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Causal Regularities of Effect of Urban Systems on Condition of Hydro Ecosystem of Dnieper River

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Abstract: Under conditions of uncontrolled increase of anthropogenic impact in use of water resources and intensity of contamination, it becomes necessary to develop and comply with water conservation measures, use environmentally friendly technologies and introduce adapted conservation measures. Emphasis was made on the fact that the influence of urban systems lead to the transformation of floodplains, destruction of river hydro ecosystem and significant deterioration of the water management and recreational values. The situation is aggravated by the operation of outdated and inefficient water discharge and water treatment systems. It leads to systematic contamination of the urban system of suburban river basin with sewage surface runoff and distribution of pollutants outside/upriver. The results of the study of process of the impact of sewage surface runoff from the urban system Kherson city on the condition of the lower Dnieper hydro ecosystems in the suburban area of the river and outside/upriver were shown. The model of the system research of causal relation "coming of water (stage I) → surface sewage runoff (stage II) → condition of the hydro ecosystem (stage III)" was offered. The seasonal nature of intensity of precipitation effects, which causes acceleration of hazardous erosion in territory of urban systems, which is a consequence of systemic diffuse pollution in suburban basin of the Dnieper River, was determinted. The hydrochemical properties of sewage runoff, which have significant seasonal dynamics, were determined. It was justified by the change in volume of water use in economic and domestic purposes. The intensity of the impact of surface runoff of the urban system of Kherson city on the hydro ecosystem of the Dnieper River at 100- and 300-meter area upriver was determined: the 100-meter area is "very polluted" (class VI) – "extremely polluted" (class VII); the 300-meter area is "polluted" (class V) – "very polluted" (class VI). It was found that the main pollutant that leads to deterioration in the quality of the water in the Dnieper River is the significant excess of petroleum products. Hydrochemical values of sewage discharges in accordance with needs for fishery exceed the MPC values 4 times. It proved the unsatisfactory ecological condition of the hydro ecosystem of the lower Dnieper river in the urban system and outside/upriver. It was proved that reusing of treated sewage surface water of Kherson city can provide irrigation for growing crops at the area of 9468 ha. The application of the suggested complex model of research and the establishment of causality of the impact of the urban system on the ecological condition of the hydrosystem of the rivers shall allow to carry out spatial differentiation of protection measures regarding reduction of the negative impact of sewage surface runoff on surface water condition and it shall improve obtaining of crop yields on irrigated land due to the reuse of sewage surface water.

Key words*:* Urban system, Surface runoff, Sewage runoff, Water quality, Hydro ecosystems, Dnieper river

The most important component of the environment and the essential factor of satisfaction of existence of living organisms, health of population, social and economic development, environmental security and sustainable development of society as a whole is the availability and condition of water resources. According to the assessment of the International Bank, about 1.5 billion people lack access to clean drinking water, more than 40% of the world's population experience water shortage, 25% of population are at risk of consumption of poor quality water. About 3 billion people live in unsanitary conditions. More than 80% of all diseases related to consumption of poor quality water (Chorna et al 2019). Surface water bodies take about 4% of the total territory of Ukraine with a resource of about 209.8 $km^3 year^{-1}$. Groundwater resources are estimated at 22.5 $km^3 year^{-1}$. Its reserves are up to 25%. According to the volume of water reserves, Ukraine belongs to the resource-poor countries since water resources do not exceed 1.5 thousand m^3 per person per year. Main consumers of water are industries (51.5%), in particular, ferrous metallurgy, energy, pulp, paper and food industries, agricultural (28.1%) and utility (18.1%) companies that cover more than 90% of the total water intake.

The majority of surface water resources in Ukraine is classified as "polluted" and "dirty" (Pichura et al 2017). Systematic accumulation and exceeding of values of maximum permissible concentrations of heavy metals (copper, manganese, zinc) and biogenic substances (nitrogen, phosphate) (Lisetskii et al 2014, Pichura et al 2019) in surface waters makes it impossible to provide favorable conditions for water use. Thus, the negative consequences of anthropogenic impact on the basin of the rivers take place. It leads to a change of the natural condition, disbalance of the integrity of the functioning of hydro ecosystem and destruction of the synergetic process of self-regulation, self-purification and self-restoration of rivers

