of the CIPQ for the indicators of mineralization, alkalinity, hydrogen index, magnesium ion concentration. That is, in the end, the exceeding of the upper limit above the actual value of the indicator will be positive and the excess of the actual concentration over the lowest allowable value will be negative. If the actual value of the indicator does not fall into a safe interval, (for example, such cases are probable for pollution of surface water in the areas of construction of oil and gas wells), then in the end, the excess of the actual value of the indicator over the upper and lower acceptable values will be negative. Exceptions are those quality indicators for which the lower threshold is set, i.e. exceeding the quality standard is desirable (for example, dissolved oxygen content, transparency, and others).

If the concentrations of a substance equal zero, the formula should be substituted with the values of concentration, which can still be detected by the most sensitive method for measuring this substance, that is, the smallest of the thresholds for its detection.

Given that the amount of biochemical oxygen consumption (BOD_5) is an integral indicator of the presence of lightly oxidised organic substances, as well as the fact that with the increase in the content of easily oxidizable organic substances and the decrease in the content of dissolved oxygen, the quality of water decreases disproportionately sharply, the norms for these indicators in the calculations of the CIPQ are offered somewhat different (Table 1).

The CIPQ was evaluated on the following scale on the basis of mathematical processing of the data on the quality of the water of the rivers Turianka, Sadzhava, Lushchava for the period of 2006–2015:

- buffer CIPQ > 5;
- optimal 3 < CIPQ < 5;
- tension of adaptive 1 < CIPQ < 3;
- zone of pessimum –1 < CIPQ < 1;
- critical –3 < CIPQ < –1;
- crisis –3 < CIPQ < –5;
- disastrous CIPQ < –5.

Table 1

Quality standards for dissolved oxygen and BOD_5 depending on the actual values [5]

The actual value of BOD_5, mg/dm^3 relative to O_2	Quality standards mg/dm^3 relative to O_2	The actual value of dissolved oxygen, mg/dm^3	Quality standards mg/dm^3
up to 3	2.26	more than 6	6
3–15	2	6–5	12
more than 15	1	5–4	20
-	-	4–3	30
-	-	3–2	40
-	-	2–1	50
-	-	1–0	60

The complex index of potential water quality was calculated for the river Turianka (after iIssue No.1 and after Issue No. 4), the river Sadzhava (after Issue No. 2) and the river Lushchava (after Issue No. 3). The research was carried out on the basis of the analysis of water samples just after the release of return water (500 m after the source of dumping) of the oil and gas industry.

The proposed methodology for assessing the qualitative component of the natural and technogenic safety of hydroecosystems gives an opportunity to assess the state of the water body more fully, to determine the probability of violations of the stability of the water ecosystem, decrease in the quality of water resources and the conditions for their reproduction, and, accordingly, to apply a set of measures more substantially to reduce the risk of negative impacts of contaminated water ecological systems.

Calculated CIPQ is a relative value, which depends on the level of anthropogenic load. The results of calculating the complex index of water quality potential from the data base of the monitoring data of the research are presented in Table 2.

The analysis of the results allows us to conclude that the river Sadzhava is polluted, and the quality of the water of the river Turianka and the Lushchava in the long-term section is satisfactory. If we analyze the changes in the indicator over the past 10 years, a slight improvement can be seen in the quality index in all water bodies. Taking into account that the Dolyna oil and gas enterprise has been working steadily all the time, we hypothesize that positive changes in quality are caused by natural factors, the main of which is the climate. To confirm the hypothesis, an analysis of meteorological indicators was carried out according to the data of the Dolyna me-

Table 2

Complex index of water quality potential in the rivers Turianka, Lushchava, Sadzhava

Years	Turianka Issue 1	The state of the hydro ecosystem	Sadzhava Issue 2	The state of the hydro ecosystem	Lushchava Issue 3	The state of the hydro ecosystem	Turianka Issue 4	The state of the hydro ecosystem
2006	2.268	tension of adaptation	3.241	optimal	4.174	optimal	2.439	tension of adaptation
2007	2.657	tension of adaptation	5.450	buffer	4.696	optimal	3.147	optimal
2008	1.719	tension of adaptation	0.353	zone of pessimum	2.970	tension of adaptation	2.287	tension of adaptation
2009	2.483	tension of adaptation	0.236	zone of pessimum	5.507	buffer	2.797	tension of adaptation
2010	4.108	optimal	1.382	tension of adaptation	10.370	buffer	4.081	optimal
2011	2.209	tension of adaptation	2.343	tension of adaptation	2.024	tension of adaptation	2.858	tension of adaptation
2012	5.597	buffer	1.671	tension of adaptation	2.617	tension of adaptation	2.723	tension of adaptation
2013	2.109	tension of adaptation	2.963	tension of adaptation	5.595	buffer	2.882	tension of adaptation
2014	3.412	optimal	0.486	zone of pessimum	4.935	optimal	2.854	tension of adaptation
2015	3.671	optimal	5.284	buffer	6.614	buffer	2.931	tension of adaptation

teorological station of the Hydrometeorological Service of Ukraine.

