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ENVIRONMENTAL AUDIT OF UKRAINIAN BASIN ECOSYSTEM OF THE PRUT RIVER

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ЕКОЛОГІЧНИЙ АУДИТ УКРАЇНСЬКОЇ ЧАСТИНИ БАСЕЙНОВОЇ ЕКОСИСТЕМИ Р. ПРУТ

Purpose. To carry out an environmental audit within the Ukrainian part of the Prut River ecosystem with analysis of existing anthropogenic pressures and impact in order to improve the monitoring system.

Methodology. Long term data of various government agencies on quantitative, qualitative and hydro-biological water parameters of investigated hydro-ecosystem has been collected and statistically processed. Complex indicators included several groups of specialized classifications: the criteria of salt composition; trophic-saprobiological criteria; specific criteria for the content of toxic substances and radiation exposure; hydro-biological criteria – bio-indication indexes.

Findings. The main loads on the Prut River basin within Ivano-Frankivsk and Chernivtsi regions of Ukraine of both anthropogenic and natural origin have been analyzed. It was confirmed practically that the sources of environmental contamination at existing loads, the impact on the territory of natural disasters pose a threat to the population and the economy with a high level of risk and potential losses. Total load of waste water and pollutants that degrade water quality has been calculated as well as indicators of pressure on the river basin from sewage. Environmental audit results allowed identifying weaknesses in water monitoring system in the Prut basin ecosystem.

Originality. For the first time the environmental assessment of quality and quantity of the Prut surface water ecosystems has been comprehensively determined with comparison of parameters at different sample points. Science-based approaches to integrated management of the Prut River basin have been improved.

Practical value. The improved surface water monitoring network in Ukrainian part of the Prut basin considering point and non-point sources of pollution, adversely affected environmental factors has been presented. The study is the basis for the development of measures to achieve safe environmental condition in river basins that meets the obligations of Ukraine under the "Environment for Europe" process and improves cooperation with EU Member States.

Keywords: *ecological safety, water quality, bio-indication indexes, monitoring, basin ecosystem*

Introduction. The main factors of influence on the qualitative and quantitative characteristics of surface water are water abstraction (intake) and wastewater discharge (sewage). The sources of surface water pollution also include sources of diffuse pollution – runoff from agricultural land (irrigation, use of fertilizers and pesticides), roads, built-up areas, man-made disasters (oil damage, accidents at enterprises). The natural factors influencing the quantitative and qualitative parameters of water resources of the basin include heavy rains and floods that contribute to the pollution of water sources due to run-off of solids and organic substances, chemicals used in agriculture, domestic waste, harmful microorganisms etc. of water catchment areas. The Prut River Basin is characterized by a dense hydrographical network. It is due primarily to two factors: a large dissection of relief and a significant amount of rainfall. In the Prut River basin there are 7,192 rivers with total length of 16,404 km. The major tributaries in Ukraine are: Pistynka, Rybnytsia, Cheremosh, Zhizhiia, Tlumachyk, Turka, Chorniava, Cherlena, Ryngach, Rekitnianka. The density of the river network is 0.94 km / km^2, which is almost three times the average for Ukraine (0.34 km/km^2) [1].

The urgent problem is data-based research to determine the long-term observations of ecological problems, the environmental objectives of each river object (water body), development of monitoring programs, planning and implementation to support an acceptable level of environmental safety.

Analysis of the recent research. Unsolved aspects of the problem. The issue of environmental safety of hydro ecosystems are widely represented in the works of domestic and foreign authors: B. R. Allenby,

O. S. Voloshkina, T. E. Hridel, A. L. Revzon, G. I. Rudko, R. Williams, E. D. Henley, M. A. Shakhranian, A. K. Shreyber, E. O. Yakovliev and others. However, the specific problem of environmental safety of hydro-ecosystem, particularly in the Prut River, features much uncertainty, lack of a unified database system status indicators, inadequate monitoring systems, etc. [1, 2].

An important task is conducting environmental audits of hydro-ecosystem as an important part of the European System Danube Basin, the identification of the cause-effect relationship between economic development and the hydro-ecosystem condition in the prospect, and monitoring system improvement. Part of the research was conducted within the EU project "Environmental protection of international river basins" (http://blacksea-riverbasins.net/en/pilot-basins/prut-basin) [3].

Objectives of the article. The aim of this work is an environmental audit within the Ukrainian part of the Prut ecosystem with analysis of existing anthropogenic and natural impacts in order to improve the monitoring system.

Presentation of the main research. According to the Dniester-Prut BUVR data, in 2011 the total volume of water abstraction in the Prut basin was 48.92 mln. m^3, including 9.59 mln. m^3 in Ivano-Frankivsk Region and 39.33 mln. m^3 in Chernivtsy Region. In 2011, the total amount was similar to that of 2010 – 49.36 mln. m^3. Water abstraction in Chernivtsy Region compared to Ivano-Frankivsk Region is much higher because of higher population and lower watering. Water abstraction from surface waters accounts for 90 % of the total water intake in Ivano-Frankivsk Region and 60 % in Chernivtsy Region. In the Ukrainian part of the Prut River basin there are developed sedimentary rocks of the Paleozoic, Mesozoic and Cenozoic of clay-sandy deposits unfavorable to the accumulation of large quantities of groundwater. Lowland part of the Prut basin is characterized by significant regulation of tributaries. There are a lot of small ponds. Nature condition in water ecosystems is disturbed. There are a lot of man-made flood protection facilities in the Prut river banks, especially in the mountain part.

