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THE STATE OF THE SURFACE WATERS OF THE NORTH-WESTERN BLACK SEA COAST

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ABSTRACT

This section presents the general assessment results of a state of the surface waters in the North-Western Black Sea region according to a complex of indicators of a surface water quality and technogenic loading on the water bodies. The assessment and classification of the surface water quality using the various methodological approaches, as well as the assessment of the technogenic loading based on the calculation of the technogenic load module on the water bodies.

Keywords: water bodies, quality, assessment, technogenic loading, module.

INTRODUCTION

The regions of the North-Western Black Sea Coast (NWBSC), which include the Odesa, Mykolaiv and Kherson regions of Ukraine, are multifunctional territories. They are used for agricultural, industrial, transport, maritime, recreational and other purposes. Within this area there is a significant number of technogenic objects that adversely affect the condition and the quality of the components of the environment, including the surface waters. The area covers the lower parts of the Danube, Dniester, Southern Bug and Dnieper basins, the coastal zone of the northwestern part of the Black Sea with estuaries and is used mainly for agricultural, fishery and recreational purposes [1].

The assessment of a state of the surface waters in the NWBSC regions is a subject of a long-term research for many scientists, including the authors [2, 3]. These are the works concerning the complex estimations of the Odessa region water resources as a whole and the separate objects, their hydroecological condition [4 – 6], the works which are devoted to the estimation of the qualitative characteristics of the Odessa region rivers and lakes [7 – 11]. Some works relate to the methodological aspects, namely improving the methods for assessing the surface waters quality [12, 13]. Also in the work [14] a general estimation of a surface waters quality in the Mikolayiv region for a long-term period is presented, in the work [15] a new approach to estimating the ecological risk of the water objects deterioration is offered, and also a state of the Ingulets river basin within the region is analyzed.

METHODS AND EXPERIMENTAL PROCEDURES

Several methods for assessing a water quality, which we believe are optimal for using, have been identified. Such methods included a graphical method, a method of assessing the land surface water quality by the hydrochemical parameters, a method of assessing the ecological state of the water bodies by the content of *Biochemical Oxygen Consumption$_5$ (BOC_5)*.
The graphical method is based on drawing up a graphical model of a surface water quality, which is a cyclogram with scales-radii corresponding to a certain hydrochemical index. The division value of each radius is equal to a maximum value of the indicator concentration, which determines a water suitability for a particular type of water using [16]. The application of this method makes it possible to determine simultaneously an excess of the maximum permissible concentration (*MPC*) by the content of all quality indicators, which are monitored.
The method of assessing a land surface water quality by the hydrochemical parameters [17] allows to perform a comprehensive assessment of a surface water quality using the combinatorial pollution index (*CPI*). It allows you to take into account any list of indicators and to determine a water quality based on the number of indicators.
The assessment of a state of the water bodies by the content of BOC_5 [18, 19] is an indirect tool for determining the ecological state in the absence of systematic data by the hydrobiological quality indicators.
To assess the technogenic loading on the surface waters, a module of technogenic loading on the water bodies (M_{WB}) by the indicators of the return waters and pollutants discharges in their composition was used. It is defined as a volume of wastewater or pollutants discharges (thousand tons) for 1 year, attributed to the area of the administrative district or the region [20].

THE RESEARCH RESULTS AND DISCUSSIONS

In the territory of the Odessa region the surface waters are distributed rather unevenly. The northern and central parts of the region are characterized by limited water reserves, and the south and the west, which belong to the lower parts of the Dniester and Danube basins, have significant reserves [21]. The drainage in the region is carried out into the Black Sea basin, the Dniester, the Khadzhibey and other estuaries, as well as into the surface water bodies.

The analysis of the pollutants in the composition of wastewater discharging into the water bodies of the region showed that the maximum volumes are observed for phosphates and dry residue, the minimum – for heavy metals, calcium and sodium.

The assessment of a surface water quality of the Odessa region using a graphical method was performed for the Danube and Dniester river basins. It can be noted that in the waters of the Danube basin during 2005 – 2018 there were exceedances of the *MPC* by fishery standards for the content of nitrites, manganese, copper and chromium (VI). The excess in the manganese content in all years was maximum. Thus, according to other studies [22], a high content of manganese in the Danube waters is characteristic. High concentrations of nitrites indicate a significant organic pollution of the Danube. According to economic and drinking standards, the maximum permissible concentrations were exceeded by the content of copper and, in some years, by the content of phenols.

In the waters of the Dniester river basin, according to fishery standards, there were constantly increased concentrations of sulfates, nitrites, iron, in some years phosphates, as well as the excess of the *MPC* for total mineralization. According to the economic and drinking requirements, constant exceedances of the MPC were observed in the total mineralization. Increased concentrations of nitrogen and phosphorus compounds in the waters of the Dniester basin are the result of agricultural activities.

Fig. 1 – 2 show the results of calculating the *CPI* in the waters of the Danube and Dniester river basins. The maximum value of *CPI* for the Danube basin surface waters (Fig. 1) according to

fishery standards was noted in 2017, the minimum – in 2018. From 2005 to 2017 there was a tendency to increasing the *CPI*. According to economic and drinking standards, the maximum *CPI* was noted in 2009. During the study period the index was ranging from 20 to 30 units (except in 2018). The marked in 2018 minimum for both types of water using is explained, first of all, by reducing the number of reviewed water quality indicators from 16 to 11. Also in 2018 there were no data on the content of indicators in the water, which almost constantly have the significantly exceeded *MPC* in 2005 – 2017, primarily by the fishery requirements (copper and manganese).