On the basis of the analysis of meteorological data, a general tendency of increase in air temperature over the last 10 years has been revealed (Fig. 1). The dynamics of the change in the average monthly air temperature for the period 2006–2015 is presented using the Matlab program. The figure shows that significant warming was observed in the period 2012–2015.

The increase in air temperature is especially noticeable in the summer months. The minimum air temperature during the summer period was recorded in 2006 (16 °C), the maximum – in 2015 (25.5 °C). The average annual air temperature from the meteorological station in the valley for different periods was:

- 2006–2010 – 8.7 °C;
- 2011–2015 – 10.7 °C.

Consequently, the air temperature increased by 2 °C for the entire study period of 2006–2015. It is known that the air temperature determines the temperature regime of water bodies and, as a consequence, affects the qualitative characteristics of the hydro ecosystem.

Most of the physical properties of water, chemical and biological processes in water depend on tempera-

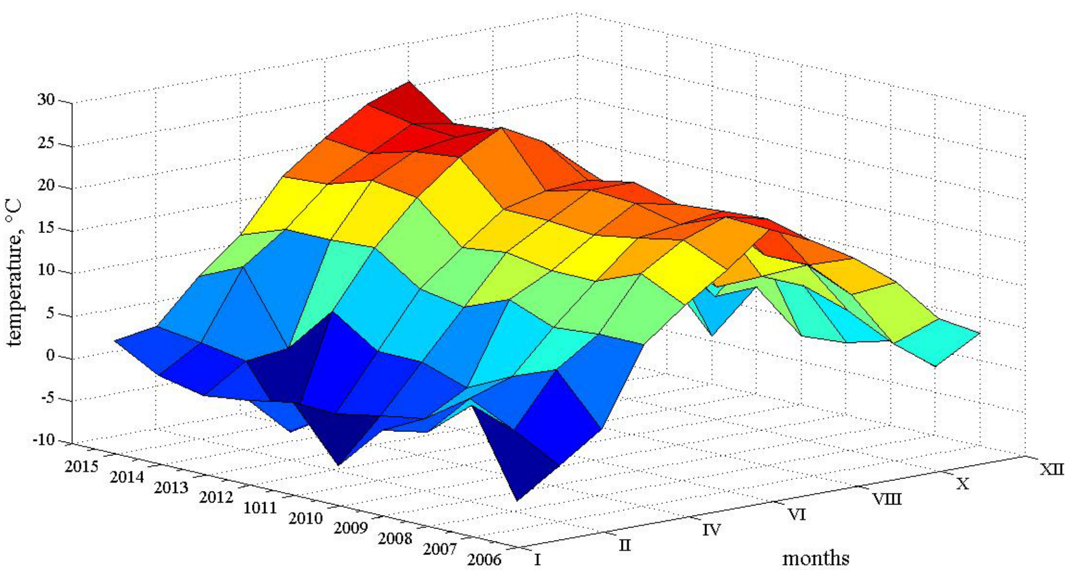

Fig. 1. Dynamics of changes in the average monthly air temperature for the period of 2006–2015

ture. The flow temperature directly affects the entire aquatic ecosystem. Extreme changes in water temperature can have an adverse effect on fertility, life cycle, space-time distribution of biodiversity. The increase in water temperature affects the kinetics of the chemical reaction and, thus, the level of water quality parameters [6].

Indeed, it is likely that global warming will lead to a change in the temperature of freshwater systems and, therefore, it is necessary to assess the potential impact of global climate change on the state of surface water resources.

The increase in temperature changes both the quantity and quality of water, and is likely to be different between large and small basins [2, 3]. Potential changes in temperature and precipitation cannot be evenly distributed to large drainage basins, and thus the regional and local levels, as well as the degree of urbanization, should be taken into account in the study of climate change impacts for the protection of water resources [7].

Consequently, water temperature is an important parameter of water flow quality, air temperature modeling is an important tool for current and future water quality assessment [2].

