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WATER CONSERVATION AND RIVER WATER QUALITY OF THE BULGARIAN BLACK SEA TRIBUTARIES

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Abstract

Various policies, strategies and activities related to sustainable management of water resources in order to meet the current and future human demand are defined as "water conservation". Nowadays many countries including members of EU have already implemented such water policies. Water conservation could be also implemented on the institutional and social level. One of the key activities to preserve the water resources is to avoid any decline in the water quality. This paper analyzes the current state of quality of the main Bulgarian tributaries of the Black Sea. Component analysis of the main physicochemical indicators according to Ordinance N-4/2012, as well as the content of some of the most common heavy metals in Bulgarian rivers was performed. The results show that river water is mainly polluted by wastewater from utilities and agriculture. The participation of heavy metals in the pollution of river waters in this region of the country is not very high and is reported only in some of the monitoring points. The waters of the Veleka river near the village of Sinemorets have the most favorable hydrochemical characteristics, while the waters of the Dvoinitsa river at the point before flowing into the Black Sea have the worst.

Keywords*: Conservation; Water quality; Black sea; Tributaries; Wastewater; Agriculture*

Introduction

Water plays a key role in everyday life, as well as in all economic sectors. It is a vital component supporting the biodiversity and secure the existence of ecosystems. A clean, "healthy" and properly functioning water system creates numerous benefits for people and society (e.g. clean water for household and industry, suitable water resources for recreation and SPA treatment, irrigation water, etc.). Water conservation is defined as careful use and preservation of water supply, and it includes both the quantity and quality of water. The benefits arising from the availability of water resources with the required quality for different purposes must be balanced by their use. Nowadays, the term "aquatic ecosystem services" is used more and more often. The correct determination and prioritization of the "benefits" of the protection and improvement of the condition (quantitative and qualitative) of water bodies is the basis of sustainable water management. Water Conservation is the practice of efficiently preserving, controlling, and managing water resources. Water conservation has become an essential practice in every part of the world, even in regions where water appears to be enough–both in

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quantity and quality. It is the most practical and environment-friendly approach to lessen our need for water [1-5].

In this connection the main aim of water conservation and water management in the EU member countries is to achieve "good" status of surface and groundwater by applying the basin principle of sustainable water use, providing optimal current and future needs of the population and economy, as well as aquatic ecosystems. The integrated river basin planning model is a new approach introduced by the Water Framework Directive - (WFD) (2000/60/EC), in which water management is carried out within the natural geographical and hydrological units [6].

The requirements of the WFD still pose a number of challenges in many respects. The water management in Republic of Bulgaria is carried out at national and basin level. According to the Water Act (WA) [7], there are four basin management areas in the country - Danube region with center Pleven, East Aegean region with center Plovdiv, West Aegean region with center Blagoevgrad and Black Sea region with center Varna. The main tool for implementing the requirements of the WFD for water conservation and to achieve a "good" quality status of water bodies are the River Basin Management Plans (RBMPs) [8].

To make it possible to achieve the main objectives set in the RBMP, joint and coordinated efforts of state institutions, stakeholders, municipal and district administrations, non-governmental organizations and water users is a must. Following this way, the long-term benefits of having enough water of "good" quality for the environment, business and economic growth are guaranteed. The water conservation, including its quality and quantity, the protection of the natural ecological environment and the creation of favorable conditions for meeting water needs are determined by the objectives of water consumption and the requirements of water users. However, the ecological status in particular the quality of the river waters nowadays has been largely determined by various anthropogenic impacts, which may result in water pollution [9-12].

This refers to the waters of all rivers in the country, including the Bulgarian Black Sea river basins. The main goal of the research is to establish the quality status and change of the river waters of the Bulgarian Black Sea tributaries for the period 2015-2020. The subject of research are the river waters from the Black Sea outflow area, and the object of research is their quality through analysis of more than 10 physicochemical indicators.

Experimental Part

Study Area

The decision to focus on the Bulgarian Black Sea tributaries, as the object of this study is dictated by the impact of diverse human activities on water quality in the Black Sea outflow region (Table 1).

