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IMPACT OF RIVERBANK ANTHROPOGENIC POLLUTION SOURCES ON THE FORMATION OF RIVER WATER QUALITY

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Abstract. The method of estimation of the impact of riverbank anthropogenic pollution sources on the formation of river water quality is proposed. A description of the influence of housing and utility providers on water bodies within Mykolaiv region is made. The obtained results can be applied in the development of measures aimed at improvement of the ecological situation in the area under study.

Key words: anthropogenic loading, environmental hazard, wastewater, harmful impact, pollution source.

1. Introduction

One of the major current problems of water resource preservation on the territory of Ukraine is critical reduction in self-replicating capabilities of rivers and depletion of the water resource potential. These processes are predominantly caused by excessive anthropogenic loading on water bodies and extensive water management. The formation of river water quality is substantially affected by a continuous discharge of insufficiently treated wastewater and disorderly wastewater removal from settlements, industrial facilities and agricultural areas. This situation urges to perform constant monitoring of water quality in water bodies, as well as control and assessment of the impact of major water pollution sources [1, 2].

The issues of comprehensive water quality assessment for water bodies have been elaborated by many Ukrainian scholars (Konenko A. D., Aliokin O. A., Oksiiuk O. P., Zhukinskyi V. S., Romanenko V. D., Yatsyk A. V., Khilchevskyi V. K., Masenko O. H., Denisova O. I.) [3–9]. However, the Ukrainian legal framework lacks a document which would officially approve a particular method of estimation of water quality, assessment and description of the impact of riverbank point pollution sources on water bodies and recommend it for application in general practice [10, 11].

Hence, a complex of regional measures on river restoration should be established with the help of a brand new approach based on estimation of the probability of occurrence of the economic activity consequences adversely affecting people and the environment.

The article aims at application of a new methodical approach to assessment of the impact of riverbank sources of wastewater discharge on the formation of surface water quality in Mykolaiv region on the example of public utilities, substantiating their hazard level by analyzing the wastewater composition and water body loading.

2. Research data and methods

The impact of riverbank sources of return water discharge on the state of water bodies within Mykolaiv region has been studied in accordance with the developed technique. It is based on the logical-mathematical model taking into account the composition of wastewater discharged by a pollution source into the water environment as well as the level of its treatment, monitoring, and water body loading [10, 11, 12].

A detailed assessment of the impact of pollution sources has been carried out with the help of assessment tables by scoring each of them on a scale of 0 to 5 points. The resulting points were grouped, average values were calculated, and the weighting factors assigned to each pollution source in each subcategory [12].

The basic indicators used to assess the degree of the impact of a particular water pollution source on the quality of water in the water basin are the pollutant concentrations in return water. The list of pollutants, normalized and controlled in all cases of return water discharge, has been established in order to meet the environmental standards of water body quality, ensure the ecological safety of human activities and aquatic ecosystems. According to the Decree of the Cabinet of Ministers of Ukraine No. 1100 dated September 11, 1996, such pollutants include: biological oxygen demand measured over 5 days (BOD_5), chemical oxygen demand (COD), total suspended matter, water mineralization, sulfates, chlorides, ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, phosphates, petroleum products, and hydrogen ion exponent pH. Additionally, concentrations of such persistent organic pollutants as iron, copper, zinc, nickel, chromium, cadmium, and mercury were taken into account in this study.

Wastewater flowing into the water body is to be safe according to its epidemiological and radiation indicators and harmless by its chemical composition; it should have appropriate organoleptic properties and cannot deteriorate the quality of water of the water body regardless of the type of its use. Accordingly, the maximum permissible concentration (MPC) for fishery waters has been selected as the main criterion when establishing the harmfulness category of the point source of pollution of water bodies. Application of such criteria completely eliminates the negative impact of pollutants contained in wastewater on the water body and hydrobionts.

In order to determine the degree of the impact of the respective wastewater discharge on the water body, harmfulness categories have been assigned to each of Mykolaiv region's water pollution sources under study. The harmfulness category of a pollution source is established with respect to the multiplicity of excess of the MPC of the pollutants contained in wastewater and taking into account the hazard they pose.

The basic indicator used to assess the level of water basin loading by the pollution source is the percentage of pollutants discharged by the source relative to the total amount of pollutants entering the water basin and transferred with the river flow [11, 12].

