UDC 504.453

A. Vasylenko,
Ph.D., professor of the department "Water supply and sanitation",
Kyiv National University of Construction and Architecture, Kyiv
L. Vasylenko,
Ph.D., docent of the department "Health and Environment",
Kyiv National University of Construction and Architecture, Kyiv
S. Fedorenko,
Ph.D., docent of the department "Health and Environment",
Kyiv National University of Construction and Architecture, Kyiv
O. Zhukova,
Ph.D., docent of the department "Health and Environment",
Kyiv National University of Construction and Architecture, Kyiv
A. Honcharenko,
first grade MA student, 101"Ecology" specialty,
Kyiv National University of Construction and Architecture, Kyiv

DOI: 10.32702/2306-6792.2018.22.10

ESTIMATION OF WATER ECOSYSTEM STRUCTURAL-FUNCTIONAL CHANGES AS A RESULT OF CLIMATE CHANGES

О. А. Василенко,
к. т. н., професор, професор кафедри водопостачання та водовідведення,
Київський національний університет будівництва та архітектури, м. Київ
Л. О. Василенко,
к. т. н., доцент, доцент кафедри охорони праці та навколишнього середовища,
Київський національний університет будівництва та архітектури, м. Київ
С. В. Федоренко,
к. т. н., доцент, доцент кафедри охорони праці та навколишнього середовища,
Київський національний університет будівництва та архітектури, м. Київ
О. Г. Жукова,
к. т. н., доцент, доцент кафедри охорони праці та навколишнього середовища,
Київський національний університет будівництва та архітектури, м. Київ
А. В. Гончаренко,
студент магістратури 1 курсу спеціальності 101 "Екологія",
Київський національний університет будівництва та архітектури, м. Київ

ОЦІНКА СТРУКТУРНО-ФУНКЦІОНАЛЬНИХ ЗМІН ВОДНИХ ЕКОСИСТЕМ У РЕЗУЛЬТАТІ ЗМІНИ КЛІМАТУ

Climate is one of the main natural resources that effect the changes of the rivers water regime. Drastic global warming of climate over the last 150 years is the result of anthropogenic intensification of global atmosphere greenhouse effect which is caused mainly by carbon dioxide burst. Special attention to the issue of global climate change was given on the Second World Climate Conference in Geneva (November, 1990) and on the 21st International Water Services Congress that was held in Madrid (September, 1997). It is prognosticated that water temperature rise and longer period of low flow will worsen the state of surface water systems which will lead to water "bloom".

More intensive rainfalls will cause the increase of suspended matters content in surface waters as a consequence of soils erosion, and may create overloads for the permit systems, water treatment and wastewaters treatment stations.

Frequent periods of low flow will lead to the decrease of contaminants dilution ability and, hence, to the increase of their concentrations. In the places with general flow lowering of water quality will be deteriorated significantly.

This article covers ecological characteristic of Polesye rivers hydroecosystems state (on the example of Teteriv and Ros rivers) in the condition of constant anthropogenic load and global changes of climate parameters. The research was conducted with a glance of spatial and time factor involving existing modern methods of control by indices and their parameters of water ecosystems development. It gave the opportunity to determine cause-and-effect relations in "hydroecosystems — natural-anthropogenic water ecosystems — social-economic systems" system and confirm changes regularities of qualitative and quantitative characteristics of water quality with maximum anthropogenic load and changes of climatic characteristics (air temperature, amount of precipitations). Introduced methods of water ecosystems ecological condition control allows reliable reasons defining of hydroecosystems degradation changes.

Клімат є одним з головних природних ресурсів, від якого залежать зміни водного режиму річок. Стрімке глобальне потепління клімату за останні 150 років є результатом антропогенного підсилення глобального атмосферного парникового ефекту, спричиненого, головним чином, викидами вуглекислого газу. Особливу увагу проблемі зміни клімату було приділено на Другій Всесвітній кліматологічній конференції (в листопаді 1990 року) в Женеві та на 21-му Міжнародному конгресі по водопостачанню в Мадриді (в вересні 1997 року). Прогнозується, що підвищення температури води та більш тривалий період низького стоку погіршать стан поверхневих водних систем, що буде сприяти "цвітінню" води.