Table 1. Main details of the Black Sea tributaries used in the study

	Map code	Source (sea level)	Lenght (km)	Catchment area (km^2)
1	BAU	Frangensko plateau- 309	38,7	338,8
2	PRU	Samuilovski Heights - 441	119	2131,8
3	KMP	Lisa mountain - 760	199	5357,6
4	DVU	Eminska Mountain - 440	52	479.
5	HJT	Eminska Mountain - 482	55	356
6	AHU	Aitoska Mountain - 166	39,9	141
7	ROV	ridge Bosna (Strandja)- 400	48,5	249
8	DYU	ridge Bosna (Strandja) - 440	37	133

Before all the analysis focuses on the impact of the developed economic activity (industrial and agricultural), the different nature of land use, the way of discharging untreated or insufficiently treated wastewater from settlements, as well as the presence of built or partially

built sewerage system and treatment wastewater stations (WWTPs). The river systems that are the subject of this article fall into the Black Sea Basin Water Management Region (BSBWMR).

It covers the territory of the catchment areas of the rivers flowing into the Black Sea from the northern to the southern border of Bulgaria, including the internal sea waters and the territorial sea. It covers the territory of the catchment areas of the rivers flowing into the Black Sea from the northern to the southern border of Bulgaria, including the internal sea waters and the territorial sea. The region is bordered by the Danube Basin Management Region to the northwest, the East Aegean Region to the southwest, the Republic of Romania to the north and the Republic of Turkey to the south. The territory of the Black Sea Basin Water Management Region (BSBWMR) covers about 14.9% of the country's territory. The area is managed by the Black Sea Basin Directorate, which is located in Varna. The administrative-territorial scope of BSBD includes fully or partially a total of 8 administrative districts of the Republic of Bulgaria (Varna, Dobrich, Shumen, Targovishte, Burgas, Yambol, Razgrad and Sliven), 51 municipalities and 633 settlements. The Black Sea Basin Management Region is the third largest in the country in terms of population [8].

Over the last decade, agriculture has continued to be one of the most significant sources of pressure on water quality in the study area. Due to the favorable soil and climatic conditions, the region is characterized by a large percentage of arable land. Artificial and natural fertilizers used in the treatment of soils seep into surface and groundwater. On the other hand, a significant source of pollutants is the discharge of partially treated or untreated wastewater from cities, villages, villa areas, resorts, holiday villages and industrial enterprises. Uncovered old municipal landfills which are not reclaimed and do not meet environmental requirements are a diffuse source of pollution and very often lead to deterioration of water quality mainly with nutrients. Livestock farms, including aquaculture, are a potential source of nutrient contamination. Although limited in scale and action in the study area, the sites of existing industrial facilities and landfills that do not meet environmental requirements, as well as chemical pollutants in infiltrates create opportunities for pollution of Bulgarian Black Sea tributaries not only with heavy metals and metalloids, but also with other priority substances and specific contaminants. The Black Sea coast is an area of active tourism development and its impact on water systems is mainly expressed in nutrient enrichment, introduction of chemical pollutants, physical damage, etc. Along with the tourist activities, the ongoing processes of urbanization, mostly related to land use change, are another significant factor that affects the environment and in particular the quality of water resources [13-17].

As mentioned, water is also used as a source of ecosystem services, with many functions, uses and benefits [1, 18]. The significant problems listed above in water management in the Black Sea basin region, and in particular in the studied river basins, can worsen water quality, which in turn implies a reduction in the benefits of their use. There are good practices both in the EU and in Bulgaria, for conservation of water resources which can and should be applied and continuously improved. The results obtained below would be useful to local governments to conduct adequate control of the studied surface waters.

Materials and Methods

Regulations

The assessment of physical-chemical status in the water samples of the analyzed river basins was made in accordance with Directive 2000/60/EC (Water Framework Directive) and its equivalent criteria transposed into the Water Act in Bulgaria [6, 7]. In this study, the data set was analyzed in accordance with current Bulgarian legislation - Ordinance N-4 on surface water characterization of 2012 (for “good” physical-chemical status) and Ordinance on environmental quality standards for priority substances and some other pollutants of 2010 (Ordinance EQSPSSOP 2010) [19, 20].