Small HPPs in the Carpathian part of the Prut basin as derivation systems create serious environmental and socio-economic problems. Hydro-geological changes occur, including such that increase the risk of lowering of the groundwater level.

Water is used for housing and communal needs and agriculture. Water abstraction for industry is small. Companies that take the most water in the Prut basin are public utility companies "Yaremchevodokanal", "Kolomyiavodokanal", "Chernivtsivodokanal" (Fig. 1, Table 1).

These enterprises are the main sources of pollution of the Prut River. In 2014 "Chernivtsivodokanal" discharged 18.4 mln. m^3 of wastewater, "Kolomyiavodokanal" – 6.4 mln. m^3.

Total groundwater abstraction with intakes of more than 10 m^3 per day in the Prut basin amounted to 37.923 thousand m^3 per day in 2014. Reducing the intake of groundwater for the past 10 years has been due to a decrease in consumption of drinking and technical groundwater for industrial purposes.

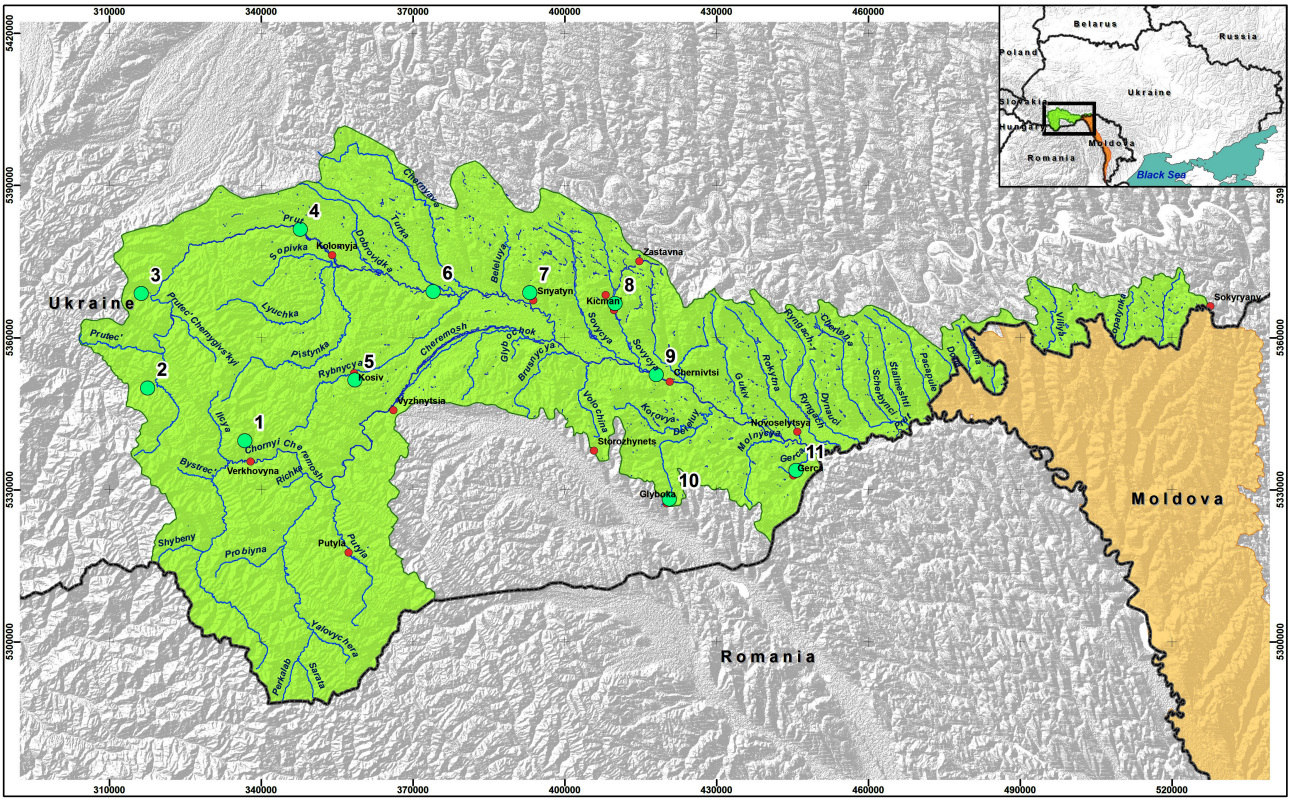

Fig. 1. Water bodies for water supplies in the Ukrainian part of the Prut River basin

Table 1

Water abstraction and water use in the Prut River basin, million m^3 (according to 2TP-Water Industry)