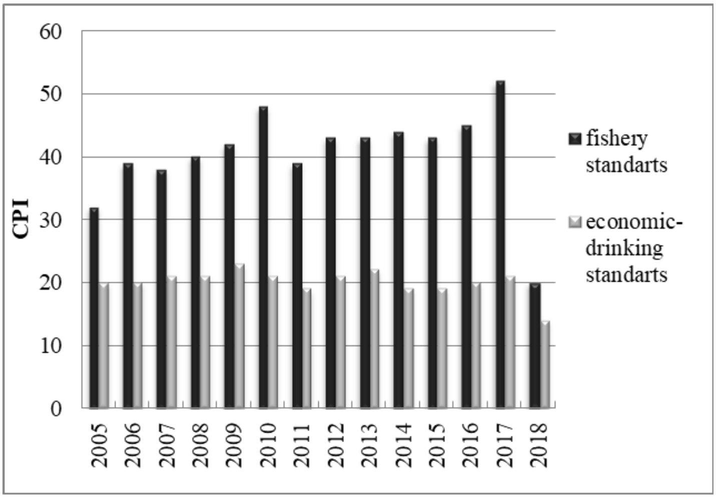


Fig. 1. The dynamics of changing the *CPI* in the waters of the Danube basin within the Odessa region

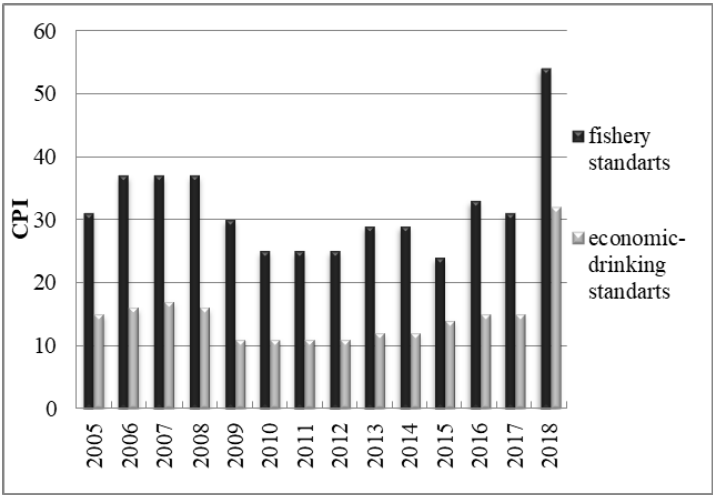


Fig. 2. The dynamics of changing the *CPI* in the waters of the Dniester river basin within the Odessa region

For the waters of the Dniester river basin (Fig. 2) by the fishery requirements, the maximum value of *CPI* was noted in 2018, the minimum was in 2015. In general 2009 – 2017 is a period of minimal pollution. According to the economic and drinking standards, the maximum *CPI* was also observed in 2018, the minimum values were observed in 2009 – 2012. These maxima for both types of water using were explained by increasing the number of reviewed water quality indicators in 2018, as well as a significant increase of the BOC_5 content in some observed sites.

Table 1 shows the results of the water quality classification in the Danube and Dniester river basins within the Odessa region. In general by the fishery standards, the water quality of the Dniester river basin is worse compared to the waters of the Danube river basin. The waters of the Danube basin are mostly characterized by quality classes IIIa – IIIb, category "dirty". The water quality of the Dniester river basin in different years is characterized by classes IIIa – IIIb (category "dirty") – IVa (category "very dirty"). According to the economic and drinking standards, the waters of the both rivers basins are characterized by the same indicators – class II, category "polluted" (except in 2018 for the Dniester).

Table 1 – The classification of a surface water quality of the Odessa region

Year	The Danube river basin		The Dniester river basin	
	fishery standards	economic and drinking standards	fishery standards	economic and drinking standards
2005	II, contaminated	II, contaminated	IIIб, dirty	II, contaminated
2006	IIIa, dirty	II, contaminated	IVa, very dirty	II, contaminated
2007	IIIa, dirty	II, contaminated	IVa, very dirty	II, contaminated
2008	IIIa, dirty	II, contaminated	IVa, very dirty	II, contaminated
2009	IIIa, dirty	II, contaminated	IVa, very dirty	II, contaminated
2010	IIIa, dirty	II, contaminated	IIIb, dirty	II, contaminated
2011	IIIa, dirty	II, contaminated	IIIb, dirty	II, contaminated
2012	IIIa, dirty	II, contaminated	IIIb, dirty	II, contaminated
2013	IIIa, dirty	II, contaminated	IIIb, dirty	II, contaminated
2014	IIIa, dirty	II, contaminated	IIIb, dirty	II, contaminated
2015	IIIa, dirty	II, contaminated	IIIb, dirty	II, contaminated
2016	IIIa, dirty	II, contaminated	IVa, very dirty	II, contaminated
2017	IIIb, dirty	II, contaminated	IIIa, dirty	II, contaminated
2018	II, contaminated	II, contaminated	IVa, very dirty	IIIa, dirty

The results of the assessment of the Danube waters by the value of BOC_5 are given in table 2. As it can be seen, in the vast majority a state of the Danube basin waters by the level of pollution is characterized by category "moderately polluted" and by the ecological state – a threshold stage. The data on the values of BOC_5 in the waters of the Dniester River were unsystematic. Thus according to the available data, a state of water in general is also characterized by the level of pollution by category "moderately polluted", by the ecological state – a threshold stage.

In the Mikolaiv region the problem of surface water objects pollution is also acute. Due to the lack of domestic and industrial emissions high-quality treatment, the situation in the region is significantly complicated.

In terms of surface water reserves, the Mykolayiv region belongs to the basins of the Southern Bug River, the Dnieper River and some rivers of the Black Sea region [23]. The region local water resources are very limited and depend on the inflows from other regions.

Table 2. The classification of the Danube water quality according to the value of BOC_5

Year	Pollution level	Ecological condition
2005	Moderately polluted	Threshold stage
2006	Contaminated	Stage of irreversible changes
2007	Moderately polluted	Threshold stage
2008	Contaminated	Stage of irreversible changes
2009	Contaminated	Stage of irreversible changes
2010	Moderately polluted	Threshold stage
2011	Moderately polluted	Threshold stage
2012	Moderately polluted	Threshold stage
2013	Moderately polluted	Threshold stage
2014	Clean	Stage of reversible changes
2015	Clean	Stage of reversible changes
2016	Moderately polluted	Threshold stage
2017	Moderately polluted	Threshold stage
2018	Moderately polluted	Threshold stage

According to the available data [24, 25], the maximum volumes of discharges are observed for such an indicator as dry residue. Also in recent years there has been an increase in discharges of nitrogen and phosphorus compounds.

The dynamics of changing the indicators of the Mikolayiv area surface waters quality was analyzed using a graphic method. In almost all the years, the maximum exceedances of the *MPC* in the waters of the Southern Bug River Basin by the fishery standards were noted for the content of copper and manganese. There were also significant exceedances of the *MPC* for fishery needs in terms of nitrites, phosphates, sulfates, total iron, zinc and nickel. The obtained data are consistent with the previous studies of the authors [26]. However the authors considered the Southern Bug water quality only for economic-drinking and communal purposes. According to economic and drinking requirements, the excess of *MPC* was noted in terms of chlorides, magnesium, total iron and the amount of surface water mineralization.