Sample and sample locations

The object of the research is water quality through the analysis of more than 10 physical-chemical indicators from the area under study (Fig. 1).

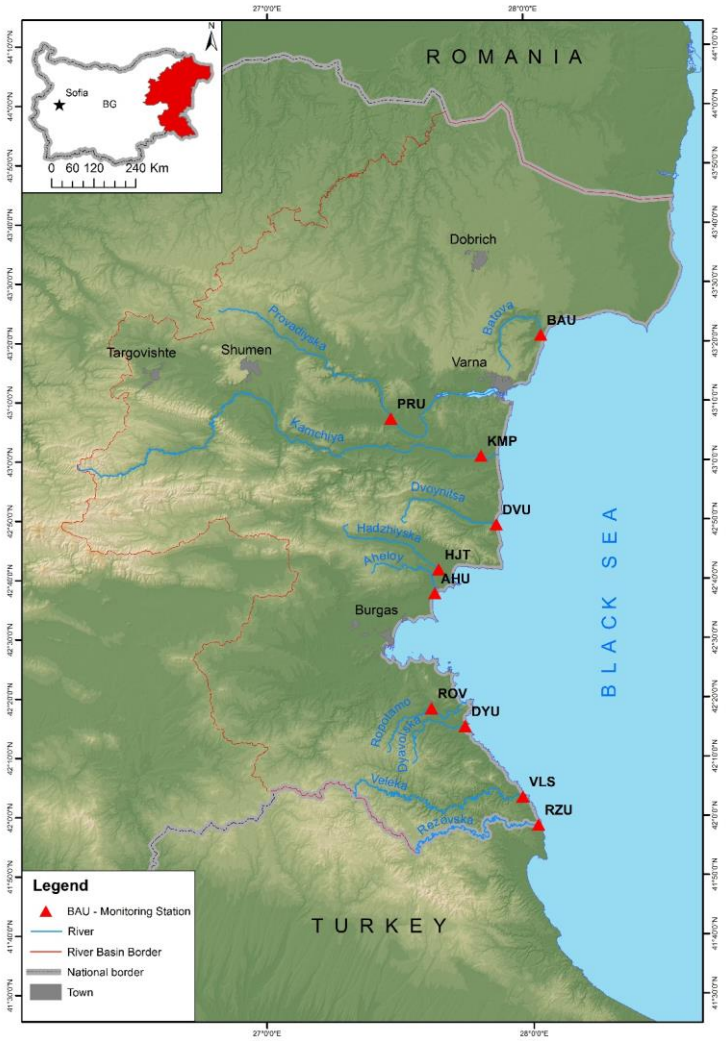

Fig. 1. The study area

The present study is based on the analysis of the values of the indicators: pH, electrical conductivity (EC), dissolved oxygen (DO), ammonium nitrogen (N-NH_4), nitrate nitrogen (N-NO_3), nitrite nitrogen (N-NO_2), total nitrogen (N-Total), total phosphorus (P-Total), orthophosphates (P-PO_4) and BOD_5. To identifying the pollution of heavy metals in the Bulgarian black sea tributaries such parameters as copper (Cu), iron (Fe), manganese (Mn), lead (Pb), arsenic (As), zinc (Zn), cadmium (Cd) and nickel (Ni) were analyzed. The study used verified data for selected points for monitoring the quality of surface waters from the National Monitoring Network in the river basins of the Batova, Provadiiska, Kamciha, Dvoinitza, Hadjiska, Aheloi, Ropotamo, Diavolska, Veleka and Rezovska rivers. The sampling points and their map codes are presented in Table 2.