(Lisetskii et al 2015, Pichura et al 2018). The main causes of pollution of surface water are: discharge of polluted communal, domestic and industrial wastewater, emission of pollutants together with surface runoff from city systems and erosion-cumulative processes in agricultural land (Dudiak et al 2019). Anthropogenic transformation of ecosystems as a result of urbanization is one of the most pressing problems associated with the intensification of the impact on natural ecosystems of the Dnieper basin. The basin covers more than 48% of the territory of Ukraine and accumulates about 80% of its water resources. It meets food and drinking needs of more than 30 million Ukrainians. Such scientists as Mostepan (2010), Yurchenko (2012), Rychak (2016), Bytkova (2018) emphasized that the main causes of impact on water bodies is unorganized control of surface runoff of urbanized areas and insufficient capacity of drainage networks for rainwater. Pollution of rivers from city systems is caused by the lack of effective engineering systems for diversion of surface runoff, low level of provision of residential areas with sewerage system (95% for cities, 61% for urban-type settlements, 2.5% for villages), operation of outdated water treatment facilities with low level of treatment of communal, domestic and industrial wastewater. Mahas (2013) noted in his studies that comprehensive planning for rehabilitation of rivers should be based on possible models of consequences of adverse effects of economic activities for establishing the pollution sources and degradation of river ecosystems. Therefore, the problem of river pollution, especially in lower parts of the flow, where natural and man-made components of surface and underground runoff are accumulated, is urgent. The purpose of the research is to establish the causal regularities of the impact of urban systems on the condition of hydro ecosystem of the Dnieper River.

MATERIAL AND METHODS

The object of the study is the process of the impact of sewage surface runoff from the urban system of Kherson city on the condition of the lower Dnieper hydro ecosystems in the suburban area of the river and outside/upriver (Fig. 1). The study was conducted in the system causal relation "coming of water (stage I) → surface sewage runoff (stage II) → condition of the hydro ecosystem (stage III)". The condition of water quality was determined at three stages during 2012-2019 according to the indicators of changes in its hydrochemical properties in line with generally accepted methods in certified laboratories of the communal utility company "Production Office of Water and Sewage Utilities of Kherson city" and the State Environmental Inspectorate in Kherson Region. There were studied 60 wastewater samples, 30 of which were taken from the collectors at the places of primary collection of the city's runoff, and 30 samples were taken at the places where the runoff collectors were opened, immediately before this water entered the river waterways.

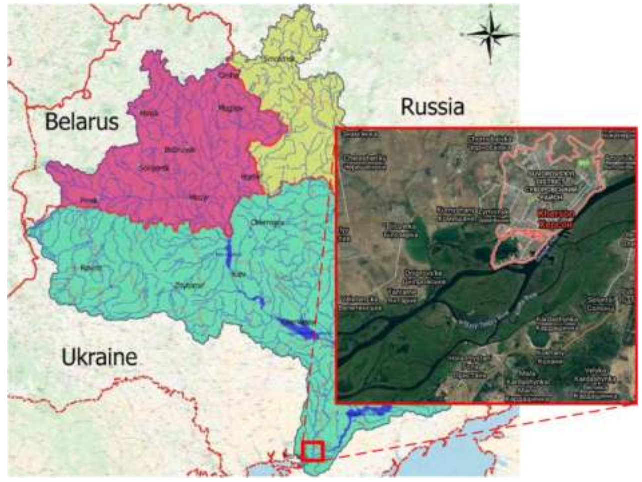

Fig. 1. Location of the of Kherson city in the Dnieper basin

Underground artesian water and precipitation are the main sources of water supply for Kherson city. Artesian water from 137 wells is used for drinking water supply of Kherson city. Its volume is 50-55 thousand m^3 per day. After use, it enters sewers and treatment facilities. After passing the biological ponds it is subject to discharge through Virovchyna River into the right branch of the Dnieper River – Koshova River. Rainwater forms a surface runoff that enters the suburban basin of the Dnieper River without treatment (Fig. 2). The comprehensive assessment of the quality of surface water, suburban water in the direction of the Dnieper River at the 100- and 300-meter zone was carried out according to different methods, in line with the current water quality standards for surface water bodies in Ukraine according to the maximum permissible concentration (*MPC*) of cultural, recreational, fishery purposes using the modified water pollution index (*MWPI*) (Klimenko et al 2012).