Більш інтенсивні дощові опади приведуть до підвищення вмісту завислих речовин у поверхневих водоймах внаслідок ерозії грунті та можуть створювати перегруженості для пропускних систем, станцій обробки води та очистки стічних вод. Часті періоди низького стоку приведуть до зниження здатності до розбавлення забруднюючих речовин і таким чином підвищення їх концентрацій. У районах із загальним зниженням стоку якість води значно погіршиться.

У статті наведено екологічну характеристику стану гідроекосистем річок Полісся (на прикладі р. Тетерів та р. Рось) в умовах постійного антропогенного навантаження та глобальних змін кліматичних параметрів. Дослідження проводились з врахуванням просторово-часового фактору з використанням існуючих сучасних методів контролю за показниками та їх параметрами розвитку водних екосистем. Це дозволило визначити причинно-наслідкові зв'язки в системі "гідроекосистеми — природно-антропогенні водні екосистеми — соціально-економічні системи" та підтвердити залежності зміни якісних та кількісних характеристик якості води з максимальною антропогенним навантаженням та змінами кліматичних характеристик (температура повітря, кількість опадів). Представлені методи контролю екологічного стану водних екосистем дозволять достовірно визначити причини деградаційних змін гідроекосистем.

Key words: water ecosystem, pollution coefficient, water quality, hydrochemical estimation, ecological index, technology intensive, self-cleaning coefficient, sustainable development.

Ключові слова: водна екосистема, коефіцієнт забруднення, якість води, гідрохімічна оцінка, екологічний індекс, техноємність, коефіцієнт самоочищення, стійкий розвиток.

PROBLEM STATEMENT

The problem of global climate change began to attract special attention in 1980s. In the middle of 1990s scientists from all over the world on the basis of long term analyses came up to a conclusion that human beings have serious impact on the occurring climate changes. In the middle of the first decade, it was determined by calculating the damage from natural disasters that 90% of climatic changes are conditioned by the anthropogenic factors and only 10% of these changes are of natural origin. [1]

Climate of our planet is a complicated system which changes due to the interaction processes between atmosphere, hydrosphere and humanity. These elements are in permanent and balanced interaction which is being destroyed nowadays because of anthropogenic impact on the biosphere and its constituents — natural types of ecosystem. Functioning of the ecosystems is intended to energy joining, storing the internal wholeness of its structure organization. In case of big gradient presence between the energy reserves of biosphere separate blocks, imbalance occurs which leads to a decrease of internal balance and increase of entropy indices. Natural ecosystems are not able to provide necessary stabilization anymore; therefore, external factors react accordingly transferring the energy in different directions. It leads to the appearance of heavy showers, storms, whirlwinds, the rise of average annual temperature indices and climatic indices amplitude changes increase, other cataclysms. When the entropy index exceeds the indices of system organization internal condition and this system is not able to withstand the external impact, connections are destroyed and system comes apart.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

On the modern stage of civilization development, characterized by a rapid growth of population on the globe and increased load on natural resources of our planet, the questions of rational usage of water and providing it to the population and economic sectors are becoming extremely relevant. In the first place, it concerns Ukraine which is among the countries with insufficient water supply for one inhabitant. Current development condition of Ukraine is characterized by worsening of the ecological state of all the biosphere constituents. Special attention to the issue of global climate change was given on the Second World Climate Conference in Geneva (November, 1990) and on the 21st International Water Services Congress that was held in Madrid (September, 1997). In particular, it was mentioned that the increase of the global air temperature for 2—3 °C is prognosticated in the next 20—40 years. The largest warming (up to 5—6 °C) will take place in high latitudes and in zones of moderate and frigid climate. Possible consequences of climate change will inevitably affect the conditions of water ecosystems of the planet as they are the most sensitive ones to climate changes [2; 4].

In Ukraine the influence of climate change to water resources was studied by Shereshevskii A.I., Gopchenko E.D., Loboda N.S., Pluntke T., Snizhko S.I., Gorbacheva L.A., etc. The authors make a conclusion that water drain of most Ukrainian rivers, except the rivers of the Carpathian region and Crimean mountain rivers, will essentially decrease during the XXI century. Some rivers like the Samara and the Sula River will stop their existence at all.

Direct connection between the quality of drinkable water and human's health was determined long time ago. According to World Health Organization data, about 75% of human's illnesses are caused by drinking the water of low quality and using the water in household which does not meet the hygienic norms [3].