Table 2. Water quality monitoring stations details in the basins of the Black Sea tributaries used in the study

	Point	Point code	Coordinates		Map code
1	Batova– river – mouth	BG2DO00831MS001	43, 3461	28,0722	BAU
2	Provadiiska – after "Provadsol"	BG2PR00511MS005	43,1259	27,4761	PRU
3	Kamciha river – Poda area	BG2KA00119MS001	43,0198	27,8214	KMP
4	Dvoinitza river- before mouth in Black Sea	BG2SE00041MS003	42,8264	27,8768	DVU
5	Hadjiska river – Tankovo village	BG2SE61MS005	42,7011	27,6553	HJT
6	Aheloi river- Aheloi camping site	BG2SE81MS008	42,6341	27,6405	AHU
7	Ropotamo river- Veselie village	BG2IU291MS003	42,3108	27,6238	ROV
8	Diavolska river- before mouth, town of Primorsko	BG2IU07411MS408	42,26008	27,75058	DYU
9	Veleka river – Sinemorets village	BG2VE00111MS001	42,0605	27,9667	VLS
10	Rezovska river -mouth	BG2RE855MS002	41,9805	28,0246	RZU

Applied methods

Mathematical-statistics and graphical methods have been applied in the current analysis. Nowadays in hydrochemical practice, two approaches are used in assessing water quality by physicochemical indicators - differentiated and complex. A complex approach provides a comprehensive assessment of the quality status of a water body, calculated on the basis of multiple indicators and is expressed as a single result in the form of a score, rank, class. A differentiated approach provides information about the condition of the studied water body by individual indicators [21-25]. In this article a differentiated approach was applied. On the baseline data, the averages and extremes maximum values of the studied indicators were calculated and analyzed.

Results and Discussion

From the analysis it is clear that in the period of research at the point of the Batova River at the estuary exceedances (up to 10 times) of the norms on the indicator's nitrates ($N\text{-}NH_3$), total nitrogen and electrical conductivity were registered. The values of dissolved oxygen generally meet the set criteria, except for 2018, 2019, 2020, when one-time deviations from the reference values were found. The results of the analysis of the content of heavy metals in river waters show that there are no exceedances of quality standards.

The waters of the Provadiyska River at the point after Provadsol are characterized almost continuously by a high content of nitrates ($N\text{-}NH_3$), nitrites ($N\text{-}NO_2$), orthophosphates ($P\text{-}PO_4$), total phosphorus and total nitrogen. The values of these indicators show exceedances of up to 10 times. The deviation of the electrical conductivity indicator is similar. According to the assessment of the average annual values of heavy metals - iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) it is found that only the calculated average annual value for the period on the indicator zinc (Zn) - 8.43µg/L, slightly exceeds the quality standard (8µg/L). The recorded maximum permitted concentrations of cadmium (Cd), lead (Pb) and nickel (Ni) are within the permissible standards.

The results show that in 2015 the Kamchia river in the Poda area is characterized by values of the indicators nitrates ($N\text{-}NH_3$), nitrites ($N\text{-}NO_2$) and total nitrogen exceeding the threshold values up to 10 times. During the other years, one-time deviations from the set criteria are registered according to the same parameters. The calculations based on the average annual value how that only the content of copper (Cu) from 2017 to 2019, although negligible, exceeds the regulatory requirements. For example, the values in 2017, 2018 and 2019 are respectively 1.15, 1.06 and 1.16µg/L. The concentrations of cadmium (Cd), lead (Pb) and nickel (Ni) do not exceed the maximum permissible during the study period.

From the analysis of the qualitative condition of the river Dvoinitsa - before flowing into the Black Sea it is found that during the whole period of research the values of almost all physicochemical parameters do not correspond to the reference values, exceeding up to 10 times. The "jumps" in the readings of ammonium nitrogen ($N\text{-}NH_4$), nitrates ($N\text{-}NO_3$), nitrites ($N\text{-}NO_2$), BOD_5 and orthophosphates ($P\text{-}PO_4$) are stable over time. Episodic cases of discrepancies between the meanings and the normative ones set by the BOD_5 indicator have been registered. The analysis of heavy metal pollution of river waters shows a deviation from quality standards for copper (Cu) and zinc (Zn) from 2015 to 2018. The calculated average annual values of copper (Cu) are respectively 1.56, 2.81, 1.84 and 2.73µg/L and of zinc (Zn) - 28.79, 25.85, 21.94 and 9.75µg/L. Higher concentrations than the normative ones of copper (Cu) and zinc (Zn) also determine the average values, which exceed the standards for the whole research period. The average annual value of copper (Cu) is 1.79µg/L and that of zinc (Zn) is 15.90µg/L.