In accordance with the applicable rules, water that is least affected by anthropogenic pressure belongs to class I. The values of its hydrochemical and hydrobiological indicators are close to the natural values for the region. Water of class II is characterized by certain changes in comparison with natural values; however, these fluctuations do not violate the ecological balance. Water that is under considerable anthropogenic influence, the level of which is close to the limit of stability of ecosystems, belongs to class III. Water of classes IV-VII has disturbed environmental parameters and its ecological condition is considered as ecological regression. The effectiveness of sewage treatment (E_q) in treatment plants is determined by comparing of its quality before incoming and after discharge from a sewage treatment plant in accordance with the method of runoff quality control (Sheludchenko 2001):

$$E_q = \frac{C_{in} - C_{out}}{C_{in}} \times 100\% \qquad (1)$$

where C_{in} is the concentration of pollutants in discharge water before purification, C_{out} is concentration of pollutants in discharge water after discharge from the treatment plant.

The suitability of sewage runoff for irrigation of agricultural crops was determinted in accordance with GOST 2730:2015, Protection of the environment. Quality of natural water for irrigation. Agronomic criteria (2015), which gives the possibility for expanding of irrigated area. The size of the area was determined by the method of calculation of resource-saving irrigation regimes for agricultural crops. The use of cartographic methods for the spatio - temporal establishment of hydrological patterns of water runoff distribution in urban system and suburban basin of the Dnieper river was suggested. The copyrighted method of the operational recording of the distribution of discharge water in the bed of the Dnieper River was used. The method is based on the use of multi-colored balls of foam materials. The following licensed software was used for processing and analyzing input data: STATISTICA Advanced + QC for Windows v. 10 Ru, Automated Neural Networks STATISTICA for Windows v. EN 10 and ArcGis 10.1.

RESULTS AND DISCUSSION

Water balance of Kherson city is to be determined by the total amount of surface runoff, seepage loss and evaporation. In particular, the volume of surface runoff was calculated on the basis of the total income of the natural moisture in 1961-2019 per area of the urban system. This value is 179.8±44.7 million m^3. The level of variation is 11.9% due to cycles of climatic conditions. SO^{2-}, HCO_3^-, Ca^+, Na^+ prevail in chemical composition of precipitation. The variation of salinity is within 50-60 mg dm^{-3}. The maximum surface runoff is recorded in the spring and summer. The seasonal nature of intensity of precipitation effects causes acceleration of hazardous erosion in territory of urban systems, which is a consequence of systemic diffuse pollution in suburban basin of the Dnieper River. In addition, redistribution of surface runoff depends on the terrain of urban system, which has form of slope in the northern, western and southern part of Kherson city. At the same time, it forms surface runoff that contains hazardous pollutants in the direction of the Virovchyna, Koshova and Dnieper Rivers. Urbanized elimination of the natural drainage network resulted in violation of the hydrological regime of local area and restructuring of the system of unloading of underground waters, which occurred mainly on the slopes of gills. At the same time a significant increase in surface runoff was found in the Kherson area bottom that absorbs most of the moisture from the inner part of the city. Artificial regulation of redistribution of surface runoff in most dangerous parts of urban system is carried out through the storm drainage network with total length 71.4 km. Storm water is discharged through the 14 sewers. Water is discharged through 6 sewers directly to Dnieper river, through 6 sewers to the Koshova river, through 2 sewers to the Virovchyna river.

It was determined that over the past 20 years the engineering support of storm drainage network was not available because it was not included in the public sewerage, had no jurisdiction (except several departmental sites on the territory of companies). Today, the entire network has only a few highways in the city along the slope of Dnieper River, which is 30% of the network. The remaining 70% are under soil and sludge contamination, therefore the surface runoff from the territory of the city is not subject to purification and filtration. The lack of the sewage network leads to direct and indirect contact with surface water of the Dnieper river. The