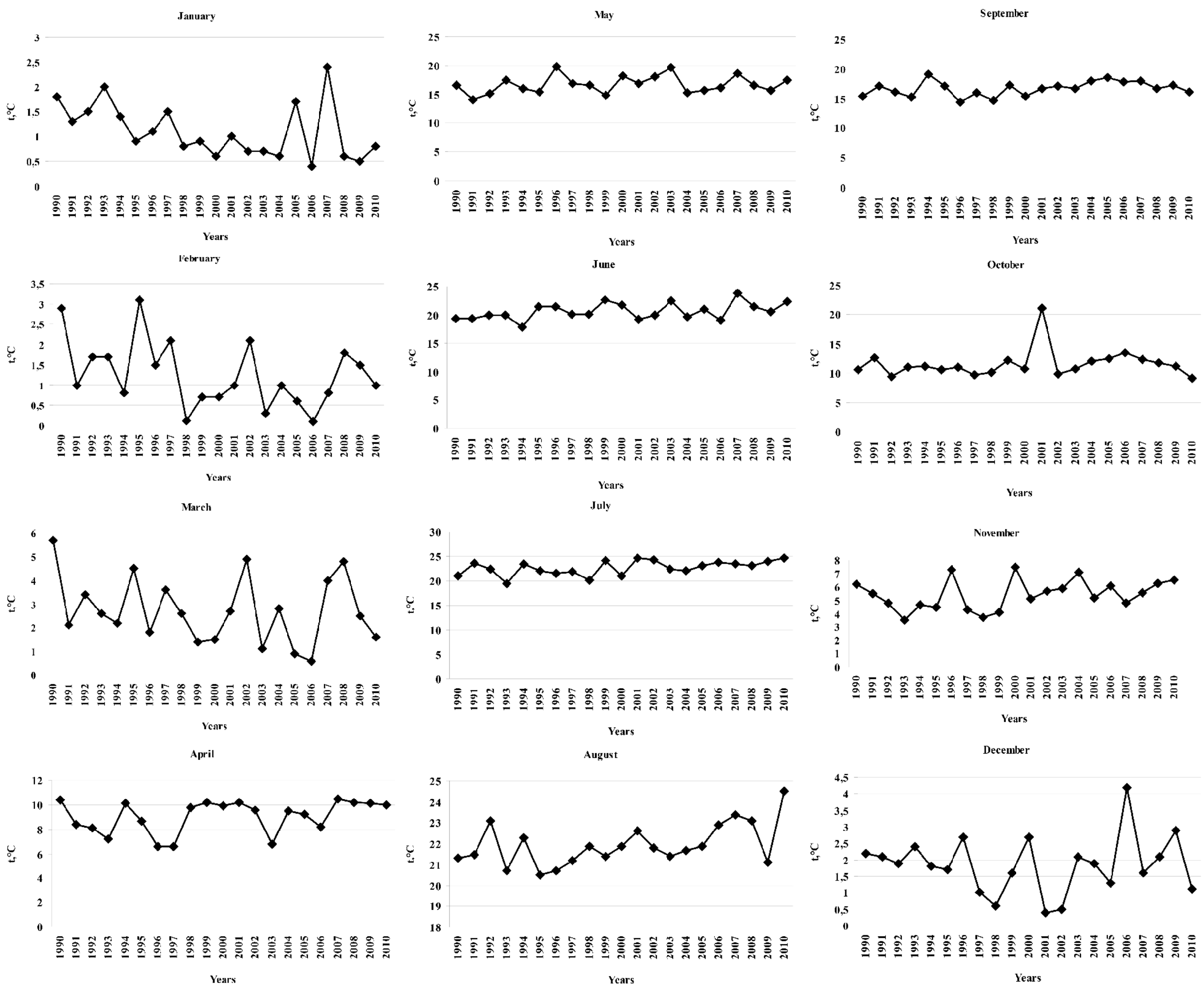
It is being predicted that the increase of water temperature, growth of rainfall intensity and longer periods of low flow will intensify many forms of water pollution (including the pollution by pumps, organic matters, pathogens, pesticides), salt and thermal pollution which will cause the eutrophication of basins and increase the content of pathogenic organisms in water. These processes will lead to a negative impact on water ecosystems, deterioration of society's health and price rise of engineering systems and communications exploitation cost. More intense rainfalls will result in content rise of suspended solids (turbidity) owing to soil erosion with pollutions insertion from the pedosphere. It will bring the deterioration of water quality, as it will cause the growth of pathogens and other polluting matters transfer into surface and underground waters [4; 5].