Administrative unit (region, city)	Water abstraction			Water use
	Total	Including		
		From surface water	From groundwater sources	
Ivano-Frankivsk region				
Verkhovynskyi	0.03	0.00	0.03	0.03
Kolomyiskyi	3.16	2.92	0.24	2.97
Kosivskyi	0.83	0.80	0.03	0.8
Sniatynskyi	2.24	1.82	0.42	2.09
Yaremche	0.41	0.38	0.03	0.38
Kolomyia	2.74	2.46	0.28	2.12
Chernivtsi region				
Vyzhnytskyi	2.6	1.5	1.1	2.6
Hertsaivskyi	1.2	0.3	0.9	1.2
Kitsmanskyi	11.9	9.8	2.1	11.8
Novoselytskyi	6.4	3.5	2.9	5.7
Putylskyi	0.7	0.0	0.7	0.7
Khotynskyi	4.2	2.9	1.3	4.0
Chernivtsi	5.3	0.2	5.1	12.8

Groundwater is used for: drinking water supply (51.3 %), agricultural needs (42.9 %), industrial and technical purposes (5.7%) and industrial spill (0.1 %).

The use of groundwater for drinking water supply decreased to 18.971 thousand m^3 per day (by 12.4 %), for agricultural needs – to 15.847 thousand m^3 per day (by 6.2 %), for industrial-technical purposes – to 2.116 thousand m^3 per day (by 51.0 %). Using groundwater for industrial bottling increased up to 0.027 thousand m^3 per day.

In the future we should expect an increase in water consumption for municipal purposes and construction of water pipes connected to the water supply and sanitation to cities and nearby villages. This is due to the increasing number of consumers and the requirements of access to quality water.

Taking into account that environmentally safe use is the use of resource that does not exceed 10 % of the total volume (the rule of ten percent), water intake in the Prut River basin rated as environmentally safe according to the studies [4].

River flow (volume of water) varies considerably throughout the year. 50 % of the total annual volume of water flows during the spring flood and storm floods in 60–70 days. During the last 290–300 days the summer-autumn and winter low-flow periods with little water flow are formed. In this regard, in low-flow periods the rivers used as sources of drinking water, or as objects that receive discharged water, feature greatly reduced ecological potential, shortages of water for water supply and for waste water dilution. Therefore, the hydrological regime of rivers should be taken into account when local authorities plan water supply systems and maximum allowable discharges of wastewaters into water bodies should be calculated.

During the past 20 years a reduction in wastewater volume has been observed. Discharge of sewage in the Chernivtsi region declined from 97 mln. m^3 in 1990 to 9.6 mln. m^3 in 2011. Reducing the amount of wastewater was mainly due to reducing of water consumption.

Major enterprises, sources of anthropogenic influence on surface water in the Prut River basin, are: "Khreshchatyk" sugar factory, "Nadvirnanaftogaz" (in Vyzhnytskyi district), "Chernivtsi oil and grease plant", Chernivtsi brick factory No. 3, "Chernivtsi Chemical Plant", "Chernivtsi vodokanal", "Kolomyia vodokanal", "Yaremche vodokanal". Pollution of rivers in the Prut basin is due to wastewater enterprises in Kolomyia, Sniatyn, Chernivtsi (Table 2).

Sewage treatment plants (STP) in settlements of Vorokhta, Deliatyn, Sniatyn, Zabolotiv, Tovmachyk (Ivano-Frankivsk region), Novoselytsia, Putyla, Vyzhnytsia, Hertsa and others (Chernivtsi region) are in poor condition and without adequate sewage treatment systems.

Reconstruction of treatment facilities in the city of Chernivtsi is needed. The fact that the main pressure collector from the main pumping station to the treatment plants has only one branch causes concern, making it impossible to prevent pollution of water in case of an accident on it. 7-year observations of the water quality at the site – below the discharge of sewage of Chernivtsi city (v. Mahala) – have demonstrated the lack of effecient treatment of utility fluids by wastewater treatment facilities of "Chernivtsi vodokanal". Therefore, according to the Index of Water Pollution

Table 2

Wastewater discharges into surface water bodies of the Prut river basin, Ukraine (million m^3), 2012

Administrative unit (region, city)	WW discharged		STP capacity, mln m^3
	Total	Including treated to standard quality	
Ivano-Frankivsk Region			
Verkhovynskyi	0.01	0.01	0.23
Kolomyiskyi	2.63	0.02	1.72
Kosivskyi	0.82	0.004	0.74
Sniatynskyi	1.96	0.12	2.44
Kolomyia	6.46	5.97	6.56
Yaremche	0.29	0.15	0.72
Chernivtsi Region			
Vyzhnytskyi	1.7	–	–
Hertsaivskyi	0.5	–	0.1
Kitsmanskyi	9.6	–	0.5
Novoselytskyi	4.1	–	0.2
Putylskyi	0.1	–	–
Khotynskyi	2,6	–	0.6
Chernivtsi	18.5	16.6	54.8

(IWP) the water in this region is classified as third class – "moderately polluted" (Table 3) [5].

The problem of wastewater treatment is also relevant for other enterprises of the processing industry, especially in the districts of Chernivtsi region. Dairy plants, meat processing plants and shops, canneries discharge wastewater without adequate treatment exceeding the established standards of pollutants into water bodies.