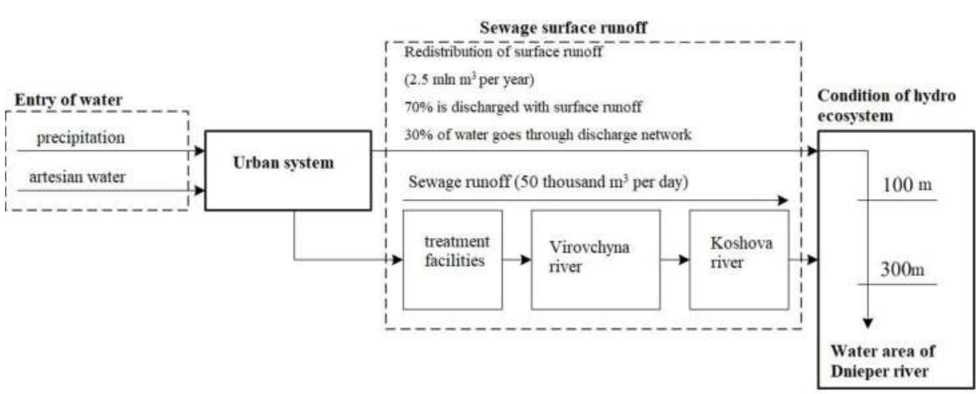

Fig. 2. Causal relation of urban system and hydrosystem

total area of land provided with storm drainage is 4240 ha or 32% of the entire city (13570 ha). 12% of rainfall evaporates, 56% of rainwater from the territory of the urban system comes with surface runoff to the waters of the Dnieper River. In 2012-2019, the average hydrochemical properties of stormwater discharges (Table 1) from areas with different landscape of the city territory for fishery exceeded the *MPC* value in certain indicators: the content of suspended solids – 97.8-163.8 times, solids –1.54-1.70 times, sulfates – 1.31-1.65 times, calcium – 1.84-2.06 times, magnesium – 2.04-3.10 times, sodium + potassium –3.13-4.05 times, petroleum products – 20-102 times. Content of ammoniacal nitrogen 1.12 times exceeds the standard value. It directly enters the Virovchyna River through storm water of the collector system of the northern part of the city.

Distribution of influence of surface runoff of the urban system of Kherson city on the water area of the Dnieper was determined by a series of interseasonal inspections of river water. The samples were taken at the lower 100 and 300-meter areas upriver from the place of discharge of most stormwater (Kherson city, Dniprovskyi district, Park of Glory, coordinates – latitude: 46° 63.5064' 0", longitude: 32° 63. 3692' 0"E). According to seasonal observations, the water quality of the coastal area of the Dnieper River for fishery according to the values of *MWPI* corresponds to the classes (Table 2). The 100-meter area is “very polluted” (class VI, *MWPI* = 7.7-8.7) – “extremely polluted” (class VII, *MWPI* = 12.46-13.32); the 300-meter area is “polluted” (class V, *MWPI* = 4.1-4.4) – “very polluted ” (class VI, *MWPI* = 7.4). The main pollutant, which leads to deterioration in the quality of the Dnieper water, is a significant excess of the content of petroleum products that enter the suburban area of the Dnieper River with untreated discharge water.

Together with surface runoff, sewage runoff also significantly affects the pollution of the rivers. Domestic and industrial wastewater is drained from the territory of Kherson city by gravity by sewerage system of the city. Its capacity is 250 thousand m^3 per day.

About 60% of the sewerage system of Kherson city is in poor technical condition. It leads to systematic breakthrough, leakage and redistribution of discharge water to the groundwater that is hydraulically connected with neogene horizons. To maintain satisfactory status of the network it was proposed to annually update at least 5% (45 km $year^{-1}$) of its length. According to the actual data in 2012-2019 about 0.8% of the sewerage network was annually updated. In addition, in 2012-2019 the daily volume of discharge water for the treatment plant of the city (urban-type settlement Komyshany) is 45-50 thousand m^3. It is discharged into the right distributary channel of the Dnieper River with conventionally cleaned water via biological ponds. Four secondary aeration sediment basins have capacity for tertiary treatment of sewage discharges up to 250 thousand m^3 with a total area 17.2 ha. The area of mirror is 105.0 thousand m^3.