In the conducted research, we tested the hypothesis about the connection of the average monthly air temperatures with the complex indicator of water quality within the limits of the influence of OGPD "Dolynanaftogaz" on the use of regression analysis. Data of a ten-year period was analyzed.

Regression analysis is the main statistical method for constructing mathematical models of objects or phenomena according to experimental data [8].

The regression analysis method solves two main problems: the analytical form of the relationship between the variation of the signs X and Y is determined using the regression equations and the degree of link density between the features is established. A regressive dependence of the qualitative state of the river inflow was constructed due to changes in the temperature of the air for the period of 2006–2015 using the TableCurve 2D program (Figs. 2, 3).

The F-Fisher test was used to verify the relevance of the connection. The critical value of the determination coefficient ($D = r^2$) depends on the percentage of security α and the number of degrees of freedom of the dispersion $k_1 = m - 1$ and $k_2 = n - m$, where n is the number of elements in the set; m is the number of groups into which the set is divided.

We determine the tabular value of the F-criterion (Ftabl) from the special statistical tables in accordance with the values of the degrees of freedom ($k_1 = 1$, $k_2 = 7$) and the level of significance 0.05. For example, the actual value of the F-criterion is 19.4 (issue 1), which is calculated in the TableCurve 2D program. As a result, F > Ftabel (19.4 > 5.5), hence, the connection between the featuress is non-random (significant).

Accordingly, the verification of the relevance of the CIPQ connection and the changes in the temperature of the air on the basis of the Fisher's F-criterion for the rivers Sadzhava (Issue 2), Lushchava (Issue 3), Turianka

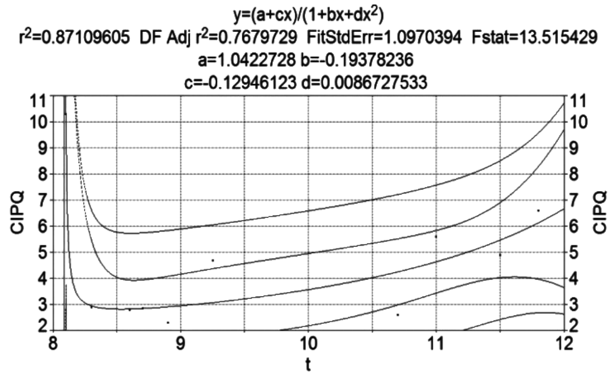

Fig. 2. Functional dependence of the complex index of potential quality of the river Lushchava after Issue 3 on the average monthly temperature of air

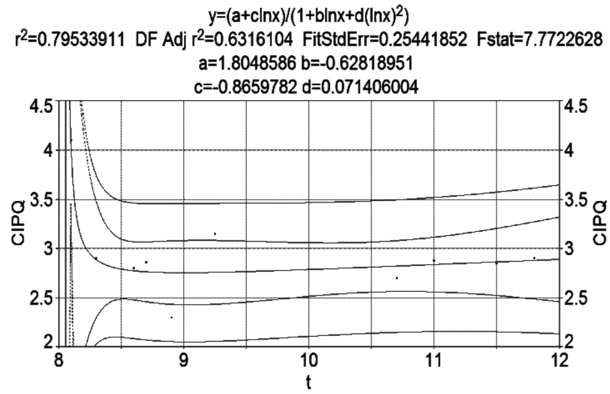

Fig. 3. Functional dependence of the complex index of potential quality of the river Turianka after Issue 4 on the average monthly temperature of air

(Isue 4) was carried out.

So, for the first time, we established the connection between a complex indicator of the quality of a natural reservoir after the discharge of waste water from the oil and gas industry and global changes in the temperature of the environment. Taking into account the multifactor of qualitative indicators of hydroecosystems, which depend on external conditions, climatic indices, anthropogenic loading, lack of measurements of indicators of quality and temperature of sewage directly at the discharging site of OGPD "Dolynanaftogaz", we consider the receipt of significant functional models of the dependence of the complex index of the quality potential on the average monthly temperatures of atmospheric air as the first step to predict the impact of global climate change on the self-cleaning of aquatic ecosystems.

As a result of the carried out research studies, the following was established: for the Precarpathian upstream rivers of the Dniester basin, the obtained dependences prove the hypothesis that within the range of average annual temperatures of reservoirs (8–11 °C) and their predicted increase by 1–2 °C over the last ten years, with the preservation of the trend in the future – global increase in the average annual temperature of the air leads to intensification of the processes of self-cleaning of reservoirs.