The quality of surface waters in the Prut river basin is predominantly "clean" and "moderately polluted" in the Carpathians. The water is also "clean" at the entrance to the Chernivtsi region, but it turns "moderately polluted" when exiting the region. The results of monitoring investigations indicate that the oxygen regime in the basin of the river Prut becomes extremely severe over the periods with the minimum flow (during winter and summer-autumn periods).

Deterioration of oxygen conditions is observed in the areas after the discharge of sewage into the river, where intensive oxygen consumption for decomposition of organic matter of wastewater occurs.

During the summer-autumn low water period reduction of dissolved oxygen is more possible, compared to the winter, with the same water flow in the river and the same volume of flow of organic substances. This is due to the influence of temperature regime on the rate of oxygen consumption and intensity of an aeration treatment process. In accordance with the results of the research in a dry period, water quality deterioration is recorded at a water flow below 3–3.5 m^3/s.

Research has established decrease in most types of fish fauna, simplification of species diversity. On the verge of extinction are highly adapted to the demanding water quality salmon. Areas of distribution of fish of high oxyphility have decreased and shifted closer to the riverhead. Short-cycle fish species whose ecological plasticity promotes rapid regeneration have significantly spread. These changes indicate a significant deterioration in water quality.

Table 3

Results of the assessment of Water Quality Index (WQI) in the Prut River basin (2005–2014) (Data of the Dniester-Prut River Basin Management Department)

Water sample point	WQI	Quality Category	Grade
Kolomyya, water intake	0.44	2	clean
Yaremche	0.54	2	clean
v. Kostychany, border with Romania and Moldova	0.67	2	clean
v. Lenkivtsi, upstream of Chernivtsi, drinking water intake	0.92	2	clean
v. Mahala, downstream of wastewater Chernivtsi	1.09	3	moderately polluted
v. Nepolokivtsi, border of Ivano-Frankivsk and Chernivtsi regions	0.72	2	clean
v. Cherepivtsi, border with Romania	0.74	2	clean
t. Deliatyn	0.55	2	clean
v. Storozhynets, water intake	0.89	2	clean

The assessment of water quality according to zoobenthos indicators, as well as to comprehensive assessment of hydromorphological, hydrochemical and hydrobiological indicators shows that the water in the upstream of the Prut River belongs to class 1– as "very clean". Therefore, this site can be recommended as a reference in assessing water quality in accordance with the requirements of the EU Water Framework Directive. Studies have been conducted in the upstream of the river Prut within the Carpathian National Park by specialists of the Institute of Ecology of the Carpathians. Eight sample points on the Prut River on the area of Carpathian National Nature Park were studied:

1. Upstream of the sport and tourist base "Zarosliak".
2. Between the base "Zarosliak" and the Geographic station of Lviv National University.
3. Between the Geographic station and Zavoiellia-Vorokhta Farm.
4. Between Zavoiellia-Vorokhta Farm and road T-0909.
5. Upstream of Vorokhta village.
6. Downstream of Vorokhta village.
7. v. Yamna.
8. Downstream of t.Yaremche.

For bio-indication of water quality in the Prut River two indexes were used: Trent Biotic Index (TBI) and its modification – Extended Biotic Index (EBI).

TBI Index is one of the most common indexes used in Europe and in the world. The index is based on availability of organisms belonging to the indicator groups in the water and their number. When the degree of water pollution increases, representatives of these groups disappear from the groups in certain sequence. Index TBI is four-graded and characterizes water saprobity.

In TBI Index calculating we can take into account the indicator taxon groups that tend to more organic rich water than the entire group as a whole.

These five categories of the EBI classification correspond to five categories of water quality taken in our country: excellent, good, fair, bad, and very bad. In Ukrainian classification the second and the third categories are divided into two subcategories: good – very good and good, satisfactory – satisfactory and moderate (Method..., 1998). These two categories are also divided according to the EBI grade.

A high score of the water quality in these indices corresponds only to reference sections of the rivers, which almost do not undergo direct or indirect anthropogenic pressure. Determining the taxonomic composition of the indicator groups was carried out by Lepneva S. G. and Klíč vodních larev hmyzu.

TBI Index in the researched sample points was 5.9–7.9. The maximum value of this index was at 1–4 sample points (6.8–7.9) and minimum – downstream of Vorokhta town (5.9). Downstream of Yaremche, the index is increasing again (6.8).

EBI Index fluctuates within 5.7–8.1 in studied water samples. Its maximum value was at 1–3 sample points (7.2–8.1), minimum was downstream of Vorokhta town (5.7). For t. Yaremche index increases to 7.8 that may indicate self-cleaning of the river.

It is worth noting that the correlation index for TBI and EBI is positive and certainty is 0.889. Since we have observed growth of TBI and EBI indexes upstream the Prut River, we can argue that water is of high quality near the source of the river Prut. General data received during the study of bioindication of the Prut River is shown in Table 4.

The research results show that the water in the upper part of the Prut River (upstream of the sport and tourist base "Zarosliak" is rated as "very good".

The area from the base "Zarosliak" to road T-0909 has a satisfactory water quality. In the area Vorokhta-Yamna the water in the river Prut is of moderate quality, while in the vicinity of Yaremche water quality is "good" (i.e. the river has the ability to purify itself). Upstream the base "Zaroslyak", the river features oligosaprobity, downstream it is characterized with β-mesosaprobity.