General assessment of the level of environmental hazard of the point sources of water pollution in Mykolaiv region is conducted using the overall coefficient of harmful impact of the pollution source on water bodies, *P*. It is calculated with the help of the following formula:

$$P = 0.7 \cdot c_{\text{av}} + 0.3 \cdot m_{\text{av}},$$

where c_{av}, m_{av} are the average values of the coefficient showing the impact of a pollution source with regard to the wastewater composition and the coefficient of water body loading by the pollution source (with the weighting factors of 0.7 and 0.3, respectively).

The input quantitative data on the actual pollutant discharge volumes and concentrations in return water which are involved in the study is a database of state statistical reports on water use completed using the official blank form 2-TP (VODHOSP).

The article presents the results of the study carried out by the authors in accordance with the state scientific and technical programs and directions of the development of science and technology. They are rendered in the following documents: "National Program for the Development of Water Management until 2013", "National Target Program for the Development of Water Management and Ecological Restoration of the Dnipro River Basin until 2021", "Regional Program on the Development of Water Management of Mykolaiv Region for the period of 2013 to 2021", as well as other regulatory documents.

3. Results and discussion

The first stage of the study suggested making a list of major sources of water pollution in Mykolaiv region. It includes 10 housing and utility providers: the municipal enterprise (ME) Pervomaisk Miskvodokanal (the town of Pervomaisk, the Southern Bug River), the Department for Water and Sewage Services and Heat Supply Networks (DWSS & HSN) of the SD South-Ukraine Nuclear Power Plant (the town of Yuzhnoukrainsk, the Southern Bug River), Biological Treatment Plants LLC (the town of Voznesensk, the Southern Bug River), the ME Prybuzke (the town of Nova Odessa, the Southern Bug River), Olshanske Miskvodokanal LLC (the village of Olshanske, the Southern Bug River), the city municipal enterprise (CME) Mykolaiv Vodokanal (the village of Galitsinove, the Bug Estuary), the Novyi Buh Branch of the Group Water Supply System (the town of Novyi Buh, the Ingul River), the ME Miskvodokanal (the town of Bashtanka, the Ingul River), the CME Mykolaiv Vodokanal (the city of Mykolaiv, the Vitovka River), and the ME Novyi Buh Vodokanal (the town of Novyi Buh, the Ingul River).

These enterprises have been ranked according to the results of assessment of their impact on the indicators of composition of the wastewater discharged into the water environment (see Fig. 1).

Below there are the findings of the study presenting the companies with the poorest indicators.

At the CME Mykolaiv Vodokanal, Galitsinove, the annual averaged concentration of the pollutants discharged into the Bug Estuary exceeds the standard quality indicators (for fishery waters) for more than 10 ingredients. Among these, the most critical excess is attributed to the following pollutants: chromium – 100 times, BOD_5 – 80 times, ammonium nitrogen – 51 times, nitrites – 45 times, COD – 40 times, copper – 40 times, suspended matter – 21 times, petroleum products – 30 times, total iron – 6 times, zinc – 3 times, nitrates – 3 times, sulphates – 2 times.

At the ME Miskvodokanal, Bashtanka, the annual averaged MPC of ammonium nitrogen is exceeded 275 times, that of BOD_5 – 114 times, COD – 46 times, nitrites – 53 times, total iron – 25.5 times, phosphates – 4.5 times, sulfates – 4.4 times, suspended matter – 3.2 times, dry residue – 3.6 times, and chlorides – 2.7 times.

At Biological Treatment Plants LLC, Voznesensk, the annual averaged concentration of the pollutants discharged into the Southern Bug River exceeds the MPC of nitrites 45 times, that of chromium – 15 times, COD – 6 times, sulfates, total iron and petroleum products –5 times, and ammonium nitrogen, nitrates, BOD – 4 times.

At Olshanske Miskvodokanal LLC, Olshanske, the amount of pollutants discharged into the Southern Bug River substantially exceeds the MPC as well. Namely, the concentration of nitrites is 22 times higher than normal, that of total iron and petroleum products is 8 times higher, nitrates – 5 times, sulfates – 4 times, BOD and COD – 3 times.

The coefficient of multiplicity of pollutant excess over the MPC has served as a basis for assigning a harmfulness category to each of the water pollution sources under study (Table 1). It was established that the greatest damage to water bodies is caused by discharges from the CME Mykolaiv Vodokanal, Galitsinove, and Biological Treatment Plants LLC, Voznesensk, both characterized as very harmful.

