

TIME-SPACE ASSESSMENT OF WATER QUALITY OF MIASS RIVER

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ABSTRACT: The pollution of natural waters, both sea and fresh, is a crucial issue all over the world. Most of the large and small rivers, streams, and reservoirs almost in every federal district of the Russian Federation are characterized as polluted and dirty. The Miass River is one of the main among the large rivers in South Ural. The ecological state of the river is characterised as bad. This work assesses a thirteen-year change of water quality in the Miass River and Argazinskoe and Shershnevskoe reservoirs, which are the source of drinking water for the residential area of the Chelyabinsk region. The river water is used to provide the cities and towns of the region, as well as numerous industrial and farming enterprises with water. Besides, effluents are discharged into the Miass river along its whole length. The results of many years of observation have shown, that heavy metals and biogenic substances are the main pollutants for the river. This work aims to analyse episodes of high and extremely high pollution of the water bodies. Episodes of high and extremely high levels of Cu, Zn and Mn are recorded annually at dam part of Argazinskoe reservoir. Episodes of high and extremely high levels of biogenic elements are recorded for the stretches of the river downstream of Chelyabinsk. Currently, some measures within the project «Clean Water» are planned to improve water quality in the studied water bodies.

Keywords: Rivers, Reservoirs, High Pollution (HP), Extremely High Pollution (EHP)

1. INTRODUCTION

Overland water quality is now one of the crucial environmental issues [1-4]. Many natural factors influence overland water quality, but they are not as significant compared to anthropogenic. One of the most adverse anthropogenic loads is pollution by various substances [5] provided by industrial effluents of metal-mining, metallurgic, metal-processing, paper and board industry, chemical, chemical and biological, pharmaceutical industries, energy sector, and others, as well as local housing and utility sector and farming enterprises.

Overland water pollution is vast in scope. According to the European Environment Agency [6], environment and chemical status of more than half (60 %) of European rivers and lakes on average are not good, despite significant political and management concerns to preserve and restore the environment for the last decades. In some countries, the values are even higher [7]. According to The National Rivers and Streams Assessment of United States Environmental Protection Agency [8], about 46 % of rivers and streams in America are in bad biological condition.

Monitoring is an essential part of

environmental control. Soon after the Water Framework Directive (WFD) was adopted by the EU in 2000, they began to implement its guidelines step-by-step. Monitoring systems now have been substantially transformed [9].

To assess the water quality of water bodies, Russia uses the following terms: «conditionally clean», «slightly polluted», «polluted», «dirty», «extremely dirty». According to the data of 2017 [10,11], most of the large and small rivers, streams, and reservoirs almost in every federal district of the Russian Federation are characterized as «polluted» and «dirty». Water in 10 rivers was assessed as «extremely dirty». The situation with the South Ural (the Chelyabinsk region) water bodies is not better. The Miass River is one of the main among the large rivers in South Ural. The river water is used to provide the cities and towns of the region, as well as numerous industrial and farming enterprises with water (water intake is 90 % of the run-off). Besides, the river is under an adverse anthropogenic impact. Water quality assessment in the Miass River is a very important environmental biomonitoring issue in the Chelyabinsk region.

The current paper aims to assess the changes in water quality in the Miass River for 2006-2019.

2. METHODOLOGY

2.1 Study Area

Numerous rivers belonging to the Ural, Kama and Tobol basins start on the territory of the Chelyabinsk region. The Miass River is one of the largest in South Ural. It coordinates: 54°47'09" N, 59°37'16" E. The river is 658 km long, its catchment area is 21800 km². Within the limits of the Chelyabinsk region, its length is 384 km, and the catchment area is 6830 km². The river flow is regulated with ten reservoirs and ponds [12]. The chemical composition of the river water belongs to the hydrocarbonate class and calcium group and below Chelyabinsk to the sulfate class [10]. The cities of the Chelyabinsk region, such as Karabash, Miass, Chelyabinsk, Kopeisk and Korkino, as well as small settlements of Argayashsky, Sosnovsky, and Krasnoarmeisky districts use the Miass River water [13]. Polluted water runs off into the river along its entire length, but near the cities of Miass, Karabash, Chelyabinsk the river is especially contaminated [10].

The riverhead water is the cleanest, as there is no managed run-off [13]. The river water is directly polluted by surface run-off and indirectly through a tributary where household sewage of an oil pipeline management office is discharged. The sewage includes components containing nitrogen and phosphorus, organic compounds, sulfates, chlorides, petroleum products and suspended solids [12].

The river then flows through the city of Miass, where the water quality is adversely influenced by industrial and household sewage of the city facilities. The sewage here includes suspended solids, petroleum products, minerals, biogenic and organic compounds, metals, fluorine [12].