The results of hydrochemical assessment of water quality in the Prut River from Yaremche town to Chernivtsi city. Evaluation of surface water quality is complex because it includes three groups of specialized classifications (criteria of salt content, trophy saprobiology criteria; criteria for specific substances of toxic content and radiation exposure).

The received data of water quality parameters was processed for four control points: Yaremche, Kolomyia, Nepolokivtsi, Chernivtsi for 15 years (1994–2014) [2]. Based on the initial data received from Ivano-Frankivsk Regional Water Management Department we calculated block indexes according to the average and maximum data (the worst scenario) (Fig. 2).

Water quality at the three sample points belongs to class II, category 2 (II_2) – water quality rates as "very good"; purity – pure; trofity – mesotrophic; saprobity – ά-oligosaprobity.

At Kolomyia sample point water quality belongs to class II_3 – water quality is "good"; purity – very clean; trofity – meso-eutrophic; saprobity – β′-mesosaprobity.

According to the maximum value of data water quality at all the sample points is II_3. In some years decline in water quality is observed in Kolomyia and Nepolokivtsi (to class III_4 – water quality is "satisfactory"; purity – slightly polluted; trofityt – eutrophic; saprobity – β″-mesosaprobity and to class III_5 – evpolitrofity, ά-mesosaprobity).

Impact of Human Activities on Groundwater Bodies. Water abstraction, point sources of pollution (insufficiently treated urban and industrial wastewater

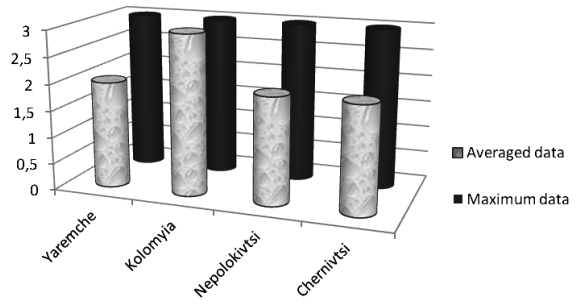

Fig. 2. Averaged environmental assessment of water quality in the Prut River on average data and maximum data

Table 4

Comparative characteristics of the sample points of the Prut River

Parameters of assessment	Sample point							
	1	2	3	4	5	6	7	8
TBI	7.9 ± 0.3	6.9 ± 0.1	7.1 ± 0.3	6.8± 0.3	6.3 ± 0.2	5.9 ± 0.8	6.0 ± 0.2	6.8 ± 0.6
Cv (%)	6.3	1.5	7.0	7.4	4.8	23.7	6.7	14.7
EBI	8.1 ± 0.3	7.2 ± 0.1	7.2 ± 0.2	6.7 ± 0.2	6.3 ± 0.2	5.7 ± 0.9	6.4 ± 0.2	7.8 ± 0.5
Cv (%)	6.2	2.8	5.6	6.0	4.8	28.1	4.7	11.5
Plecoptera*	24	14	9	13	10	7	3	3
Ephemeroptera	26	23	20	14	15	26	36	70
Trichoptera	35	44	46	17	12	15	5	7
Gammaridae	7	3	1	0	0	0	0	0
Oligochaeta	5	2	4	1	1	3	1	1
Chironomidae	9	2	4	2	1	2	3	1
pH	8.2	8.7	7.7	8.5	8.7	9.8	9.2	9.4
t ° + C	8	10	13	18	20	23	21	22
width of the river	2–3	4–7	7–10	8–15	10–14	9–11	12–15	15–20
saprobity	oligo-	β-mezo	β-mezo	β-mezo	β-α-mezo	β-α-mezo	β-α-mezo	β-α-mezo
Water quality	good	satisfactory	satisfactory	satisfactory	moderate	moderate	moderate	good

* – the average number of organisms in the three samples at one River sample point (org./m^2)

discharges, inadequate management of municipal, livestock and industrial wastes), as well as the diffuse sources of pollution (agricultural activities – use of fertilizers and pesticides) are all classified as sources of surface and groundwater pollution. The main facilities to affect the state of groundwater in the basin of the river Prut are residential areas, cattle farms, landfills, and agricultural land. Upper-most unprotected Quaternary aquifers are therefore contaminated with nitrates, sulphates, chlorides, and ammonia. According to the monitoring data of State Enterprises 'Geoinform' there are 8 sources of groundwater pollution along the Prut river basin (4 areal and 4 local) within Chernivtsy region.

Agriculture affects groundwater resources through water abstraction, wastewater disposal, increasing erosion, inflow of mineral and organic fertilizers and untreated wastewater from the cattle farms and poultry plants. A total volume of introduced mineral fertilizers over Chernivtsi region in 2011 was 107.3 thousand quintals with an average of 88 kg/hectare. Only a small amount of fertilizer is introduced in the mountain area (30–40 kg/ha), while a considerably greater amount is used on the plain areas. In general, the fertilization level of the Prut river catchment area may be considered as average for the region. The same situation is for the organic fertilizers, although only limited data is available in this respect – 0.5 tones/ha.