Increasing negative impact of discharges on deterioration of hydro ecosystem of the lower Dnieper was determined. It is intensified by the deterioration of technical conditions of treatment facilities, in particular, untimely cleaning of sediments basins. It leads to discharge of significant amount of contaminated silt that enters the river together with about 400 tons of surface-active substances, oxides of nitrogen, sulphur, phosphorus, petroleum products, etc. During some periods, the volume of these substances is up to 1500 tons per day. In 2012-2019, the average value of individual indicators of the hydrochemical properties of sewage discharges (Table 3) that enter directly the water of Virovchyna River and are redistributed to the Koshova and Dnieper Rivers according to the fishery criteria exceeded *MPC*: suspended solids – 4.2 times; dry residue –1.3 times; sulphates –1.7 times; chlorides –1.2 times; sodium+potassium –2.6 times; ammoniacal nitrogen –3.8 times; petroleum products – 2.0 times. The change in hydrochemical properties of discharge water is reasonably justified by signified seasonal dynamics. It is characterized by change of volume of water used in household activities of population. The removal of dry residues to the treatment system in the autumn (salt, soil and sand components and biogenic and detrital substances) is 1.4 times less than in the summer. Therefore, the effectiveness of treatment systems in Kherson city accoding to the difference between indicators of the hydrochemical properties for entering and discharge of the sewage is 50.0-97.0%.

The dependence of the efficiency of treatment from pollutants that come from treatment plants was determined. The results of the study of hydrochemical properties of the condition of treated discharge water at discharge point show significant reduction of pollutants that come to treatment system from sewage water. However, the hydrochemical properties of the discharge water at the discharge point in the river according to individual indicators exceed the *MPC* values for fishery 4 times. This is due to the absence of local treatment facilities at most companies of Kherson city. It causes entering of highly concentrated industrial discharge water to communal treatment plants, which accelerates deterioration of the technical condition of city sewer networks, violation of the technological regulations of treatment. In 2019, a significant number of unauthorized discharges of polluted discharge water by industrial companies into the Dnieper river was recorded (Table 4). The

Table 1. Average annual values of hydrochemical indicators of storm water in Kherson for 2012-2019

Location of sample collection from collector		Suspended substance, mg dm^{3}	pH	Dry residue, mg dm^{-3}	Sulphates, mg dm^{-3}	Chlorides, mg dm^{-3}	Phosphates, mg dm^{-3}	Calcium, mg dm^{-3}	Magnesiu, mg dm^{-3}	Sodium + Potassium, mg dm^{-3}	Ammoniacal nitrogen, mg dm^{-3}	Nitrate nitrogen, mg dm^{-3}	Petroleum products, mg dm^{-3}
MPC according to fishery criteria													
MPC value	20	6.5–8.5	1000	100	300	3.5	180	50	120	0.50	40	0.05	
Old city													
Beginning	X	1875.0	7.35	1526.0	131.0	227.5	2.15	326.0	156.5	369.0	0.34	22.0	0.9
	σ	223	0.9	185.0	15.5	29.6	0.30	45.2	18.6	44.2	0.04	2.62	0.10
End	X	2475.0	7.32	1544.0	132.0	230.0	2.6	331.0	154.5	375.0	0.36	23.0	1.0
	σ	345	0.75	214.0	15.3	27.5	0.40	39.7	18.3	45.1	0.05	2.59	0.12
+/-		+60.0	-0.03	+18.0	+1.0	+3.5	+0.45	+5.0	-2.0	+6.0	+0.2	+1.0	+0.1
MPC exceedance		123.8	–	1.54	1.32	–	–	1.84	3.10	3.13	–	–	20.0
Southeastern part of the city (zone of the coastal slope of the Dnieper River)													
Beginning	X	1879.0	7.45	1674.0	160.0	290.0	3.9	377.5	143.5	404.5	0.38	20.0	6.6
	σ	225.0	0.90	198.0	19.2	34.8	0.47	45.2	17.2	48.2	0.05	2.40	0.80
End	X	1955.0	7.5	1698.0	165.0	287.0	3.5	371.2	142.0	406.3	0.37	22.0	5.1
	σ	230	0.92	200.0	20.2	36.4	0.42	42.6	16.8	50.1	0.05	2.32	0.61
+/-		+76.0	+0.05	+24.0	+5.0	-3.0	-0.4	-6.3	-1.5	+1.8	-0.1	+2.0	-1.2
MPC exceedance		97.8	–	1.70	1.65	–	–	2.06	2.84	3.40	–	–	102.0
Northern part of the city (with a slope of the area to the left slope of the top of the Virovchyna river)													
Beginning	X	3200.0	7.1	1671.0	130.0	219.0	4.5	342.0	105.0	479.5	0.58	36.0	3.6
	σ	384	0.85	195.0	15.6	26.3	0.54	41.0	12.6	62.3	0.07	4.32	0.43
End	X	3275.0	6.9	1664.0	131.0	215.0	4.4	364.0	102.0	485.7	0.56	34.0	3.7
	σ	375.0	0.74	193.0	15.7	25.6	0.53	45.1	11.8	65.4	0.06	3.85	0.49
+/-		+75.0	-0.2	-5	+1.0	-4	-0.1	+22	-3	+7.2	-0.2	-2	+0.01
MPC exceedance		163.8	–	1.66	1.31	–	1.26	2.02	2.04	4.05	1.12	–	74.0