Contribution of each pollution source to the formation of the water body loading has been established and characterized according to the results of assessment of the water body loading and pollutant transfer with river runoff. Fig. 2 demonstrates the results of ranking of the sources under consideration.

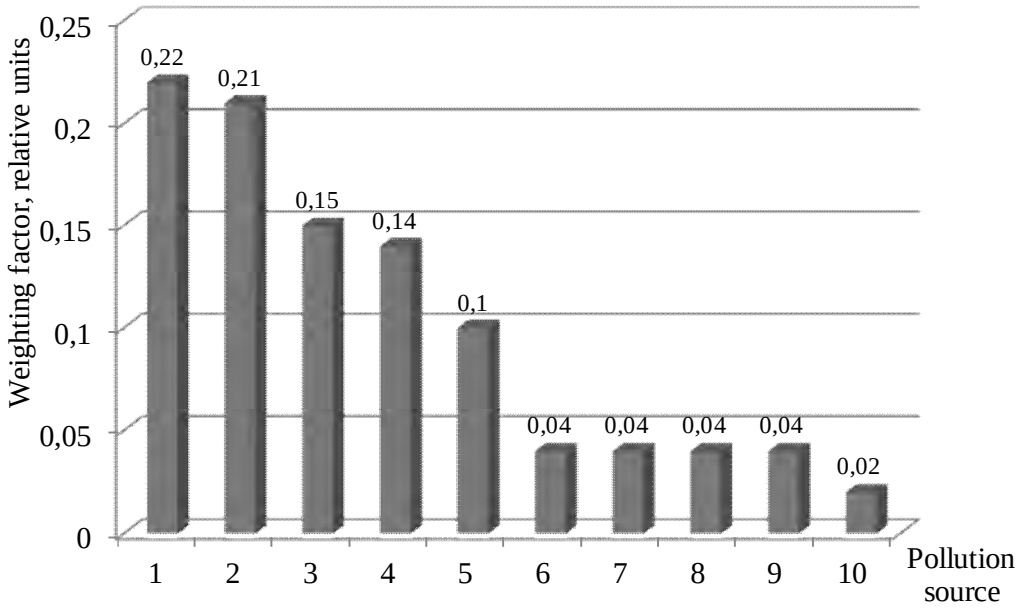

Fig. 1. Housing and utility providers
of Mykolaiv region ranked according to wastewater composition:
1 – CME Mykolaiv Vodokanal, Galitsinove; 2 – ME Miskvodokanal, Bashtanka;
3 − Biological Treatment Plants LLC, Voznesensk; 4 − Olshanske Miskvodokanal LLC,
Olshanske; 5 – ME Prybuzke, Nova Odessa; 6 – ME Pervomaisk Miskvodokanal, Pervomaisk;
7 – ME Novyi Buh Vodokanal, Novyi Buh; 8 − Novyi Buh Branch
of the Group Water Supply System, Novyi Buh; 9 – CME Mykolaiv Vodokanal, Mykolaiv;
10 – DWSS & HSN of the SD South-Ukraine Nuclear Power Plant, Yuzhnoukrainsk

Table 1

Characteristics of the harmful impact of point sources of water pollution in Mykolaiv region

Name and location of the point source of water pollution (enterprise), water body to which wastewater is discharged	Coefficient of multiplicity of pollutant excess over the MPC, c_{av}	Harmfulness category of the pollution source	Type of the harmful impact on the water body
1	2	3	4
MCE Mykolaiv Vodokanal, Galitsinove, the Bug Estuary	2.6	IV	very harmful
Biological Treatment Plants LLC, Voznesensk, the Southern Bug River	1.6	IV	very harmful
CME Mykolaiv Vodokanal, Mykolaiv, the Vitovka River	1.4	III	moderately harmful
Olshanske Miskvodokanal LLC, Olshanske, the Southern Bug River	1.3	III	moderately harmful
ME Miskvodokanal, Bashtanka, the Ingul River	1.2	III	moderately harmful
ME Pervomaisk Miskvodokanal, Pervomaisk, the Southern Bug River	0.8	III	moderately harmful
ME Prybuzke, Nova Odessa, the Southern Bug River	0.7	III	moderately harmful
DWSS & HSN of the SD South-Ukraine Nuclear Power Plant, Yuzhnoukrainsk, the Southern Bug River	0.4	II	hardly harmful
ME Novyi Buh Vodokanal, Novyi Buh, the Ingul River	0.4	II	hardly harmful
Novyi Buh Branch of the Group Water Supply System, Novyi Buh, the Ingul River	0.4	II	hardly harmful