Further, the hypothesis is checked by constructing functional dependencies of changes in the individual indicators of water quality with changes in air temperature.

BOD_5 is an important ecological indicator of the state of natural reservoirs. Organic substances in natural watercourses are biodegradable (affected by mineralization), which is accompanied by the consumption of dissolved oxygen and can lead to its complete disappearance and the emergence of anaerobic conditions. This process, which leads to mineralization of organic matter, is due to the activity of bacteria contained in sewage water and in water of the reservoir [9].

Together with organic substances of domestic and industrial sewage water, a large number of saprophytic and pathogenic bacteria comes in the reservoir; therefore, the concentration of organic substances directly indicates the bacterial contamination of the reservoirs and this is what the sanitary value of the BOD index is characterized by [10].

Aerobic bacteria quickly reproduce in water with high levels of organic matter as oxygen is essential for their vital functions. This may result in a decrease in the content of dissolved oxygen, create hypoxic conditions and the loss of certain types of hydrobionts.

Daily oscillation values of BOD_5 depend on the initial concentration of dissolved oxygen, which can change overnight by 2.5 mg/dm^3 depending on the ratio of processes of its consumption and production.

This indicator characterizes the state of pollution of water bodies, whose main indicators are the content of organic substances and ammonium compounds, on which the conditions for maintaining the necessary level of oxygen content in rivers depend largely [11].

Regression analysis was carried out between changes in air temperature and water quality on the basis of BOD_5 for all 4 issues of the Dolyna oil and gas production enterprise on the basis of hydrochemical data for the period of 2006–2015.

The closest connection between the studied indicators can be traced after Issue 2 (the river Sadzhava), where the determination coefficient ($D = r^2$) is 0.87. The reliability of the result confirms the actual value of the Fisher's criterion, which is 10.7 > 5.5 (F > Ftabel). It should be noted that the index BOD_5 of the Sadzhava exceeds the norm by 5.6–28.6 times at a maximum allowable concentration of 3 mg/dm^3. It indicates a significant pollution of this hydroecosystem under the influence of anthropogenic activities.

The conducted regression analysis proves that there is a certain correlation between water quality on the basis of BOD_5 and the long-term changes in air temperature (Table 2). The greater the pollution of subject to the water object is, the tighter the dependence is. Functional dependencies of BOD_5 on changes in air temperature for the rivers Sadzhava and Lushchava are shown in Figs. 4, 5.

Consequently, for the indicator BOD_5 according to our research, the rule is true: the increase in the air temperature leads to an increase in the values of the indicator, while the connection becomes closer with the increase in the pollution of the water object.

A well-known pattern is: an increase in the temperature of a water object is a catalyst for hydrochemical processes, which accelerated by 10 times or more. The temperature of the water body in the climatic zone of Ukraine varies according to the latitudinal zoning law and for the most water bodies, it follows the air temperature. Water temperature changes occur more slowly and more smoothly than changes in the temperature of air due to the fact that the water mass has a significant thermal inertia. In the daily temperature mode, the delay in time is 2–3 hours, in the annual temperature mode it is 10–15 days. Proceeding from this natural pattern, it is not possible to obtain functional dependencies between instant measurements of water quality and air temperature. Therefore, an attempt was made to obtain functional relationships between instant measurements of water quality and average monthly air temperature, which proved to be successful (Table 3).

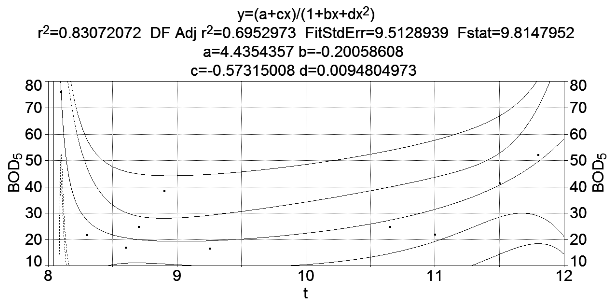

Fig. 4. Functional dependence of BOD_5 of the Sadzhava after Issue 2 on average monthly air temperature