It is estimated by the specialists that by 2030 the stock level of water objects might be reduced by 40% during the summer period in the most vulnerable regions of the planet [1].

Therefore, optimization of the ecological situation (not only in Ukraine) is possible only in case of developing the approaches and principles of regulation the environmental safety which will be followed by all the countries. Design of new scientific methodological control and estimation principles of ecological safety condition level of natural systems development is one of such important approaches. If one takes the development of water ecosystems into consideration, then it is necessary to recognize the recommendations of Global Water Partnership international committee (2003), where water resource management should [6] take not only organizational and methodical questions into account, but the studies results of interaction between natural and social-economical systems as well. The design of nature conservation measures is carried out on the basis of studying the interaction inside the system of "hydroecosystem — ground ecosystems". Unfortunately, this concept does not have any concrete approaches of its realization.

The number of precipitations, temperature and evaporability which depends on humidity, speed of wind flow, temperature and radiation balance of Earth are the dominant climatic factors of impact on quantitative and qualitative indices of water ecosystems.

A great number of scientific works (Ivaniuta S.P., Yakovlev E.A., Udod V.M., Snizhko S.I., Bozhok Y.V., Khilchevskyi, V.K., Yatsyk A.V., Loboda N.S., etc.) were dedicated to the researches of anthropogenic impact level on the environment. However, the majority of these researches are dedicated to the estimation of structural and functional changes of ecosystems



Pic. 1. Changes dynamics of average monthly temperatures over the period of research and trends of their changes

in regions with permanent load, whereas regions with medium anthropogenic load (regions of steppe and forest-steppe, with advanced agricultural complex) attract little interest of researchers [7; 8].

TASK SETTING

Considering all the mentioned above, the aim of our researches is the study of structural-functional changes of the Ukrainian Polesye water ecosystems as the result of climatic changes.

This work will analyze the questions connected with the estimation of quantitative and qualitative indices of quality of the Ukrainian Polesye rivers water basins, using the Teteriv and Ros rivers, flowing within Zhytomyr and Kyiv oblasts, as the examples. Looking into the cause-and-effect factors of changing the water ecosystems development and operation in the conditions of permanent medium technogenic load and advanced agriculture-based industry became the fundamental factor of such researches.

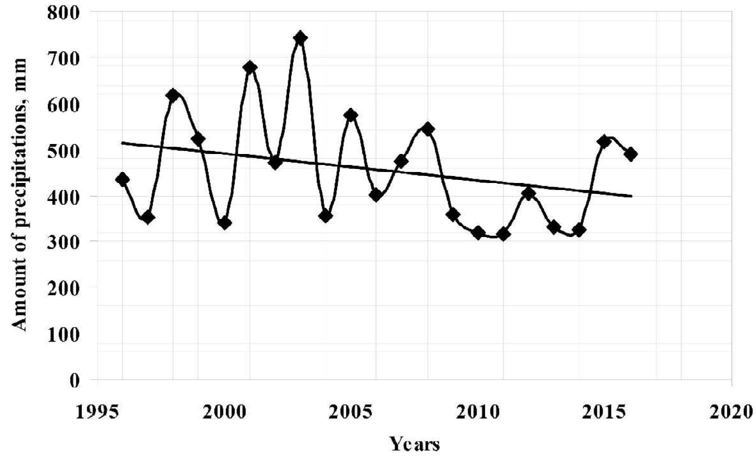
Determination changes regularities of ecosystem structural-functional properties and climatic characteristics together with identification of self-regulating function level (ability to maintain the stability of parameters) define this approach.

In order to achieve the goals set it was necessary to solve the following tasks:

— processing and analysis of ecological monitoring data which characterize qualitatively and quantitatively the condition of water ecosystems and climatic constituents;

— defining the indices which will become the basis for defining the structural-functional changes characteristics;

— calculation of water ecosystems self-cleaning coefficient, technology intensive index and ecological index;



Pic. 2. Changes dynamics of average indices of annual amount of precipitations

— to work out corresponding regularities of qualitative characteristics and climatic parameters changes.