deterioration of ecological condition of hydro ecosystem of the lower Dnieper in the area of urban system was determined. It was caused by the absence of surface water treatment facilities of surface waters and its unsatisfactory technical condition for sewage treatment, spatial and seasonal distribution of precipitation and water use, which determines the rate and volume of removal of pollutants of urban system by sewage runoff, its spatial redistribution in the deltoid and reed bed hydro network upriver and partial self-purification of water in the lake and reed bed ecosystems of Dnieper River. Downstream water of the river complies with the needs of the fishery, but the *MPC* values of water are not satisfactory and correspond to the class "moderately polluted" (class III) – "polluted" (class IV)".

To reduce the impact of urban system on the hydro ecosystem of the lower Dnieper, the water protection measures were developed for the purification and reuse of sewage runoff of Kherson city for underground irrigation of urban and suburban areas. For additional biological treatment of sewage surface runoff and prevention of an emergency discharge of untreated sewage to the suburban area of the Dnieper River, the construction of the emergency waste stabilization pond was proposed. With minor daily volumes of sewage (45-50 thousand m^3), it is to be capable of holding a 5-7 days discharge, which shall allow avoid emergency situation and repair the city sewage system. Afterwards, water of waste pond shall be redirected for post-treatment using highly modified strains of microorganisms, *Clostridium, Peptococcus, Butyrivibrio, Bacillus,* which increase the efficiency of extraction of pollutants from sewage and break down complex polymeric molecules of proteins, carbohydrates, nucleic acids and lipids to simple chemical compounds. The construction of local treatment facilities for the implementation of mechanical treatment with subsequent post-treatment of surface waters at public wastewater treatment plants was proposed. It was established that the annual volume of untreated and conventionally purified sewage surface runoff that enter the Dnieper river is 20.5 million m^3, including sewage runoff 18.0 million m^3 and surface sewage runoff 2.5 million m^3. The use of this water after treatment for irrigation was recommended as it has improvement value due to the content of nitrogen, phosphorous and potassium compounds. According to the qualitative assessment of sewage drains in line with

Table 2. Assessment of water quality in different parts of the lower Dnieper river

Location of sampling		Quality assessment					
		For fishery			For amenity needs		
		WPI value	Quality class	Characteristic	WPI value	Quality class	Characteristic
Spring	River water 100 m	13.32	7	Extremely polluted	1.9	3	Moderately polluted
	River water 300 m	4.4	5	Polluted	1.02	3	Moderately polluted
Summer	River water 100 m	12.46	7	Extremely Polluted	2.02	3	Moderately polluted
	River water 300 m	7.43	6	Extremely polluted	1.55	3	Moderately polluted
Autumn	River water 100 m	8.7	6	Extremely polluted	1.77	3	Moderately polluted
	River water 300 m	7.44	6	Extremely polluted	1.56	3	Moderately polluted
Winter	River water 100 m	7.7	6	Extremely polluted	1.57	3	Moderately polluted
	River water 300 m	4.1	5	Polluted	0.96	2	Clean

Table 3. Hydrochemical characteristics of the sewage at the discharge point for 2012-2019