Impact of industry and transport. Wastewater treatment remains the main problem for the enterprises of food processing industry: cheese factories, meat packing plants, and canneries operate without proper sewage treatment plants and discharge wastewater with high concentration of pollutants (exceeding standards by tens or even hundreds of times) into the water bodies. A major environmental issue in the basin is the extraction of sand and gravel from the riverbeds, which may be referred to as mining industry. In many cases, grovels are extracted without authorization. Considerable sand and gravel extraction has resulted in decrease in the level of riverbed for the Prut and the Cheremosh in places by 1–1.5 meters, with even greater decrease (by 2–2.5 meters) near Chernivtsi.

Solid and industrial wastes. Handling of hazardous and domestic solid wastes is a major environmental problem in the area. There are 11 municipal solid waste landfills with an area of 67 hectares in Chernivtsi region; eight of them, with the total area of 32 hectares, are inconsistent with the designed capacity. Rural landfills are still an issue in some settlements. According to the data from the State Statistical Committee of Ukraine, in 2011 Chernivtsi region generated over 225,000 tons of waste, 160,000 tonnes of which came from the city of Chernivtsi.

The drastic increase in solid wastes production and the lack of equipped landfills facilitate results in the infiltration of extremely hazardous toxic, carcinogenic chemicals and biological pollutants into ground and surface water bodies. In the course of this study, no information was found on the qualitative composition of infiltrates from the major landfills in the basin area.

The main reason for the growth of the accumulation of solid waste in the Prut River Basin is the lack of separate collection facilities and recycling companies.

Based on the research studies, it is proposed to conduct monitoring studies at sample points presented in Table 5.

It would help to determine background concentrations of physical and chemical parameters in the Prut River basin. Therefore, this study will be bases for new monitoring system in accordance with EU requirements [6, 7].

Conclusions. The Prut River basin in Ukraine is a unique natural and climatic territory that is rich with water, forest and recreational resources. Factors of current anthropogenic pollutions and natural threats cause high level of risks and potential losses for the population and the economy of the area.

The analysis of the existing pressures and their impact allows elaborating the detail monitoring network and to identify weaknesses in the monitoring system of the Prut River basin:

- Lack of sample points of water quality in small rivers, especially in areas which flow through populated areas.

- Lack of systematic database for surface and groundwater (their number, quality, quantity, usage, pollution levels etc.).

- Lack of the water quality assessment of surface and groundwater (except MAC exceeding multiplicity); lack of measured concentration of synthetic surface-active agents (surfactants), phosphorus and other pollutants in river waters in accordance with normative documents.

- Lack of data on the pollutants that come from non-point sources, description of the sources and their potential threats to the aquatic environment.

- Hydro-biological monitoring data (held by the Central Geophysical Observatory of the Hydrometeorological services of Ukraine) are not the key indicators in assessing the quality of surface water as required by the EU Water Framework Directive.

- Hydromorphological monitoring in order to research the destruction of river banks, changing in their beds, laying sediment is not carried out due to lack of funding.

Environmental audit that was conducted in this study allowed allocating unresolved environmental issues. For the first time the environmental assessment of quality and quantity of surface water in the Prut River basin was defined with parameter comparison at different sample points. Science-based approaches to integrated water resources management in the Prut River basin have been improved. The object of our further research will be substantiation of measures to resolve the existing environmental issues (environmental risks), improvement of environmental monitoring and ensuring environmental safety and should be addressed to the developing of "The Prut River Basin Management Plan".

References/Список літератури

1. Arkhypova, L. M., 2011. Natural and technogenic safety of hydroecosystems: monograph [Pryrodno-

Table 5

Water sampling points in the Prut River basin recommended for the monitoring system