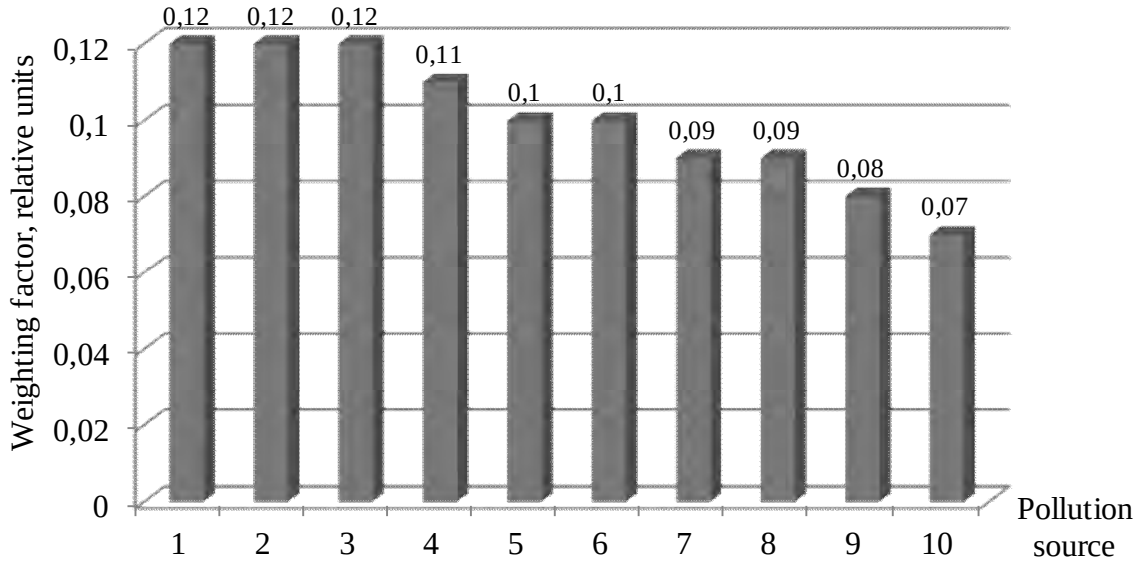

Fig. 2. Housing and utility providers of Mykolaiv region ranked according to water body loading: 1 − CME Mykolaiv Vodokanal, Galitsinove; 2 − ME Miskvodokanal, Bashtanka; 3 − Biological Treatment Plants LLC, Voznesensk; 4 − Olshanske Miskvodokanal LLC, Olshanske; 5 – DWSS & HSN of the SD South-Ukraine Nuclear Power Plant, Yuzhnoukrainsk; 6 − CME Mykolaiv Vodokanal, Mykolaiv; 7 − ME Novyi Buh Vodokanal, Novyi Buh; 8 − Novyi Buh Branch of the Group Water Supply System, Novyi Buh; 9 − ME Pervomaisk Miskvodokanal, Pervomaisk; 10 − ME Prybuzke, Nova Odessa

Thus, the largest loading on the Southern Bug River basin in Mykolaiv region is caused by several housing and utility providers: MCE Mykolaiv Vodokanal, (Galitsinove, the Bug Estuary), ME Miskvodokanal, (Bashtanka, the Ingul River), and Biological Treatment Plants LLC (Voznesensk, the Southern Bug River). The level of loading with pollution there can be characterized as substantial, while the weighting factor of its impact is the highest. Slightly lower values of the weighting factor with regard to water body loading in Mykolaiv region are those of Olshanske Miskvodokanal LLC, Olshanske, and the DWSS & HSN of the SD South-Ukraine Nuclear Power Plant, Yuzhnoukrainsk, which discharge pollutants into the Southern Bug River, as well as the CME Mykolaiv Vodokanal, Galitsinove, polluting the Vitovka River, which flows into the Bug Estuary. The level of water body loading at these pollution sources can be defined as moderate. The same applies to the water treatment facilities of the water supply system of the ME Novyi Buh Vodokanal and the Novyi Buh Branch of the Group Water Supply System, both located in Novyi Buh and discharging return water into the Ingul River. Only two enterprises, the ME Pervomaisk Miskvodokanal in Pervomaisk and the ME Prybuzke in Nova Odessa, introduce a low level of loading to the Southern Bug River.