The waters of the river Hadjiiska near the village of Tankovo are in good quality throughout the six-year research period. The values of nitrites ($N\text{-}NO_2$), orthophosphates ($P\text{-}PO_4$), ammonium nitrogen ($N\text{-}NH_4$), hydrogen, total nitrogen and phosphorus, BOD_5 show one-off exceedances of their regulatory requirements in individual years. According to the results obtained for the content of heavy metals, the average annual values that do not meet the quality standards are in relation to the indicators copper (Cu) (throughout the study period) and zinc (Zn) (2016 and 2017). The concentration of copper (Cu) varies from 4.06µg/L in 2017 to 1.28µg/L in 2020, and these are respectively the highest and lowest average annual value that do not meet regulatory criteria. In 2016, iron (Fe) had an average value of 111.50µg/L and this is the only exceedance of the permissible content (100.00µg/L).

The Aheloy River near Aheloy in the period 2015-2020 has deteriorated in terms of nitrates ($N\text{-}NO_3$), nitrites ($N\text{-}NO_2$) and total N. From 2019, deviations from the limit values are also found in the indicators BOD_5 and dissolved oxygen, in 2020 electrical conductivity indicator also did not meet the "good" quality condition. The values of the indicators listed above exceed the permissible criteria by up to 10 times. The average annual values of copper (Cu) are characterized by exceeding the standards of river water quality during the whole research period. The established maximum value is 4.69µg/L in 2018. The minimum deviation from the permissible concentration was registered in 2020 and is respectively 1.21µg/L.

Insignificant non-compliance with the regulatory requirements for zinc (Zn) was found only in 2015 - 8.10µg/L. No exceedances of the quality standards were found for all other heavy metals subject to analysis and evaluation.

The qualitative characteristics of the waters of the Ropotamo River at the point near the village of Veselie are characteristic episodic values exceeding the allowable (up to 10 times) indicators of nitrites ($N\text{-}NO_2$), orthophosphates ($P\text{-}PO_4$), total phosphorus, BOD_5 and electrical conductivity. Due to this circumstance, the river fully meets the normative criteria for "good" quality status. The calculated values of heavy metals indicate that the quality standards were exceeded only for the copper (Cu) indicator during the study period. The maximum value - 3.89µg/L, which exceeds the permissible concentration (1.00µg/L) was registered in 2017.

The high values (between 10 and 25 times and over 25 times above the norms) of the electrical conductivity indicator determine the deteriorated quality of the waters of the Dyavolska River before the outfall of the Primorsko. The values deviate between 10 and 25 times from the regulated ones during most of the study period. From 2017 to 2019, the limit values were exceeded even more than 25 times. The maximum value – 24 700µS/cm was reported on 09.08.2017. Indications not meeting the norms (up to 10 times above them) of the quality indicators orthophosphates ($P\text{-}PO_4$), total phosphorus and total nitrogen, ammonium nitrogen ($N\text{-}NH_4$) and BOD_5 have been registered.The registrated average annual values of the content of heavy metals indicate small exceedances of the permissible standards (1.00µg/L) only for the indicator copper (Cu) in 2017 (2.75µg/L), and 2018 (2.37µg/L) (Figs. 2 and 3).