№	Coordinates		Settlement	Sampling	River	Proposed parameters
	Latitude	Longitude				
1	48°14’00,82”	24°37’47,37”	Vorokhta	Upstream of MSW landfill and recultivated landfill	Ardzhelyuzha	Phenols, NH_4, NO_2,NO_3
2	48°14’01,90”	24°37’39,76”	Vorokhta	Downstream of MSW landfill and recultivated landfill	Ardzhelyuzha	Pb, Cd, Hg, BOD, COD, PO_4, Phenols
3	48°20’48,92”	24°28’33,04”	Polianytsia	Downstream of new treatment facilities of “Bukovel” resort	Prutets Yablynetskiy	NH_4, NO_2,NO_3, СПАР, PO_4
4	48°30’01,87”	24°36’41,01”	Deliatyn	Downstream of the “Serene” Enterprise and “WOG” gas station	Nameless	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4
5	48°31’04,40”	24°33’20,48”	Deliatyn	Downstream of military town	Peremyiska	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4
6	48°33’43,32”	24°46’25,93”	Lanchyn	Downstream of the settlement	Slobushnytsia	Oil Products, Phenols, NH_4, NO_2,NO_3, synthetic surfactants, PO_4, pesticides
7	48°34’32,13”	24°54’58,39”	Tovmachyk	Downstream of STP	Tovmachyk	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
8	48°31’51,71”	25°05’39,31”	Kolomyia	Downstream of MSW landfill	Kosachivka	Pb, Cd, Hg, BOD, COD, PO_4, Phenols
9	48°30’08,66”	25°18’57,36”	Kelykhiv	Water reservoir	Chorniava	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
10	48°28’07,06”	25°23’29,58”	Vovchkivtsi	Downstream of the settlement	Chorniava	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
11	48°27’30,69”	25°17’48,92”	Illintsi	Downstream of Zabolotiv MSW landfill	Prut	Pb, Cd, Hg, BOD, COD, PO_4, Phenols
12	48°26’04,80”	25°34’46,89”	Snyatyn	Inflow into the r. Prut	Nameless	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
13	48°27’12,73”	25°35’30,34”	Sniatyn	Downstream of MSW landfill	Turetskyi	Pb, Cd, Hg, BOD, COD, PO_4, Phenols
14	48°26’00,75”	25°36’27,77”	Sniatyn	Downstream of “Sniatynska Nova” Poultry	Turetsky	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
15	48°25’30,62”	25°36’25,46”	Sniatyn	Downstream of STP	Prut	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
16	48°15’36,82”	25°16’03,09”	Chornoguzy	Downstream of Vyzhnytsia landfill	Nameless	Pb, Cd, Hg, BOD, COD, PO_4, Phenols
17	48°15’19,95”	25°16’04,02”	Chornoguzy	Downstream of Vyzhnytsia landfill	Mikhiderka	Pb, Cd, Hg, BOD, COD, PO_4, Phenols
18	48°28’40,75”	25°47’20,52”	Klivodyn	Inflow into the Sovytsia river	Nameless	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
19	48°25’45,12”	25°46’47,45”	Kitsman	Downstream of the settlement	Sovytsia	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
20	48°22’40,81”	26°00’02,79”	Chernivtsi	MSW Landfill: Nameless, right tributary of the river Moshkiv	Moshkiv	Pb, Cd, Hg, BOD, COD, PO_4, Phenols
21	48°15’56,56”	26°07’20,63”	Boiany	Unnamed left tributary of the river Prut	Prut	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
22	48°13’06,38”	26°16’18,74”	Novoselytsia	Within the settlement	Stara Granytsia	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
23	48°12’36,01”	26°25’55,16”	Vanchynets	Within the settlement	Danautsy	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
24	48°14’50,32”	26°33’14,70”	Koshuliany	Within the settlement	Stalyneshty	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4, pesticides
25	48°28’29,0”	24°63’85,55”	Yaremche (Dora)	Inflow into the Prut	Kamianka	Oil Products, Phenols, NH_4, NO_2, NO_3, synthetic surfactants, PO_4

tekhnohenna bezpeka hidroekosystem]. Ivano-Frankivsk: Publishing house IFNTUNG.
2. Korchemliuk, M. and Arkhypova, L., 2015. Estimation of key pressures on the Prut river basin in Ukraine. *Environmental safety. Kremenchug National University named after M. Ostrogradskiy* No. 1(19), pp. 41–45.
3. Environmental Protection of International River Basins Project. A Pressure-Impact Analysis/Risk Assessment According to the EU WFD. The Prut basin, draft, part 2/ Prepared by UNENGO "MAMA-86", available at: http://blacksea-riverbasins.net/en/pilot-basins/prut-basin
4. Water Code of Ukraine, 1995 (No. 213/95), Kyiv: Supreme Council of Ukraine, No. 24.
5. State sanitary rules and norms STATE STANDARDS 2.2.4-171-10, 2010. (No. 400). Kyiv: Official Journal of Ukraine, No. 39.
6. Directive 2000/60/EC of European Parliament and of the council of 23 October 2000 establishing a framework for Community action in the field of water policy// Official J. of the European Communities, L 327/1, 22.12/2000/EN.
7. Council Directive 98/83/EC of 5 December 1998 on the quality of waters intended for human consumption.

Мета. Провести екологічний аудит території української частини екосистеми р. Прут з аналізом існуючих антропогенних і техногенних навантажень та впливів з метою вдосконалення моніторингової системи.

Методика. Зібрані й статистично опрацьовані багаторічні дані різних державних установ щодо кількісних, якісних і гідробіологічних показників водних ресурсів досліджуваної гідроекосистеми. Комплекс показників включав декілька груп спеціалізованих класифікацій за: критеріями сольового складу; трофо-сапробіологічними критеріями; критеріями вмісту специфічних речовин токсичної та радіаційної дії; гідробіологічними критеріями – індексами біоіндикації.

Результати. Проаналізовані основні навантаження як антропогенного, так і природного походження на басейн ріки Прут у межах Івано-Франківської та Чернівецької областей України. Фактично підтверджено, що джерела забруднення навколишнього середовища за існуючих навантажень, вплив на територію природних катастроф становлять загрозу населенню та економіці з достатньо високими рівнями ризиків і потенційних збитків. Обраховане сумарне навантаження стічних вод та забруднюючих речовин, що погіршують якість води, індикатори навантаження на річковий басейн від стічних вод. Результати екологічного аудиту дозволили виділити недоліки в системі моніторингу вод у басейновій екосистемі р. Прут.

Наукова новизна. Уперше визначена екологічна оцінка якості й кількості поверхневих вод екосистеми р. Прут комплексно із порівнянням параметрів у різних створах. Удосконалені науково обгрунтовані підходи до інтегрованого управління річковим басейном р. Прут.