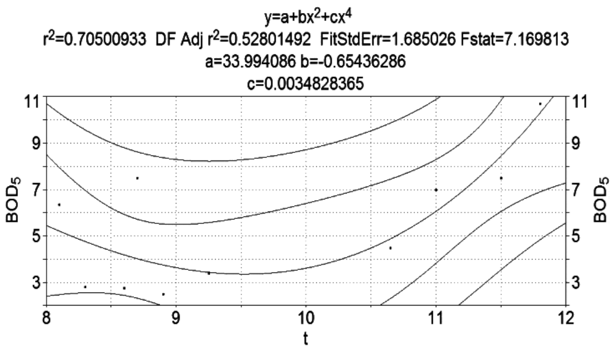

Fig. 5. Functional dependence of BOD_5 of the Lushchava after Issue 3 on the average monthly temperature of air

Table 3

Correlation between the water quality indicators of the rivers of the Dniester basin and the average monthly temperature in the ten-year dynamics

Water object	The presence of connection r^2	
	CIPQ(t)	BOD_5 (t)
r. Turianka (Issue 1)	0.98	0.86
r. Sadzhava (Issue 2)	0.65	0.83
r. Lushchava (Issue 3)	0.87	0.70
r. Turianka (Issue 4)	0.80	0.64

Defined dependencies of quality indicators of surface water on the change of natural factors will allow carrying out an objective assessment of the ecological state of the natural watercourses of the Sadzhava, Lushchava, and Turianka, to determine the priority problems and trends of changes in the quality indicators in the future, which will, as a result, contribute to the development of long-term forecasts and environmental measures.

Conclusions. The scientific novelty of the conducted research is the receiving of meaningful functional models of the dependence of the quality of water objects on average monthly atmospheric air temperatures. A comprehensive index of potential quality of selected rivers of the Carpathian region was determined; the climate changes in the Dolyna district of Ivano-Frankivsk region in 2006–2015 were analyzed; a correlation-regression analysis of the integrated index of water quality potential was conducted, depending on changes in the temperature of the air. It was found that the average monthly and average annual air temperature increased significantly at 2 °C in the period of 2012–2015 (especially in the summer).

The continued research is seen in predicting the impact of global climate change on the self-cleaning of aquatic ecosystems. Thus, for the Precarpathian rivers of the upper Dniester basin, the obtained dependences prove the following hypothesis: within the range of average annual temperature of reservoirs (8–11 °C) and their predicted increase by 1–2 °C over the last ten years, with the preservation of the trend in the future – the global increase in average annual air temperatures leads to the intensification of the processes of self-purification of reservoirs, taking into account the sampling of 500 m below the flow after the discharge of sewage from the oil and gas company “Dolynanaftogaz”. The enterprise disposes the wastewater into three different rivers of the Dniester basin: Turianka, Sadzhava, and Lushchava. The latter is the dirtiest river of the Carpathian region. The following tendency is revealed: the dirtier the river is, the more intensive processes of self-purification are going on, which will be the subject of our further research. For the BOD_5 indicator, according to our research, the rule is: the increase in the air temperature leads to an increase in the values of the indicator, and the connection becomes closer with the increase in the pollution of the water object.

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Закономірності впливу кліматичних змін на якісні показники поверхневих вод басейну Дністра

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Мета. Обґрунтувати закономірності впливу кліматичних змін на якісні показники поверхневих вод басейну Дністра з урахуванням впливу стічних вод нафтогазодобувного підприємства.

Методика. Екологічна оцінка якості поверхневих вод, що перебувають під впливом скиду стічних вод підприємства нафтогазової промисловості Карпатського регіону, здійснювалась способом, що полягає у визначенні комплексного індексу потенціалу якості водних об'єктів. Проведена статистична обробка бази даних гідрохімічного моніторингу поверхневих водних об'єктів басейну р. Свіча за період 2006–2015 рр., бази метеорологічних даних Долинської метеостанції з подальшим математичним моделюванням і регресійним аналізом за допомогою програм MatLab, TableCurve 2D.

Результати. Проведено аналіз стану гідроекосистем, до яких здійснювався водовідвід стічних вод. Отримана тривимірна модель зміни температури повітря в Долинському районі Івано-Франківської області з 2006 по 2015 рр. Встановлена кореляційно-регресійна залежність якісних показників поверхневих вод з урахуванням кліматичних змін. У результаті проведених досліджень встановлено наступне: для Прикарпатських річок верхньої течії басейну Дністра отримані залежності доводять гіпотезу: у межах діапазону середньорічних температур водойм (8–11 °С) і їх підвищення на 1–2 °С протягом останніх десяти років зі збереженням тенденції в майбутньому – глобальне підвищення середньорічних температур повітря призводить до інтенсифікації процесів самоочищення водойм. У цей час показник біохімічного споживання кисню ($БСК_5$) зростає. Проведений регресійний аналіз доводить, що існує певна залежність між якістю води за $БСК_5$ і багаторічними змінами температури повітря. Залежність виявляється тим тіснішою, чим більшому забрудненню підлягає водний об'єкт.