The calculation of the Mikolayiv region surface waters *CPI* (fig. 3) showed that according to the fishery standards the CPI value is 3 – 4 times higher than by the economic and drinking standards. In general for both types of water using there is a decrease in the overall level of water pollution from 2010 to the present. The minimum *CPI*, noted in 2016 and significantly different from other years (primarily by the fisheries standards), is the result of several reasons:

- reducing the number of analyzed indicators from 16 to 7;

- in 2016 the analysis did not take into account the substances for which there were previously constant and significant exceedances of the *MPC* (nitrites, magnesium, phosphates, total iron, copper, zinc, nickel and manganese).

On the basis of the received data the classification of the Mikolayiv region surface waters quality for the long-term period is executed (tab. 3). In all the years, except for 2016, the surface waters quality of the region according to the fishery standards is characterized by class VIa, category "very dirty", according to the economic and drinking standards – the only class II, category "polluted". Compared with the surface waters of the Odessa region, the waters of the Mikolayiv region are characterized by the worse quality according to the fishery standards.

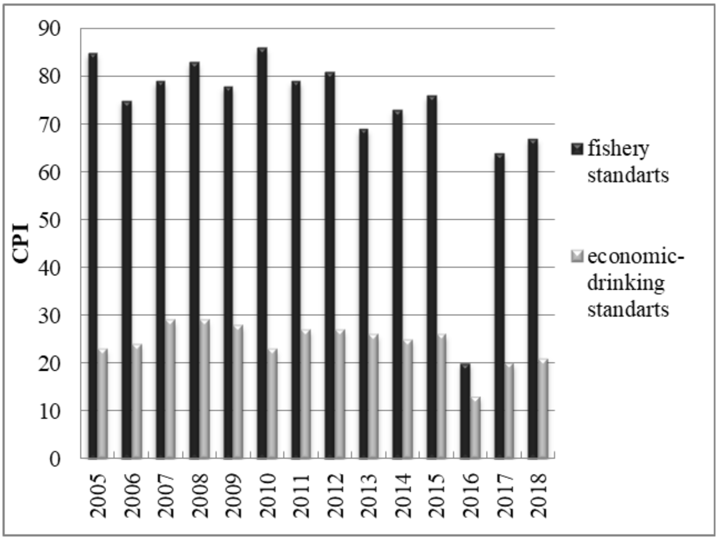


Fig. 3. The dynamics of changing the surface waters *CPI* in the Mikolayiv region

Table 3. The classification of a surface water quality in the Mikolayiv region

Year	Fishery standards	Economic and drinking standards
2005	VIa, very dirty	II, contaminated
2006	VIa, very dirty	II, contaminated
2007	VIa, very dirty	II, contaminated
2008	VIa, very dirty	II, contaminated
2009	VIa, very dirty	II, contaminated
2010	VIa, very dirty	II, contaminated
2011	VIa, very dirty	II, contaminated
2012	VIa, very dirty	II, contaminated
2013	VIa, very dirty	II, contaminated
2014	VIa, very dirty	II, contaminated
2015	VIa, very dirty	II, contaminated
2016	IIIa, dirty	II, contaminated
2017	VIa, very dirty	II, contaminated
2018	VIa, very dirty	II, contaminated

The results of the classification of the Mykolayiv region surface waters by the value of BOC_5 are given in table 4. As it can be seen the surface waters of the region by the level of pollution are mainly characterized by categories "moderately polluted" – "polluted", by the ecological state – a threshold stage and a stage of irreversible changes. Compared to the Odessa region, the surface water bodies of the Mikolayiv region are characterized by the worst ecological state indicators.

Table 4. The classification of the Mikolayiv region surface water quality by the value of BOC_5

Year	Pollution level	Ecological condition
2005	Moderately polluted	Threshold stage
2006	Clean	Stage of reversible changes
2007	Contaminated	Stage of irreversible changes
2008	Contaminated	Stage of irreversible changes
2009	Moderately polluted	Threshold stage
2010	Moderately polluted	Threshold stage
2011	Moderately polluted	Threshold stage
2012	Moderately polluted	Threshold stage
2013	Moderately polluted	Threshold stage
2014	Contaminated	Stage of irreversible changes
2015	Contaminated	Stage of irreversible changes
2016	Contaminated	Stage of irreversible changes
2017	Contaminated	Stage of irreversible changes
2018	Moderately polluted	Threshold stage

26 rivers flow through the territory of the Kherson region, including the Dnieper River with the Kakhovka Reservoir, the Ingulets River. The waters of the Dnieper feed the Kakhovka magistral canal and the North Crimean canal [27]. The largest water users in the region are agriculture and utilities, as well as industrial enterprises.

Sewage is discharged into the Kalanchak River, the Kalanchak Estuary and the Black Sea [28]. The maximum volumes of discharges according to [29, 30] data are observed for dry residue, sulfates and chlorides.

Analyzing the dynamics of changes in the Kherson region surface water quality indicators using the graphical method shows that in 2005 – 2008 there were significant exceedances of the MPC by the fishery standards (> 10 *MPC*) for nitrites, chromium (VI), copper and nickel. Maximum excesses were observed in the content of chromium (VI). Significant exceedances of the fishery standards were also noted in the content of sulfates, phosphates, manganese, values of BOC_5 and mineralization. According to the economic and drinking requirements, the excess of MPC was most often observed in such indicators as mineralization, BOC_5, nickel.

The increased content of nitrogen and phosphorus compounds in the water is a consequence of agricultural production in the Kherson region. The Ingulets River flows through the region, the chemical composition of its waters is formed under the influence of highly mineralized wastewater from the Kryvyi Rih iron ore basin.

The CPI of the Kherson region surface waters was calculated (Fig. 4). The analysis of the given figure shows that the maximum value of CPI for both types of water using was noted in 2008. This is explained by the fact that that year the number of analyzed indicators was maximum (17), that influenced the results of the *CPI* calculation. The index value for the fishery requirements, as for other regions of the NWBSC, is much higher than for drinking. In 2014 – 2015, there is a minimum *CPI*, which is caused by several factors:

- reducing the number of analyzed indicators to 10 – 11;

- a lack of available data when analyzing the indicators that significantly degraded a quality of the surface waters in the region (chromium (VI), copper, nickel, etc.).