Практична значимість. Запропонована вдосконалена мережа моніторингу поверхневих вод української частини басейну р. Прут з урахуванням точкових та дифузних джерел забруднення, природних факторів негативного впливу. Дослідження є базовими для розробки заходів з досягнення безпечного екологічного стану в басейнах річок, що відповідає зобов'язанням України в рамках дій „Довкілля для Європи" та покращенню співпраці з країнами-членами ЄС.

Ключові слова: *екологічна безпека, якість води, біоіндикаційні індекси, моніторинг, басейнова екосистема*

Цель. Провести экологический аудит территории Украинской части экосистемы р. Прут с анализом существующих антропогенных и техногенных нагрузок и воздействий с целью усовершенствования мониторинговой системы.

Методика. Собраны и статистически обработаны многолетние данные различных государственных учреждений относительно количественных, качественных и гидробиологических показателей водных ресурсов исследуемой гидроэкосистемы. Комплекс показателей включал несколько групп специализированных классификаций по: критериям солевого состава; трофо-сапробиологическим критериям; критериям содержания специфических веществ токсического и радиационного воздействия; гидробиологическим критериям – индексами биоиндикации.

Результаты. Проанализированы основные нагрузки как антропогенного, так и природного происхождения на бассейн реки Прут в пределах Ивано-Франковской и Черновицкой областей Украины. Фактически подтверждено, что источники загрязнения окружающей среды при существующих нагрузках, влияние на территорию природных катастроф представляют угрозу населению и экономике с достаточно высокими уровнями рисков и потенциальных убытков. Подсчитана суммарная нагрузка сточных вод и загрязняющих веществ, ухудшающих качество воды, индикаторы нагрузки на речной бассейн от сточных вод. Результаты экологического аудита позволили выделить недостатки в системе мониторинга вод в бассейновой экосистеме р. Прут.

Научная новизна. Впервые определена экологическая оценка качества и количества поверхностных вод экосистемы р. Прут комплексно со сравнением параметров в разных створах. Усовершенствованы научно-обоснованные подходы к интегрированному управлению речным бассейном р. Прут.

Практическая значимость. Предложена усовершенствованная сеть мониторинга поверхностных вод украинской части бассейна р. Прут с учетом точечных и диффузных источников загрязнения, природных факторов негативного

воздействия. Исследования являются базовыми для разработки мероприятий по достижению безопасного экологического состояния в бассейнах рек, отвечают обязательствам Украины в рамках действий „Окружающая среда для Европы“ и улучшению сотрудничества со странами-членами ЕС.

Ключевые слова: *экологическая безопасность, качество воды, биоиндикационные индексы, мониторинг, бассейновая экосистема*

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MATHEMATICAL SIMULATION OF GAS MIXTURE FORSED IGNITION FOR THE CALCULATION OF THE DAMAGING FACTORS OF EMERGENCY EXPLOSION

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МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ ВИМУШЕНОГО ЗАПАЛЮВАННЯ ГАЗОПОВІТРЯНОЇ СУМІШІ ПРИ РОЗРАХУНКУ ВРАЖАЮЧИХ ФАКТОРІВ АВАРІЙНИХ ВИБУХІВ

Purpose. Selection and substantiation of the method of calculating the parameters of the ignition of gas mixtures with a heated body, the calculation of parameters and the evaluation of the reliability of performance of the established criteria for the initiation of the gas explosion.

Methodology. Mathematical simulation, numerical experiment, analysis and synthesis of the results.

Findings. The task of unsteady-state conduction problem of finding the temperature distribution in the thermal layer, near a source of ignition of air-gas mixture was set. Boundary conditions for a spherical source of ignition were defined. To solve the problem it was proposed to use the method of integral heat balance in which the thermal conductivity equation is replaced by the integral heat balance. Solutions of this equation are sought in the form of a polynomial of the second degree, i.e., the desired temperature profile in the thermal layer is represented as a quadratic parabola. As a result, an equation of the parabola as a dependence of temperature on the coordinates, time, heat capacity and heat generation from the ignition source is obtained. This solution allowed determining the effect of thermal oxidation of methane and, on that basis showing the convergence of the numerical method with the results of the analytical solution.

Originality. On the basis of the theory of thermal ignition and quasi-static approach, an analytical solution of the problem is found by methods of the integral balance, non-stationary temperature distribution in the thermal layer near a source of ignition of air-gas mixture. The thermal effect of oxidation of methane near a source of ignition is defined and the convergence of the numerical method of calculation of parameters of shock airwaves with the results of the analytical solution in terms of performance of the ignition criterion is shown.

Practical value. The resulting solution makes it possible to analyze the accuracy of the computing process methods of numerical simulation of gasdynamic parameters of shock waves in the air of the initiation of combustion and explosion of gas-air mixtures. The analysis of the accuracy of the computational process allows the use of numerical methods in practical calculations of finding a safe distance from the centers of the explosion in the liquidation or predicting the consequences of accidents.

Keywords: *gas-air mixture, ignition criteria, transient heat transfer, kinetics of combustion, thermal layer, temperature profile, mathematical model, thermal profile*