Наукова новизна. Уперше на основі статистичного аналізу отримані функціональні закономірності зміни комплексного індексу потенціалу якості водних об'єктів у залежності від зміни середньомісячної температури повітря. Уперше було встановлено зв'язок між окремим показником якості води природної водойми (на прикладі $БСК_5$) у межах впливу на поверхневу гідроекосистему скидів стічних вод підприємства нафтогазової галузі й глобальним підвищенням температури довкілля.

Практична значимість. Результати дослідження можуть бути використані для визначення пріоритетних проблем поверхневих вод, подальшого прогнозування впливу змін клімату на якість води річок Тур'янка, Саджава, Лущава, що знаходяться в межах впливу підприємства нафтогазової промисловості, та сприятимуть розробці науково обґрунтованих заходів щодо забезпечення екологічної безпеки поверхневих вод і попередження виникнення надзвичайних екологічних ситуацій у Карпатському регіоні. Виявлена тенденція інтенсифікації процесів самоочищення в поверхневих водних об'єктах із підвищенням температури стане предметом наших подальших більш детальних досліджень.

Ключові слова: *поверхневі води, індекс потенціалу якості води, температура повітря, стічні води, нафтогазова промисловість*

Закономерности влияния климатических изменений на качественные показатели поверхностных вод бассейна Днестра

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Цель. Обосновать закономерности влияния климатических изменений на качественные показатели поверхностных вод бассейна Днестра с учетом влияния сточных вод нефтегазодобывающего предприятия.

Методика. Экологическая оценка качества поверхностных вод, что находятся под влиянием сброса сточных вод предприятия нефтегазовой промышленности Карпатского региона, осуществлялась способом, который заключается в определении комплексного индекса потенциала качества водных объектов. Проведена статистическая обработка базы данных гидрохимического мониторинга поверхностных водных объектов бассейна р. Свеча за период 2006–2015 гг., базы метеорологических данных Долинской метеостанции с последующим математическим моделированием и регрессионным анализом с помощью программ MatLab, TableCurve 2D.

Результаты. Проведен анализ гидроэкосистем, к которым осуществлялся водоотвод сточных вод. Получена трехмерная модель изменения температуры воздуха в Долинском районе Ивано-Франковской области с 2006 по 2015 гг. Установлена корреляционно-регрессионная зависимость качественных показателей поверхностных вод с учетом климатических изменений. В результате проведенных исследований установлено следующее: для рек Прикарпатья верхнего течения бассейна Днестра полученные зависимости доказывают гипотезу: в пределах диапазона среднегодовых температур водоемов (8–11 °С) и их повышения на 1–2 °С в течение последних десяти лет с сохранением тенденции в будущем – глобальное повышение среднегодовых температур воздуха приводит к интенсификации процессов самоочищения водоемов. В это время показатель биохимического потребления кислорода ($БПК_5$) возрастает. Проведенный регрессионный анализ показывает, что существует определенная зависимость между качеством воды по показателю $БПК_5$ и многолетними изменениями температуры воздуха. Зависимость проявляется тем теснее, чем большему загрязнению подлежит водный объект.

Научная новизна. Впервые на основе статистического анализа получены функциональные закономерности изменения комплексного индекса потенциала качества водных объектов в зависимости от изменения среднемесячной температуры воздуха. Впервые была установлена связь между отдельным показателем качества вод естественного водоема (на примере $БПК_5$) в пределах влияния на поверхностную гидроекосистему сбросов сточных вод предприятия нефтегазовой отрасли и глобальным повышением температуры окружающей среды.

Практическая значимость. Результаты исследования могут быть использованы для определения приоритетных проблем поверхностных вод, дальнейшего прогнозирования влияния изменений климата на качество вод рек Турьянка, Саджава, Лущава, которые находятся в пределах влияния предприятия нефтегазовой промышленности, и способствовать разработке научно обоснованных мероприятий по обеспечению экологической безопасности поверхностных вод и предупреждению возникновения чрезвычайных экологических ситуаций в Карпатском регионе. Обнаруженная тенденция интенсификации процессов самоочищения в поверхностных водных объектах с повышением температуры станет предметом наших дальнейших более детальных исследований.

Ключевые слова: *поверхностные воды, индекс потенциала качества воды, температура воздуха, сточные воды, нефтегазовая промышленность*

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