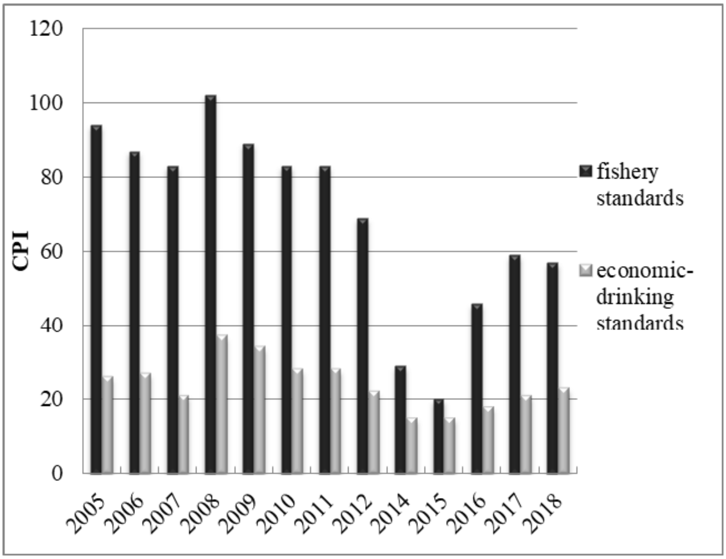


Fig. 4. The dynamics of changing the surface waters *CPI* in the Kherson region

In 2016 – 2018 the list of indicators almost did not differ from the list of 2005 – 2012. However there is a significant decrease in the *CPI* value.

In most cases a quality of the surface waters of the region (Table 5) according to the fishery requirements is characterized by classes IVa – IVg, category "very dirty", for drinking water – class II, category "polluted", class IIIa, category "dirty".

The ecological condition of the Kherson region surface waters was also assessed according to the content of BOC_5 (Table 6). Thus almost the whole period the surface waters of the region are characterized by the worst indicators in terms of pollution ("dirty") and in terms of the environmental state ("stage of irreversible changes").

If we compare the indicators of a surface water quality in the regions of the NWBSC, the waters of the Kherson region are characterized by the worst quality in terms of hydrochemical indicators and in terms of the ecological state (content of BOC_5).

We calculated the projected trends in the dynamics of the surface water pollution level in the regions of the NWBSC (Fig. 5 – 7). The presented drawings show that for the Mikolayiv and Kherson regions a stable tendency towards a decrease in the surface waters pollution within the next 10 years is noted. As for the Odessa region, in general, pollution indicators tend to increase. Thus the probability of the surface water quality deterioration in the regions of the NWBSC is observed for the basins of the Danube and Dniester rivers within the Odessa region.

An important factor in analyzing the state of the components of the environment, including the state of the water bodies, is the assessment of technogenic loading.

Table 5. The classification of the surface water quality of the Kherson region

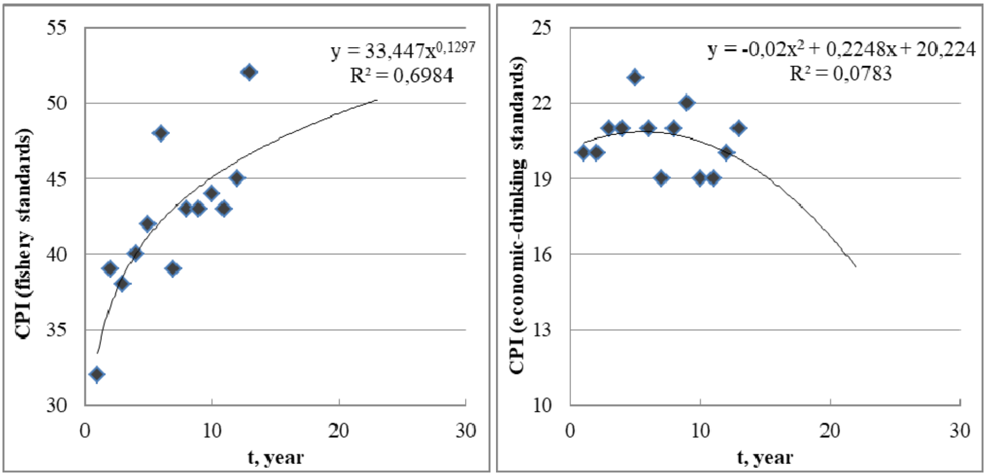
Year	Fishery standards	Economic and drinking standards
2005	IVg, very dirty	II, contaminated
2006	IVc, very dirty	IIIa, dirty
2007	IVc, very dirty	II, contaminated
2008	IVc, very dirty	IIIa, dirty
2009	IVb, very dirty	II, contaminated
2010	IVc, very dirty	IIIa, dirty
2011	IVc, very dirty	IIIa, dirty
2012	IVa, very dirty	II, contaminated
2014	IIIa, dirty	II, contaminated
2015	IIIa, dirty	II, contaminated
2016	IVa, very dirty	II, contaminated
2017	IVa, very dirty	II, contaminated
2018	IVa, very dirty	II, contaminated

Table 6. The classification of the Kherson region surface water quality by the value of BOC_5

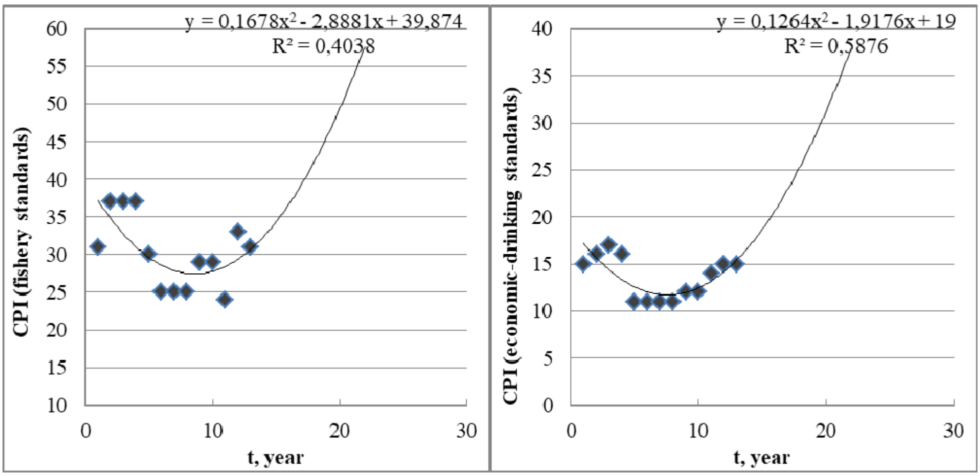
Year	Pollution level	Ecological condition
2005	Dirty	Stage of irreversible changes
2006	Dirty	Stage of irreversible changes
2007	Dirty	Stage of irreversible changes
2008	Dirty	Stage of irreversible changes
2009	Dirty	Stage of irreversible changes
2010	Dirty	Stage of irreversible changes
2011	Dirty	Stage of irreversible changes
2012	Dirty	Stage of irreversible changes
2014	Moderately polluted	Threshold stage
2015	Dirty	Stage of irreversible changes
2016	Dirty	Stage of irreversible changes
2017	Dirty	Stage of irreversible changes
2018	Dirty	Stage of irreversible changes