Season and years		Suspended substance, mg dm^{-3}	pH	Dry residue, mg dm^{-3}	Sulphate, mg dm^{-3}	Chloride, mg dm^{-3}	Phosphates, mg dm^{-3}	Calcium, mg dm^{-3}	Magnesium, mg dm^{-3}	Sodium + Potassium, mg dm^{-3}	Ammonia cal nitrogen, mg dm^{-3}	Nitrate nitrogen, mg dm^{-3}	Petroleum product, mg dm^{-3}
MPC according to fishery criteria													
MPC value		20	6.5-8.5	1000	100	300	3.5	180	50	120	0.50	40	0.05
Before treatment	2327	8.2	32568	5733	6236	51.7	151.2	32.3	1226.7	49.2	186.7	0.12	0,12
	441.3	0.24	4501	529	350	6.8	70.5	14.8	271.8	10.8	41.3	0.04	0,04
After treatment	84.0	8.5	1300	168	365.7	1.8	150.3	4.4	313.9	1.9	25.7	0.10	0,10
	12.5	0.3	207.0	20.8	43.6	0.6	47.9	1.4	69.6	0.8	12.3	0.04	0,04
+/-		-2243	0.35	-31268	-5565	-5870	-49.9	-0.87	-27.9	-912.8	-47.3	-161	-0.02
MPC exceedance		4.2	–	1.3	1.7	1.2	–	–	–	2.6	3.8	–	2.0

agronomic criteria, it was determined that the water is suitable for irrigation upon conditions of preliminary improvement. Total irrigation norm was calculated for typical crop rotation (forage crops – 33 %, grain crops – 67 %) (Table 5).

According to the annual volume of sewage surface runoff of Kherson city, its reusing can provide irrigation for growing crops at the area of 9468 ha, with a weighted average irrigation rates gross 2165 $m^3 ha^{-1}$, with the rate of water loss net 2079 $m^3 ha^{-1}$. The energy conversion efficiency of underground irrigation system was also considered (η = 0.96). It is possible to irrigate one million hectares of agricultural land due to the formation of the total volume of sewage surface runoff on the territory of Ukraine. The adoption of the proposed measures shall reduce the level of negative impact of sewage runoff in hydro ecosystem of the lower Dnieper River. It shall reduce the consumption of water for irrigation and provide production of agricultural crop yields due to reuse of sewage runoff.

Table 4. Number of recorded MPC exceedances in sewage runoff of companies in Kherson city in 2019

Wastewater quality indicators	Number of found violations
Suspended substances	50
Ammoniacal nitrogen	90
Phosphates	103
Biochemical oxygen demand (BOD_5)	18
Chlorides	7
Fats	64
Synthetic Surfactants (SS)	47
Sulfates	1
Iron	26
Zinc	1
Sulfides	12
Chemical oxygen demand	20
Nitrates	1
Nitrites	50
Petroleum products	12
Dry residues	10

Table 5. Grain and fodder crop rotation and the value of irrigation norms of agricultural crops

Rotation of agriculture crops	Irrigation norm, $m^3 ha^{-1}$
Alfalfa	3000
Alfalfa	2700
Winter wheat	1050
Cereal and bean mixture	1150
Corn for grain	1250
Corn for grain	1250
Spring wheat	1150
Alfalfa seeding	900

CONCLUSIONS

The influence of urban systems leads to the transformation of floodplains and braids, destruction of the river hydro ecosystem and significant deterioration of the water management and recreational values. The situation is aggravated by the operation of outdated and inefficient water discharge and water treatment systems. It leads to systematic contamination of the urban system of suburban river basin with sewage surface runoff and distribution of pollutants upriver. The dependence of the amount of sewage surface runoff from preceptation and the volume of drinking water in Kherson city was established. The effectiveness of treatment systems in Kherson city accoding to the difference between indicators of the hydrochemical properties for entering and discharge of the sewage is 50-97%. The negative impact of surface runoff of the urban system of Kherson city at 100- and 300-meter area of the water basin upriver was determined: the 100-meter area is “very polluted” (class VI) – “extremely polluted” (class VII); the 300-meter area is “polluted” (class V) – “very polluted” (class VI). It was found that the main pollutant that leads to deterioration in the quality of the water in the Dnieper River is a significant excess of petroleum products. Hydrochemical values of sewage discharges for fishery exceed the MPC values 4 times. It leads to unsatisfactory ecological condition of the hydro ecosystem of the lower Dnieper River in the urban system and outside/ upriver. It was determined that the application of the suggested integrated model of research and the establishment of causality of the impact of urban system on the ecological condition of the hydrosystem of the rivers allowed to carry out spatial differentiation of protection measures regarding reduction of the negative impact of sewage runoff on surface water condition and it shall improve obtaining of crop yields on irrigated land due to the reuse of sewage rainfall.