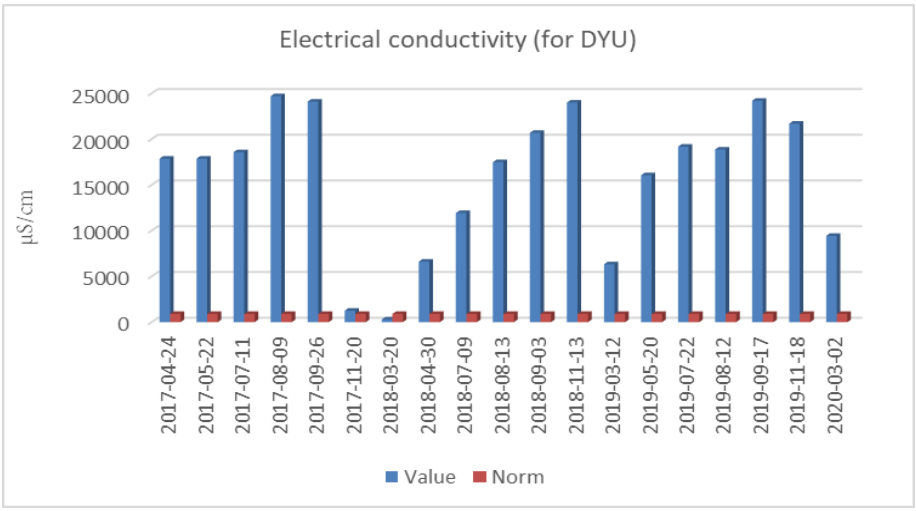

Fig. 2. Change in the values (for the analyzed period) of the EC calculated for the Diavolska River before the mouth

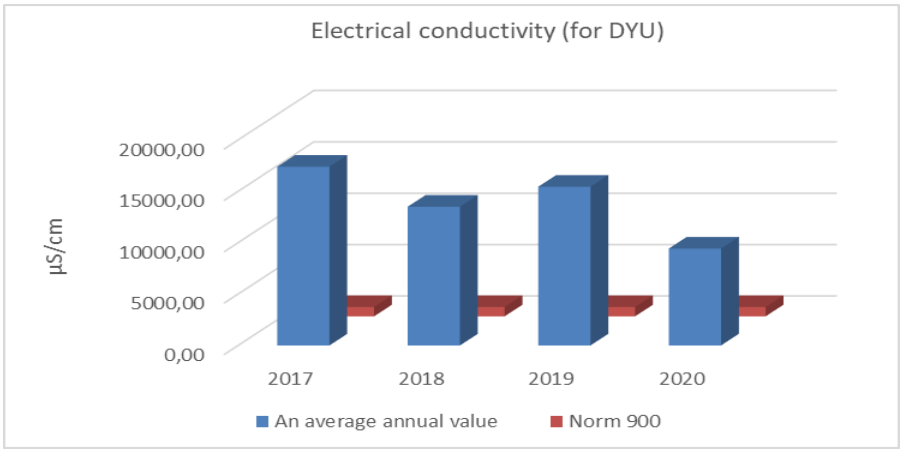

Fig. 3. Change in the average annual values of the EC calculated for the Diavolska River before the mouth

The waters of the Veleka River near the village of Sinemorets meet the criteria for "good" condition throughout 2015 on all studied hydrochemical indicators. In the remaining years including 2020, the river is characterized by single "bounces" - up to 10 times above the norms of electrical conductivity and pH.

The river in this section has deteriorated quality characteristics in terms of copper (Cu) content. In the years (2015, 2017, 2018 and 2020) of the studied six-year period, the average annual values exceed the quality standard for this indicator. The highest concentration of copper (Cu) - 2.03µg/L was reported in 2020. In 2015, the content of iron (Fe), copper (Cu) and zinc (Zn), although in small quantities (122,90µg/L for Fe, 1.84µg/L for Cu and 26.8µg/L for Zn) exceeds the permissible. Manganese concentration (Mn) remains within the normative requirements.

At the point at the mouth of the Rezovska River, the electrical conductivity is the indicator whose registered values show a permanent discrepancy between the threshold values

for acceptable quality of river waters. From the beginning to the end of the analyzed period, the exceedances are usually up to 10 times, but in 2016 and 2017, exceedances between 10 and 25 times were also detected. On 15.08.2016, a maximum value of - 15 650µS/cm was reported. The analysis of the content of heavy metals shows that only in 2015 the average annual value only for iron (Fe) - 119.2µg/L exceeds the statutory value (100.00µg/L). The values of all other heavy metals during the six-year study period meet the river water quality standards (Figs. 4 and 5).