In the Odesa region, there are 132 enterprises that discharge pollutants into the surface water bodies. The main pollutants are utilities, namely “Infoxvodokanal” (Odessa), “Chornomorskvodokanal”, “Artsyz Vodokanal”, “Podilskvodokanal”, “Belgorod-Dniestrovskvodokanal”, “Teplodarvodokanal”, “Baltavodokanal” and also a cellulose-cardboard factory (Izmail) [31].

The largest volumes of water intake are carried out from the surface sources (95 % of the total water intake in the region). According to using the water for various needs the use for drinking needs took the first place until 2012, since 2013 the first place has been occupied by using the water for irrigation. Minimum water using indicators are observed in the agricultural sector.



the Danube river basin



the Dniester river basin

Fig. 5 – The projected assessment of the surface water pollution level in the Odessa region

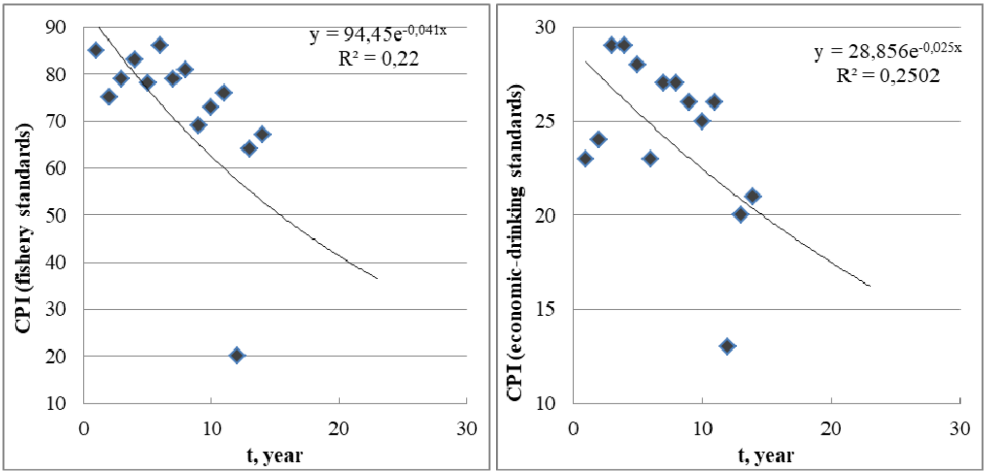


Fig. 6. The projected assessment of the surface water pollution level in the Mykolayiv region

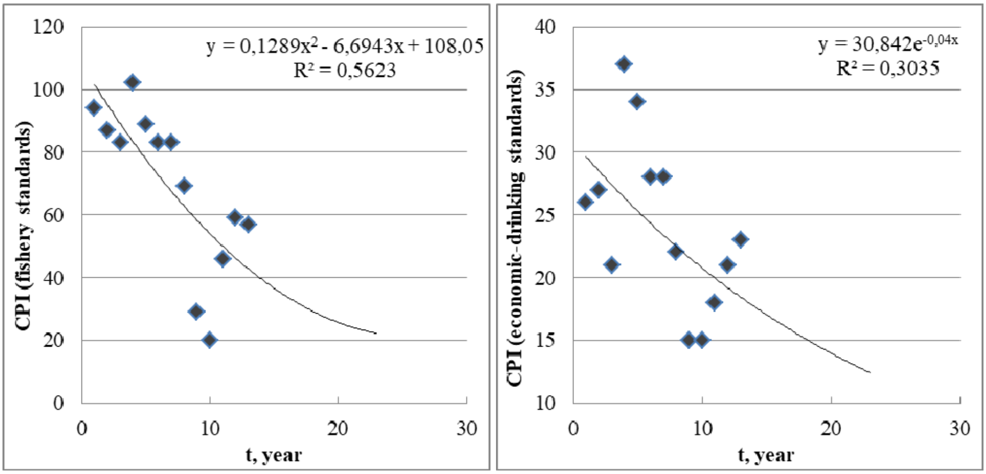


Fig. 7. The projected assessment of the surface water pollution level in the Kherson region

Sewage and other return waters are discharged mainly into the surface water bodies. At present, 40 – 50 % of discharged pollutants are characterized as “normative cleaned". In recent years, there has been a significant increase in return water discharges, which may be due to an increase in the water abstraction in the region.

By the types of economic activity, the main water-consuming industries are housing and communal services and agriculture.

The assessment of technogenic loading on the Odessa region water bodies according to the indicators of wastewater and pollutants discharges in their composition was performed using the M_{WO} indicator (Fig. 8). Thus from 2009 to 2016 there was a decrease in the total loading on the surface water bodies in the region due to a decrease in wastewater discharges. In 2017 – 2018, this figure increased significantly, which, as noted above, is due to an increase in discharges. Until 2013, with the overall decrease in the volume of wastewater discharges, the number of pollutants in their composition had been increasing.