The loading on water bodies in Mykolaiv region resulting from return water discharge by these point pollution sources predominantly consists of the following components:

in the Southern Bug River basin: mineralization, which accounts for 64 % of the total amount of pollutants entering the water bodies and being transported with their flow, chlorides (19 %), sulfates (11 %), nitrates and COD (1 % each);

in the Bug Estuary: mineralization (65 %), chlorides (15 %), sulfates (9 %), cholesterol (5 %), nitrates, BOD_5, and suspended matter (1 % each);

in the Ingul River basin: mineralization (61 %), sulfates (19 %), chlorides (12 %), cholesterol (2 %), nitrates and suspended matter (1 % each).

According to the overall coefficient of harmful impact of the pollution source on water bodies, *P*, there have been established the hazard category of the housing and utility providers under consideration (see Table 2).

Thus, the results of the study considering the degree of environmental hazard have revealed that there are three hazardous housing and utility providers within Mykolaiv region. They are as follows.

1. The CME Mykolaiv Vodokanal, located in Galitsinove and discharging return water into the Bug Estuary, is the main pollutant of the region's water resources, as 89 % of its total discharge is polluted wastewater. The enterprise has a huge negative impact on the state of the Bug Estuary, as well as the sanitary and epidemiological situation in Mykolaiv. The main reasons for the unsatisfactory operation of its treatment facilities are the critical condition of deep-water discharge of wastewater after its treatment and the insufficient capacity of the treatment facilities at the stage of secondary sedimentation.

2. The enterprise Biological Treatment Plants LLC (Voznesensk) discharges return water into the Southern Bug River, although it is basically under-treated wastewater. The harmful emissions of this enterprise contribute to a considerable level of river loading.

3. The ME Miskvodokanal (Bashtanka) discharges return water into the Ingul River. Sewage treatment facilities in Bashtanka are ineffective, and the averaged annual concentration of pollutants discharged into the Ingul River significantly exceeds the MPC.

According to the general classification and description of hazardous point pollution sources (hazard category II), their impact on a water body is highly hazardous for the life and health both of human beings and hydrobionts. The wastewater discharge of such sources essentially changes the hydrological or hydrochemical characteristics of the receiving water body. This leads to a considerable contamination of the water body and impossibility of its use as a source of utility and drinking water supply. The water body becomes hardly suitable for any type of public water consumption.

In terms of environmental hazard, moderately hazardous facilities include the ME Pervomaisk Miskvodokanal (Pervomaisk), the DWSS & HSN of the SD South-Ukraine Nuclear Power Plant (Yuzhnoukrainsk), the ME Prybuzke (Nova Odessa), and Olshanske Miskvodokanal LLC (Olshanske). They all discharge return water into the Southern Bug River. In addition, the supply water treatment facilities of CME Mykolaiv Vodokanal (Mykolaiv) are also considered moderately hazardous; it discharges return water into the Vitovka River, which flows into the Bug Estuary. Particular attention should be paid to the sewage treatment facilities in Pervomaisk, since they are obsolete, worn out and need reconstruction. Depreciation of their fixed assets makes up 90 %. Due to ineffective operation of the sewage treatment facilities, the ME Pervomaisk Miskvodokanal pollutes the Southern Bug River with under-treated wastewater, while the MPC exceeds

appropriate standards. The volume of under-treated wastewater being discharged accounts for 44.8 % of the total return water discharge from the town of Pervomaisk. The biological treatment facilities located in the village of Olshanske need urgent reconstruction as well.

The impact of moderately hazardous pollution sources on water bodies (hazard category III) is dangerous to the local community and hydrobionts. The wastewater discharge of such sources changes the hydrological or hydrochemical characteristics of the receiving water body. These changes reduce the suitability of the water body for any type of public water consumption.

According to the degree of environmental hazard, marginally hazardous facilities within Mykolaiv region include housing and utility providers which discharge return water after the supply water treatment facilities (intended for removing impurities and pollutants from raw water and disinfecting it before supplying to consumers). These include the ME Novyi Buh Vodokanal (Novyi Buh) and the Novyi Buh Branch of the Group Water Supply System (Novyi Buh), which discharge return water into the Ingul River.