PRESENTATION OF RESEARCH BASIC MATERIAL

In order to define scientific regularities of the Teteriv and Ros rivers water systems homeostasis mechanism preservation in conditions of climate change, ecological monitoring data of Central geophysical observatory (hydrologic annuals) were systemized and processed. The data for a long-term period, 45 indicators of hydrochemical characteristics in each case, annual flow amount indices, amount of precipitations, temperature and evaporability were used.

During the data systematization and processing, normative methods [7; 8] were used, as well as defining of technology intensive, intensity processes inside the reservoir, self-cleaning ability of the water ecosystem, technology intensive index, ecological index, etc. This work shows the data about calculation gauges located along the Teteriv and Ros rivers. Changes dynamics of the rivers pollution level (average indices by periods) and structural-functional properties is almost ongoing and, therefore, this work analyzes the data for the last 10-year period.

In order to fulfill the set tasks, it was reasonable to conduct preliminary reconnaissance researches of the ecological basin condition of the researched rivers.

The Teteriv River is the Dnieper right inflow (it goes into the Kyiv Reservoir at the village of Sukholuchye which is 85 km north to Kyiv). Its length is 385 km. The river is unnavigable. The main flows are: Hnylopyat, Huyva, Zdvizh — to the right; Irsha — to the left [9].

The Ros River is the Dnieper right inflow (it goes into the Kremenchuk Reservoir close to the village of Khreschatyk). Its length is 346 km, basin square is 12 575 km^2. The main inflows are: the Orikhova river — to the right; the Roska river — to the left [9].

Considering the action intensities of technogenic factors and the fact that these river systems are located in different natural condition, we have noted some peculiarities of their development.

Average ecological condition index of the Ros river basin is equal to 2.3 m^3 which means that the basin ecosystem is out-of-balance. Ecological index of water during the period of winter mean water was high and made up 1.75. On other stages of hydrological regime the quality of water was within the I class, but during the spring tide the increase of BOD_5 occurs; during the summer mean water phosphates increase occurs. According to the water acceptability appraisals for household, the content of organic matters, chrome ions and minor bacterial pollution became the limiting criteria.

In general, most small rivers of the Ros river basin are polluted by mineral oils and nitrogen compounds. In some places MPC exceeds in quantity indices, COD with some heavy metals (copper, zinc, nickel). Growing crops does not meet the demands as the result of which organic and mineral fertilizers, pesticides and fertile topsoil are washed off the fields into hydrographical network. Average agricultural usage of soils is 71%, while the amount of forests is only 11%.

Significant volumes of wastewaters discharges and the wash-out from the urbanized territories in combination with decrease of rivers water content and, hence, their abilities of self-cleaning, lead to the reduction of basin water quality. The decrease of rivers water content is caused by both changes on the catchment area and significant water withdrawals for the household needs.

Table 1. Structural-functional changes in water ecosystems of the Teteriv and Ros rivers by engineering-ecological indices and their average parameters

River	Periods	WPI value	Water quality class	Technology intensive index	I_e	Resistance coefficient to anthropogenic load (I_{rs})	% watercourse self-recovery			Biosynthesis intensity	Ability to oxidize the organic matters, %			
							High	Middle	Low		BOD MPC COD MPC	BOD MPC COD MPC	BOD MPC COD MPC	BOD MPC COD MPC
Teteriv	1996-2006	1,92	III (polluted)	0,56	3,1	$0{,}51 \le I_{rs} \le 1{,}0$	73	23	4	12,1	0,11	0,22	0,36	0,31
	2007-2016	2,31		0,62	3,2									
Ros	1996-2006	2,14	III (polluted)	0,59	1,99	$0{,}51 \le I_{rs} \le 1{,}0$	54	38	8	10,4	0,1	0,24	0,38	0,28
	2007-2016	2,24		0,71	2,3									

Hydrochemical condition of the Teteriv River from its source to the site on the border with Kyiv oblast is slightly worsening by all indications. Rapid growth of biogenic elements of salt ammonium from 0,68 mg/dm^3 (on the site above the city of Chudniv) to 1,94 mg/dm^3, phosphates from 0,11 mg/dm^3 to 0,34 mg/dm^3 is observed. Water mineralization of the Teteriv River (within the borders of Zhytomyr) on average over the long term period is the following: 316 mg/dm^3 in spring tide; 459 mg/dm^3 in summer-autumn mean water; 522 mg/dm^3 in winter mean water. The content of oxygen dissolved in water was satisfactory within 15,70 — 16,70 mgO_2/dm^3 (at the rate of 4,0 mgO_2/dm^3).