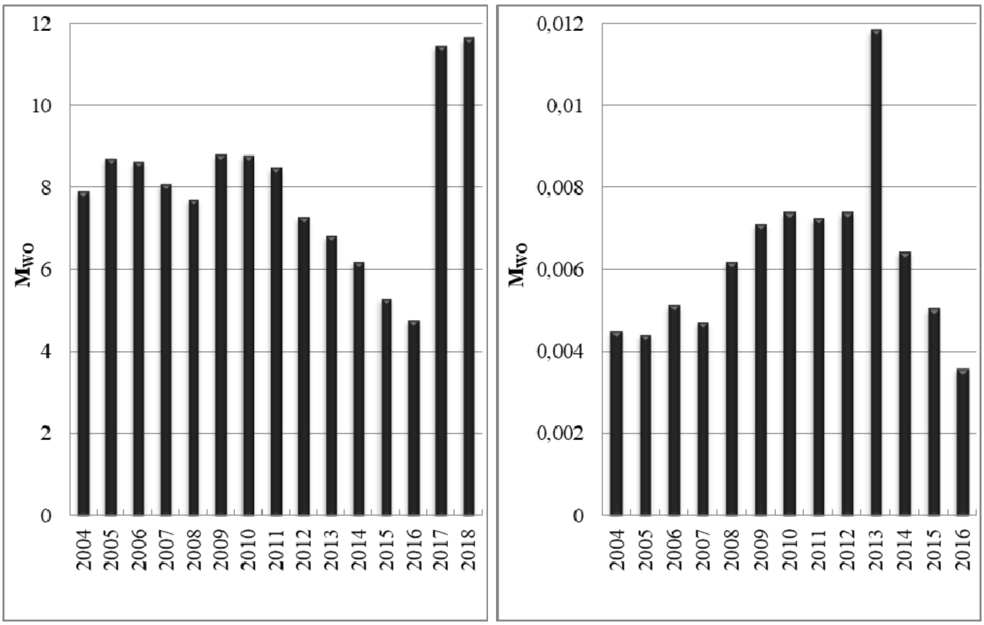
The analysis of the discharge volumes from the main polluting enterprises showed that the Odesa region water objects receive the maximum technogenic loading according to the indicators of wastewater discharges under the influence of the "Infoxvodokanal" activity. Among other enterprises the largest discharge rates are observed for the cellulose-cardboard factory in Izmail.

The analysis of the prognostic load indicators on the Odessa region surface water bodies (Fig. 9) testifies to the tendency of increasing the indicators, first of all by the volumes of wastewater discharges.

In the territory of the Mikolayiv region about 160 enterprises having the permission for water using are operating nowadays. The main water bodies polluters in the region are the vodokanal enterprises, namely "Mykolayivvodokanal", "Olshanske", "Pervomaisky city vodokanal", "Pribuzke", Bashtanka "City vodokanal", "Ochakivvodokanal".

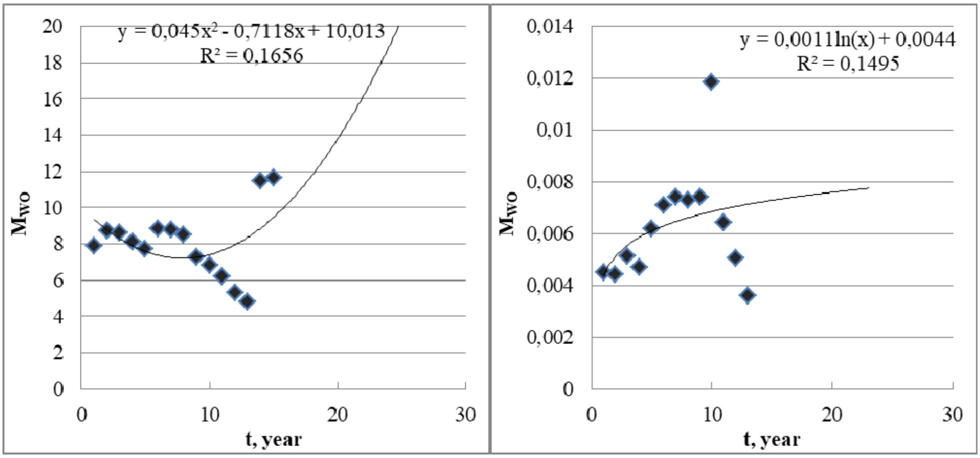
In the Mikolayiv region from 2003 to 2010 the water intake indicators decreased almost in 1,5 times and at present they are fluctuating within 226 – 290 million m^3. The water using indicators have also declined. The maximum water consumption is observed for the production needs, the minimum – for the agricultural needs without taking into account the irrigation needs.

There is also a significant decrease in the values of indicators from 2003 to the present in terms of wastewater discharges. The largest amount of wastewater is discharged into the surface water bodies (more than 90 %). Untreated water prevails in the wastewater composition. The share of "normatively cleaned" wastewaters is very low. This is a consequence of inefficient operation of the municipal sewage treatment plants.



by the volumes of wastewater discharges by the volumes of pollutants discharges

Fig. 8. The value of the M_{WO} indicator in the Odessa region in 2004 – 2018

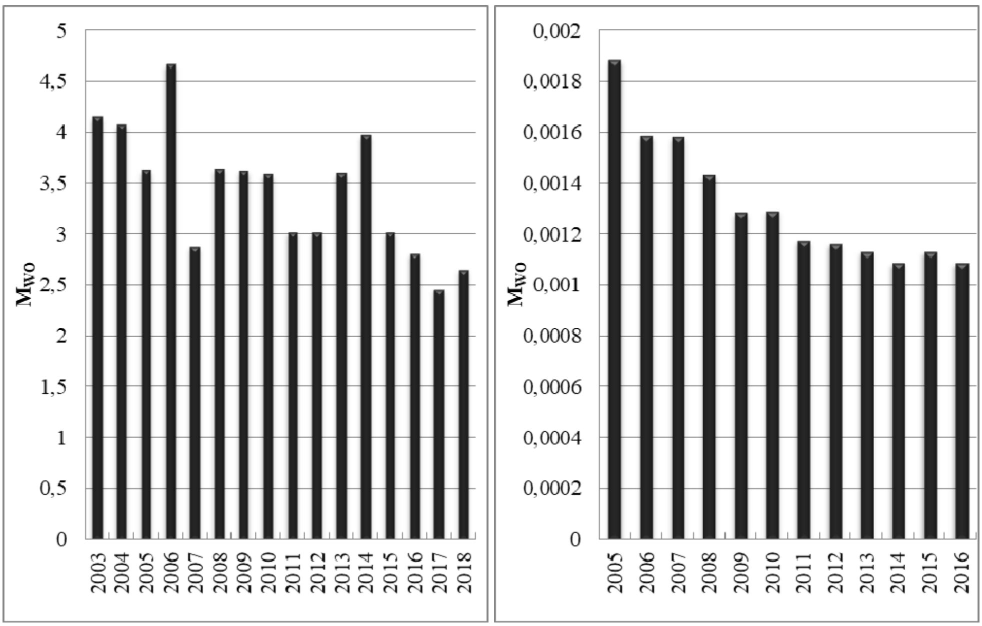


wastewater pollutants

Fig. 9. The projected assessment of the level of technogenic loading on the Odessa region water bodies

By the types of economic activity the most water-consuming industries are agriculture (taking into account the irrigation and fish farming needs) and energy. Significant water consumption indicators are also observed for the housing and communal service needs.