Table 2

Assessment of the degree of environmental hazard of the point pollution sources

Name and location of the point source of water pollution (enterprise), water body to which wastewater is discharged	Average values		Overall coefficient of harmful impact of the pollution source on water bodies, P	Hazard category	Degree of environmental hazard
	Coefficient of multiplicity of pollutant excess over the MPC, c_{av}	Coefficient of water body loading caused by the pollution source, m_{av}			
1	2	3	4	5	6
ME Pervomaisk Miskvodokanal, Pervomaisk, the Southern Bug River	0.8	1.9	1.1	III	moderately hazardous
DWSS & HSN of the SD South-Ukraine Nuclear Power Plant, Yuzhnoukrainsk, the Southern Bug River	0.4	2.3	1.0	III	moderately hazardous
Biological Treatment Plants LLC, Voznesensk, the Southern Bug River	1.6	3.3	2.1	II	hazardous
ME Prybuzke, Nova Odessa, the Southern Bug River	0.7	1.9	1.1	III	moderately hazardous
Olshanske Miskvodokanal LLC, Olshanske, the Southern Bug River	1.3	2.5	1.7	III	moderately hazardous
ME Novyi Buh Vodokanal, Novyi Buh, the Ingul River	0.4	2.2	0.9	IV	marginally hazardous
Novyi Buh Branch of the Group Water Supply System, Novyi Buh, the Ingul River	0.4	2.1	0.9	IV	marginally hazardous
ME Miskvodokanal, Bashtanka, the Ingul River	1.4	3.5	2.0	II	hazardous
CME Mykolaiv Vodokanal, Mykolaiv, the Vitovka River	1.4	2.3	1.7	III	moderately hazardous
CME Mykolaiv Vodokanal, Galitsinove, the Bug Estuary	2.6	4.0	3.0	II	hazardous

The impact of marginally hazardous pollution sources on water bodies is quite small. The wastewater discharge from such sources does not change the hydrochemical characteristics of the

receiving water body to a great extent. Moreover, the water body does not cease to be suitable for any type of public water consumption. However, the natural attractiveness of the water body as a recreational area may be worsened because of the persistent objectionable odor and poisonous or irritating impact. This may impede the use of beaches.

Consequently, as shown by the results of ranking of utility providers and the analysis of the degree of environmental hazard of point pollution sources, it is feasible to apply the new methodological approach for the comprehensive assessment of the impact of riverbank sources of wastewater discharge on the state of water bodies and the formation of surface water quality.

Conclusions

1. The article proposes a new methodological approach to the assessment of the impact of riverbank sources of return water discharge on the state of water bodies, taking into account the composition of wastewater, degree of its purification, and loading on the water body.

2. The pollution sources, housing and utility providers of Mykolaiv region, have been ranked according to the indicators of wastewater composition and water body loading.

3. It has been established that almost all housing and utility providers of the region discharge insufficiently treated wastewater.

4. Sewage treatment facilities of the region do not match the current situation in the water disposal sector. Their production capacity exceeds the amount of wastewater passed through them, and the outdated treatment technology does not allow achieving the target, standard indicators. More than 60 % of the facilities require reconstruction, improvement of the technological process and equipment, etc.

5. With account for the overall coefficient of harmful impact of the pollution source on water bodies, each water pollution source under study has been assigned a hazard category; the degree of its environmental hazard has been assessed as well.

6. According to the results of the study, it has been established that the CME Mykolaiv Vodokanal located in the village of Galitsinove and discharging return water into the Bug Estuary is the main source of pollution of the region's water resources. It has a tremendous negative impact on the state of the Bug Estuary and the sanitary and epidemiological situation in Mykolaiv. Such companies as Biological Treatment Plants LLC (Voznesensk) and the ME Miskvodokanal (Bashtanka) are also classified as hazardous, discharging return water into the Southern Bug River and the Ingul River, respectively. The basic reasons for unsatisfactory operation of their treatment facilities are identified and analyzed.

Marginally hazardous enterprises are those with discharge from supply water treatment facilities, namely, the ME Novyi Buh Vodokanal and the Novyi Buh Branch of the Group Water Supply System (both located in Novyi Buh).

7. Reduction of the negative impact of wastewater discharge from housing and utility providers on the water bodies of Mykolaiv region, as well as compliance with the established standards and requirements for the wastewater treatment quality, requires implementing a set of water protection measures. These suggest preventive maintenance of the treatment facilities for their correspondence to the project capacity with account for depreciation, construction of biological polishing facilities, and construction of local treatment facilities at cities' enterprises.

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