In comparison with the previous years, one can trace a slight worsening of the following indices: COD — 3,20—3,30 compared 3,00 mgO_2/dm^3 and BOD_5 — 2,60—4,00 compared to 3,30 mgO_2/dm^3. There are no significant changes in other indices; general condition of the river remains stable.

Estimation of the Teteriv River water quality according to the salt composition shows that minimal indices of river water conform to the I class quality by the pollution criteria and they are transitional from the I class to the II class by the worst values.

Minimal values of the ecological index (Ie) were within the limits of 2,8 and 3,5. Average values of this index over the whole period of research ranged from 3,1 to 3,3. It characterizes the water as rather clean. At this, values of separate indices in water samples above and below the city of Zhytomyr were: I_1 = 1,8 and 2,0, I_2 = 3,1 and 4,2, I_3 = 3,6 and 3,9 correspondingly.

It is set that the climate of Ukraine is changing synchronously with the changes of global climate.

Temperature factor of air influences spatial and temporal spread of rainfalls, their size, and duration; on the final stage it also influences the change of surface flow characteristics. We have graphed temperature changes over the researched period to estimate the changes of temperature regime on the basis of meteorological observations average data. Climate changes have seasonal peculiarities. Linear trend of territory temperature, where the research has been conducted (pic.1), allows us to state that average monthly temperatures in the period between December and March have the tendency to decrease, whereas during the remaining month temperature increases. The average value of temperature rise is 1—2 °C. The most positive temperature trends are being observed in recent years.

Hydrochemical and hydrobiological changes in the condition of rivers water ecosystems have been previously established before the biocoenotic changes, characterizing the intensity of processes inside the reservoir (Table 1). Accumulation of organic matters that are hard to oxidize occurs; hydrochemical and hydrobiological changes in ecosystems impact the level of intensity changes of the processes inside the reservoir (oxidizing ability, assimilatory ability, resistance to technogenic load, etc.) and they have impact in general which is confirmed by the calculations results. High level of water environmental pollution takes place owing to ineffective work of most sewage treatment facilities, unrefined surface flow incoming from the urbanized territories, non-observance of norms in the field of engineering approaches to protect the water resources.

The amount of precipitations analysis (pic. 2) over the researched period shows us that the main regularity is not only the change of their amount but their fluctuation as well (periods of increased and decreased regime of humidification occur), the tendency to decrease the amount of precipitations over the years is observed.

CONCLUSIONS OF CONDUCTED RESEARCH

In the condition of permanent impact on the environment by the anthropogenic factors and global climate change, the estimation of water ecosystems quality needs special attention.

It is established that the quality of natural surface waters depends directly on climatic changes which is confirmed by the change of ecological index, WPI value and the ability of self-recovery.

It is determined that over the last two decades the index of air temperature on the territory of Polesye has increased by 1—2 °C, which in its turn has influenced the amount of precipitations — the tendency of their annual amount decrease is observed.

Thus, the organization of wastewaters cleaning from the urbanized territories before their discharge into water objects is becoming significant. Meeting the SCS requirements of the rainfall run-off cleaning up to 70% is also significant.

Literature:

1. Climate change and water resourse, Edited by Brison Bate, Zbignev Kundzevichh, Sao Khon, Janna Palutikoff, Published by IPCC, 2008. — 211 pp.

2. Melnyk Y.S. Stability of water resources quality in Eastern Ukraine during the climate change Y.S. Melnyk, V.V. Pidlisiniuk, T.F. Kozlovska // Scientific journal "Transactions of Kremenchuk Mykhaylo Ostrohradskyi National University". — Ed. 2/2011(67). — P. 1. — P. 127—130.