The estimation of technogenic loading on the Mikolayiv region water objects of (fig. 10) is done. In terms of wastewater discharges, the M_{WO} value has decreased by almost 1.5 times since 2006. According to the pollutants discharges indicators, there has been a steady decrease in loading almost 2 times since 2005. This is a consequence of the reduction of wastewater discharges and, accordingly, pollutants in their composition.

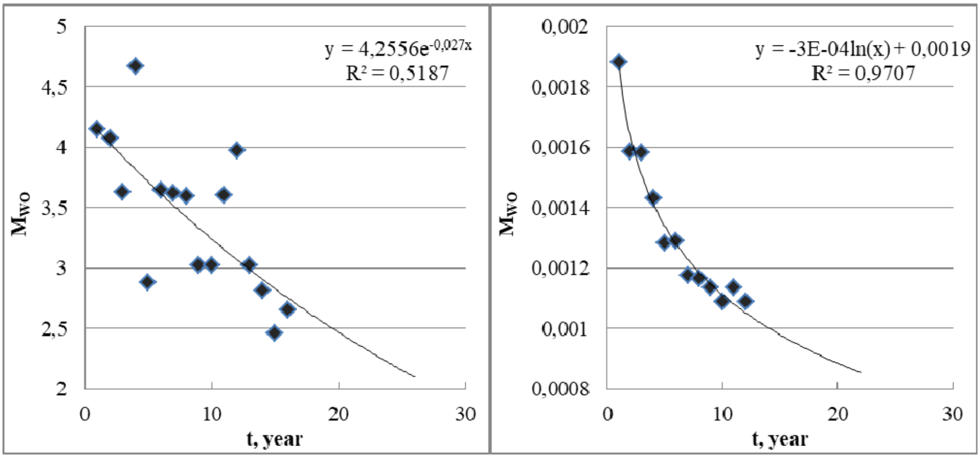


by the volumes of wastewater discharges by the volumes of pollutants discharges

Fig. 10. The value of the M_{WO} indicator in the Mykolayiv region in 2003 – 2018

The analysis of loading from the main enterprises-polluters showed that the volumes of discharges from "Mikolayivvodokanal" exceed the corresponding indicators of other enterprises by 1 – 2 orders. Among the other enterprises, in recent years the maximum discharge volumes have been observed for Pervomaisky Vodokanal.

The received projected indicators (fig. 11) testify to the tendency to reducing the level of technogenic loading on the Mikolaiv region water objects.



wastewater pollutants

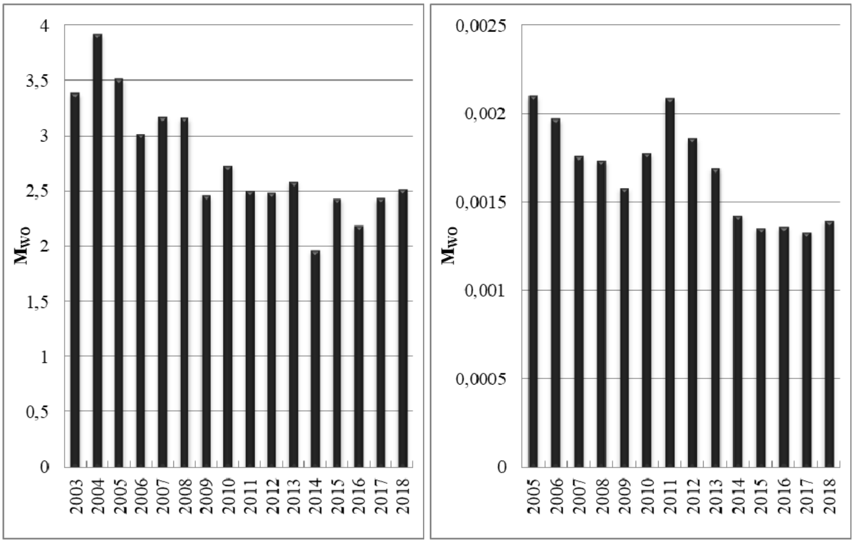
Fig. 11. The projected assessment of the level of technogenic loading on the Mykolaiv region water bodies

According to [32] data in 2019 in the Kherson region 1161 water users were registered. In recent years the main water bodies polluters are the "Palada" plant (Kherson), the Kherson river port and such enterprises as "Source" of the Kalanchak village council, "Rice of Ukraine", "Zhukova" and "Southern" (village Oleksiyivka), "Sewage treatment plants" of the Skadovsk city council [28].

The analysis of water intake in the region showed that there is a steady increase in all indicators. The largest water intake is from the surface water sources, the smallest – from the sea sources. With the increase in water intake, there is an increase in water using. The maximum volumes are marked for the irrigation needs, the minimum are for other agricultural needs. With the general increase in water intake, there is a decrease in wastewater discharges. The maximum number of wastewater discharges is carried out into the surface water bodies. In terms of the degree of purification constantly clean wastewater is dominated.

By the types of economic activity the greatest needs in water resources in the region are observed for the agricultural enterprises compared to other industries.

The estimation of the level of technogenic loading on the surface water bodies of the region according to the volumes of wastewater discharges and pollutants in their composition (Fig. 12) indicates a significant decrease in the M_{WO} indicator (by almost 30 %).



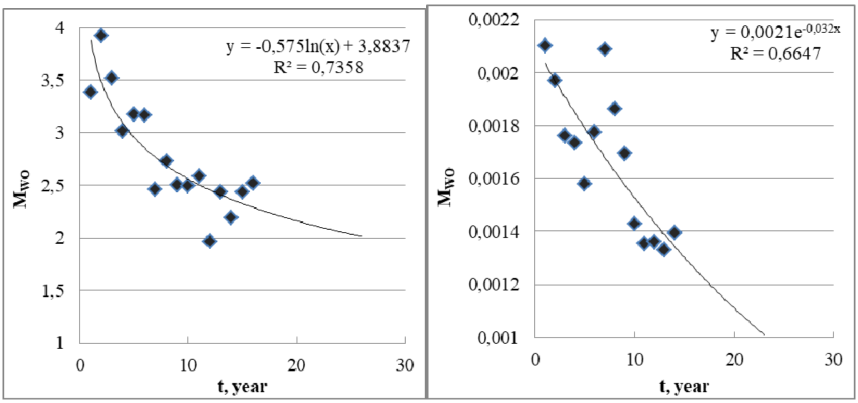
by the volumes of wastewater discharges by the volumes of pollutants discharges

Fig. 12. The value of the M_{WO} indicator in the Kherson region in 2003 – 2018

The analysis of technogenic loading on the water bodies from the main polluting enterprises of the Kherson region showed that the discharge volumes from the Kherson water supply system exceed the corresponding ones by 1 – 2 orders of magnitude. Among other enterprises, the significant discharge volumes are noted for "Rice of Ukraine".