REFERENCES

Bytkova TV, Rychak NL and Hrychanyi OM 2018. Rainwater utilization in urban areas and stormwater quality management: An ecological and economic dimension. *Bulletin of the VN Kharkiv National University Karazin. Economic Series* **94**: 15-28 (in Ukrainian).

Chorna TM and Husyatinska NA 2019. Environmental and economic aspects of drinking water supply in Ukraine. Collection of reports: *International Congress and Technical Exhibition "Ecology-heat-supply-energy-saving-water-supply-sewerage"*. Chernomorsk: 78-90pp (in Ukrainian).

Dudiak NV, Pichura VI, Potravka LA and Stratichuk NV 2019. Geomodelling of destruction of soils of Ukrainian steppe due to water erosion. *Journal of Ecological Engineering* **20**(8): 192-198.

Ecological assessment of surface water quality of land and estuaries of Ukraine: Methodology. 1994. *CPI 211.1.4.010-94.* Kiev: 37 (in Ukrainian).

GOST 2730:2015. Protection of the environment. Quality of natural water for irrigation. Agronomic criteria 2016. Kiev: 9 (in Ukrainian).

Klimenko MO, Vozniuk NM and Verbetskaya KY 2012. Comparative analysis of surface water quality standards. *Scientific reports of NULES of Ukraine* **8** (30): http://www.nbuv.gov.ua/e-journals/Nd/2012_1/12kmo.pdf (in Ukrainian).

Lisetskii FN, Pavlyuk YV, Kirilenko ZA and Pichura VI 2014. Basin organization of nature management for solving hydroecological problems. *Russian Meteorology and Hydrology* **39**(8): 550-557.

Lisetskii FN, Pichura VI, Pavlyuk YV and Marinina OA 2015. Comparative assessment of methods for forecasting river runoff with different conditions of organization. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **6**(4): 56-60.

Mahas NI and Trohimenko AG 2013. Assessment of the current anthropogenic load on the Southern Bug river basin. *Environmental Safety* **2**: 48-52 (in Ukrainian).

Mostepan OV 2010. Investigation of the effect of storm water from highways in pollution of water bodies (in Kharkiv, for example). *Bulletin of Kharkiv National Automobile Road University* **48**: 37-41 (in Ukrainian).

Pichura VI, Domaratsky YA, Yaremko YI, Volochnyuk YG and Rybak VV 2017. Strategic ecological assessment of the state of the transboundary catchment basin of the Dnieper River under extensive agricultural load. *Indian Journal of Ecology* **44**(3): 442-450.

Pichura VI, Malchykova DS, Ukrainskij PA, Shakhman IA and Bystriantseva AN 2018. Anthropogenic transformation of hydrological regime of the Dnieper river. *Indian Journal of Ecology* **45**(3): 445-453.

Pichura VI, Potravka LA, Dudiak NV, Skrypchuk PM and Stratichuk NV 2019. Retrospective and forecast of heterochronal climatic fluctuations within territory of Dnieper Basin. *Indian Journal of Ecology* **46**(2): 402-407.

Rychak NL, Moskovkin VM and Kuznetsova BB 2016. Calculation of economic damage from surface waters of atmospheric origin (for example, the housing subsystem). *Bulletin of the VN Kharkiv University Karazin. Geology-Geography-Ecology Series* **11**(47): 239-248 (in Ukrainian).

Sheludchenko BA 2001. Engineering ecology: textbook. *Part II. Hydrosphere*. Zhytomyr: 220 (in Ukrainian).

State sanitary regulations and rules "Hygienic requirements for drinking water intended for human consumption". 2010. *DSanPiN 2.2.4-171-10*. Kiev: http://zakon2.rada.gov.ua/laws/show/z0452-10 (in Ukrainian).

Yurchenko VO, Korotchenko MV, Brigade OV and Mikhailov LS 2012. Investigation of technological characteristics of surface runoff from highways. *Highway of Ukraine* **4**(228): 44-47 (in Ukrainian).

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