3. Report on condition of world health protection // World health Organization, 2010. Access mode: http://www.who.int/whr/2010/whr10_ru.pdf?ua=1

4. Zhukova E.G. Impact of climate change on rivers water regime (on the example of Calmius water basin)/ E.G. Zhukova, A.A. Bodnev, O.P. Lysko // Surroindings of human being: natural, technogenic, social: materials Int. scient.-pract. Conf., April 26—27, 2017. — Bryansk, BGITU Publishing, 2017. — P. 23—25.

5. Zhukova O.G. Climate changes impact on surface waters ecological state / O.G. Zhukova, L.O. Vasylenko, Y.O. Bereznytska// VI All-Ukrainian Congress of ecologists with international participation (Ecology-2017), Vinnytsia, September 20—22, 2017: scientific works anthology. — Vinnytsia: VNTU, 2017. — P. 57.

6. Tropp H. Developing Governance Capacities [Text] / H. Tropp // Stockholm Water Front. — 2005. — № 2. — P. 10—11.

7. Udod V.M., Vildman I.L. Scientific justification of assimilatory potential indices usage and assimilatory capacity for ecological estimation of rivers hydroecosystems state [Text] / V.M. Udod, I.L. Vildman// Ecological safety. — 2014. — Ed.1 (17). — P. 50 — 53.

8. Yatsyk A.V. Methods of anthropogenic load calculation and classification of small Ukrainian rivers basins ecological state [Text] / Yatsyk A.V. and others. — K.: Ministry of Ecology and Natural Resources of Ukraine.— 2007. — 71 pp.

9. Vyshnevskyi V.I. Hydrological characteristics of rivers of Ukraine / V.I. Vyshnevskyi, O.O. Kosovets. — K., 2003. — 324 pp.

10. The Water Code of Ukraine. News of the Verkhovna Rada of Ukraine (NVR). — 1995. — № 24, article.189 [Electronic resource]. — Access mode: http://zakon4.rada.gov.ua/laws/show/213/95-%D0%B2%D1%80

References:

1. Bate, B. Kundzevichh, Z. Khon, S. and Palutikoff, J. (2008), Climate change and water resourse, IPCC, Geneva, Switzerland.

2. Melnyk, Y.S. Pidlisiniuk, V.V. and Kozlovska T.F. (2011), "Stability of water resources quality in Eastern Ukraine during the climate change", Scientific journal "Transactions of Kremenchuk Mykhaylo Ostrohradskyi National University", vol. 2/2011(67), pp. 127—130.

3. World health Organization (2010), "Report on condition of world health protection", available at: http://www.who.int/whr/2010/whr10_ru.-pdf?ua=1 (Accessed 10 Nov 2018).

4. Zhukova, E.G. Bodnev, A.A. Lysko, O.P. (2017), "Impact of climate change on rivers water regime (on the example of Calmius water basin)", Surroindings of human being: natural, technogenic, social: materials Int. scient.-pract. Conf., BGITU Bryansk, Russia, April 26—27, pp. 23—25.

5. Zhukova, O.G. Vasylenko, L.O. and Bereznytska, Y.O. (2017), "Climate changes impact on surface waters ecological state", VI All-Ukrainian Congress of ecologists with international participation (Ecology-2017), VNTU, Vinnytsia, Ukraine, September 20—22, p. 57.

6. Tropp, H. (2005), "Developing Governance Capacities", Stockholm Water Front, vol. 2, pp. 10—11.

7. Udod, V.M. and Vildman, I.L. (2014), "Scientific justification of assimilatory potential indices usage and assimilatory capacity for ecological estimation of rivers hydroecosystems state", Ecological safety, vol. 1 (17), pp. 50—53.

8. Yatsyk, A.V. (2007), Methods of anthropogenic load calculation and classification of small Ukrainian rivers basins ecological state, Ministry of Ecology and Natural Resources of Ukraine, Kyiv, Ukraine.

9. Vyshnevskyi, V.I. and Kosovets, O.O. (2003), Hydrological characteristics of rivers of Ukraine, Kyiv, Ukraine.

10. Verkhovna Rada of Ukraine (1995), "The Water Code of Ukraine", available at: http://zakon4.rada.gov.ua/laws/show/213/95-%D0%B2%D1%80 (Accessed 10 Nov 2018).

Стаття надійшла до редакції 12.11.2018 р.