The projected values of technogenic loading on the water bodies indicate their decrease during the next 10 years (Fig. 13).

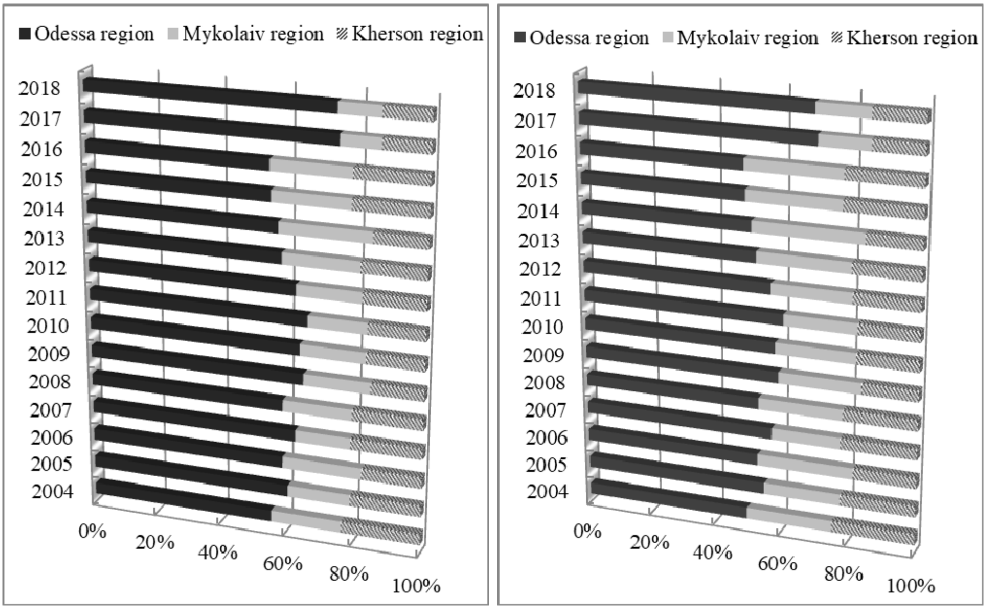
A comparative analysis of technogenic loading on the surface water bodies of the NWBSC regions was also performed (Fig. 14 – 15). As it can be seen from both figures, the greatest loading is on the surface water bodies of the Odesa region (55 – 75 % of wastewater discharges and 60 – 75 % of pollutants discharges from the total volumes). The second place is taken by the Kherson region. According to the value of the M_{WO} indicator, the maximum level of loading is also noted for the Odesa region. According to the wastewater discharges indicators, after the



wastewater pollutants

Fig. 13. The projected assessment of the level of technogenic loading on the Kherson region water bodies

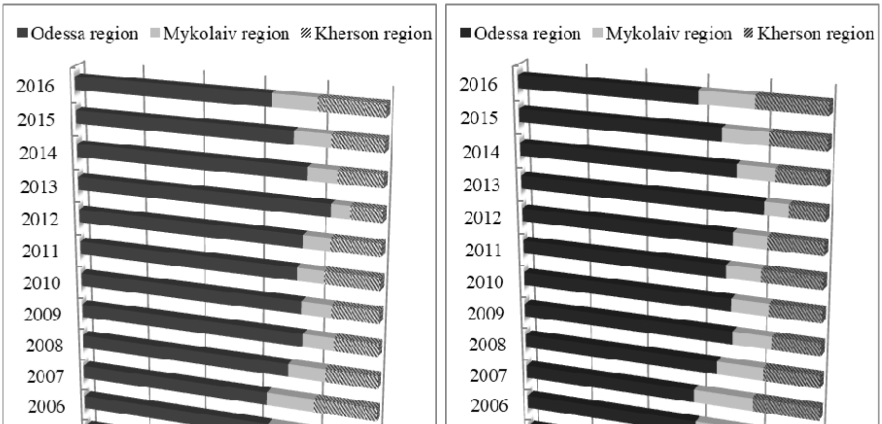
Odesa region, the value of M_{WO} is the largest in the Mykolayiv region as a whole, and according to the volume of pollutants discharges it is the largest in the Kherson region.



by the volumes of wastewater discharges by the value of M_{WO}

Fig. 14. The comparative analysis of technogenic loading on the regions of the NWBSC in terms of wastewater discharges into the surface water bodies

The analysis of materials for a long-term period and the obtained calculations show that the maximum level of technogenic loading is observed for the Odesa region, the minimum – for the Kherson region in terms of the volumes of wastewater discharges into the surface water bodies.



by the volumes of pollutans discharges by the value of M_{WO}

Fig. 15. The comparative analysis of technogenic loading on the regions of the NWBSC in terms of pollutant contaminants in the wastewater discharging into the surface water bodies

CONCLUSION

The section presents the general assessment results of a state of the surface waters in the North-Western Black Sea region according to a complex of indicators of a surface water quality and technigenic loading on the water bodies. The obtained calculations allow us to draw the following conclusions:

1. In all regions of the NWBSC, a non-compliance with the standards was most often noted for fishery requirements. According to the value of *CPI* the Odessa region surface waters were characterized by quality classes IIIa – IVa (category "dirty" – "very dirty") according to fishery standards, the Mykolaiv region – mainly class VIa (category "very dirty"), the Kherson region – classes IVa – IVg (category "very dirty"). According to economic and drinking standards, the water quality in the regions was characterized by class II – IIIa (categories "polluted" – "dirty"). The estimation of an ecological state of the waters showed that waters of the Odessa region are characterized as "moderately polluted" with a threshold stage of an ecological condition, the Mikolayiv region – "moderately polluted" and "polluted" (accordingly a threshold stage and a stage of irreversible changes), the Kherson region – "dirty" with a stage of irreversible changes.

2. The comparative analysis showed that the waters of the Kherson region are characterized by the worst quality for the fishery and drinking requirements, as well as by the ecological condition.

3. According to the volumes of wastewater and pollutants discharges into the surface water bodies, the maximum level of technogenic loading is observed for the Odesa region, the minimum – for the Kherson region.

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