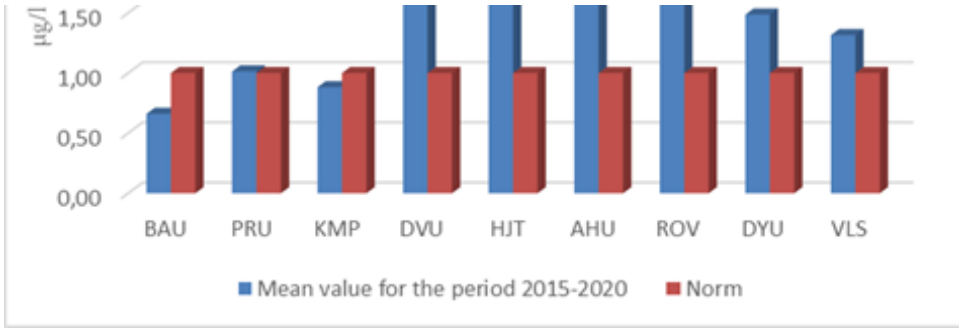

Fig. 4. Change in the values of the Cu concentrations calculated for the studied rivers

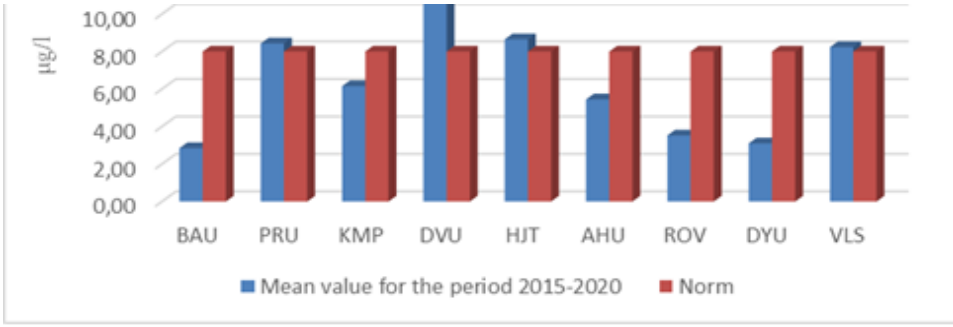

Fig. 5. Change in the values of the Zn concentrations calculated for the studied rivers

As a result of the performed component analysis and assessment of the quality of the waters of the Bulgarian Black Sea tributaries, the following conclusions can be made:

- ✓ For all studied river sections and indicators for river water quality, the exceedances of the norms up to 10 times are predominant.
- ✓ Electrical conductivity is the only indicator for which values exceeding 25 times the norms are found (Dyavolska River before the estuary near the town of Primorsko).
- ✓ The measured values, which most often do not meet the regulatory requirements for "good" status of river waters, are on the indicators - electrical conductivity, nitrates (N-NH_3), nitrites (N-NO_2) and total nitrogen.
- ✓ During the study period, one-off deviations from the normative criteria of the indicators were registered as followed - orthophosphates (P-PO_4), total phosphorus, ammonium nitrogen (N-NH_4) and BOD_5.
- ✓ With most favorable hydrochemical characteristics are the waters of the Veleka River near the village of Sinemorets, and with worst are the waters of Dvoinitsa River at the point before flowing into the Black Sea.
- ✓ Of the studied heavy metals, although insignificant, but relatively constant are the exceedances of quality standards for copper (Cu) and less often for zinc (Zn).

Conclusions

The main problem related to the pollution of the surface waters of the Bulgarian Black Sea tributaries is the discharge - directly or indirectly in the water bodies, of untreated or insufficiently treated wastewater from the settlements. The largest production activities and potential sources of pollution of river waters in the Black Sea basin management region are food and chemical industry, extraction of non-metallic raw materials and production of glass and ceramics. Agriculture and land use are the main sources of diffuse pollutants, with agricultural activities increasing the content of nitrogen, phosphorus, nitrates and phosphates.

On the other hand, the pesticide storage facilities are a possible pollutant with some priority and hazardous substances. A significant diffuse source of river water pollution are the old still operating or non-reclaimed landfills, which do not meet the environmental legal requirements.

They are subject to closure and reclamation (technical and biological). In order to conserve the water quality of the Bulgarian Black Sea tributaries, it is necessary to carry out a set of activities, such as improving the sewerage network in the settlements, construction of wastewater treatment plants, including local ones. Illegal landfills need to be eradicated and old ones repossessed.

Acknowledgments

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