Downstream, within the limits of the city of Karabash, the Miass River is regulated by Argazinskoe reservoir that gets household and industrial sewage of the city of Miass [14]. The northwest of the water body is especially exposed to pollution [15]. The Sak-Elga River also contributes to the pollution of the Argazinskoe reservoir. It joins the Miass River 3 km upstream of the reservoir. Industrial sewage of the city of Karabash is flown into this tributary of the Miass River. Besides, until 1958, the waste of the copper smelter of Karabash, which is a fine material of aluminosilicate and sulfide composition, was dumped into the floodplain. As a result, a deposit of technogenic soils of about 120 hectares was formed, polluting the water in the Sak-Elga River with heavy metals [16].

Up to the city of Chelyabinsk, the Miass River is regulated by the Shershnevskaya dam [17-19]. There is no managed run-off in the river stretch

from Argazinskoe to Shershnevskoe reservoirs. The river water is polluted by surface run-off [12]. Shershnevskoe reservoir is the only source of household water for the cities of Chelyabinsk, Kopeisk, Korkino, Emanzhelinsk. The water quality in the reservoir is determined by the use of the coastal area for recreational purposes, as well as the indirect discharge of wastewater through the creek of some businesses. Wastewater is composed of biogenic and organic compounds (BOD), mineral salts, petroleum products, suspended solids, manganese [12].

The most adverse impact on the Miass River is downstream of Chelyabinsk where industrial and household sewage is flown.

2.2 Data of Monitoring Chemical Pollution of the Studied Rivers and Reservoirs

To analyze the dynamic pattern of water quality in the Miass river, Argazinskoe and Shershnevskoe reservoirs, the data of monitoring chemical pollution of water-bodies in the Chelyabinsk region given in comprehensive reports on the environment of the Chelyabinsk region were taken. The reports are at open access on the site of the Ministry of Ecology in the Chelyabinsk region [20,21]. The data about the state of water bodies presented on the website of the Chelyabinsk centre for Hydrometeorology and environmental monitoring were also used [22].

The water quality in the Miass River and the reservoirs are monitored monthly. The water is analysed on basic ions, gas composition, biogenic and organic compounds, heavy metals, specific pollutants [12]. Such environmental standards as fishery and hygienic MPC (the most «severe» standards existing in the Russian Federation) were used to assess water quality in the studied water bodies. Table 1 shows MPC values and the criteria of high pollution (HP) and extremely high pollution (EHP) [23].

Table 1 Fishery MPC, HP and EHP criteria

Index	MPC, mg·l ⁻¹	HP, mg·l ⁻¹	EHP, mg·l ⁻¹
Mn	0.01	0.30	0.50
Zn	0.01	0.10	0.50
Cu	0.001	0.03	0.05
Fe	0.10	3.0	5.0
Ni	0.01	0.10	0.50
NH ₄ ⁺	0.40	4.0	20.0
NO ₂ ⁻	0.020	0.20	1.00
PO ₄ ³⁻	0.2	2.0	10.0
COD	15	150	750
BOD ₅	2	10	400
Oil pipeline	0.05	1.5	2.5
Phenols	0.001	0.03	0.05

Cu, Zn, Mn, Fe, Ni, PO_4^{3-} , F^- , NO_2^- , NH_4^+ , COD, BOD_5 , oil pipeline, and phenols belong to the critical indices of water pollution.

The average Ni content was registered 1.1-1.2 times higher than the MPC only in one site in the Miass River in 2012 and 2013 (site 6, downstream Chelyabinsk). F^- content slightly exceeded the standards by 1.2-1.3 times in sites 6 and 7 in 2012. In 2013 this site (site 6) was registered as one where only phenol content two times exceeded MPC for all the period of research.

Increasing levels of Cu, Zn and Mn have been registered in all the sites since 2006 (Fig.2, a-c). These metals content met the environmental security standards only in sites 6 and 7 in 2006-2007. There is no managed run-off on site 1, but there is a constant increase in metal content. South Ural belongs to the territories of natural geochemical anomalies with an increased geochemical background of metal content - Mn, Cd, Zn, Fe, Cu, and others. As a result, the background content of Cu and Zn, for instance, in water usually exceeds fishery standards by 2-3 times, Mn - 12-16 times [12]. Site 3 (the upper pool of Argazinskoe reservoir) is identified as the most adverse in terms of Cu, Zn, and Mn content, as the exceedance of MPC is 24.5, 19 and 47 respectively. Water chemistry here is determined by the pollution introduced by the Sak-Elga River. In some years, the average annual Zn content exceeded the high pollution level (>10 MPC), and Mn was close to an extremely high level (> 50 MPC). However, due to the high self-purification capacity, site 4 (dam storage of Argazinskoe

reservoir) is characterized by reducing metal content by the natural background level. The situation is similar to other sites.

Site 2 is marked as stable low Fe pollution with maximum exceedance of 1.3. Site 3 is more polluted (maximum exceedance is 5.3) (Fig.2,d). Fe content in other sites meets the fishery standards.

Fig.3 shows the average annual exceedance of the content of biogenic elements in the studied water bodies. The maximum content of ammonium, nitrites, and phosphates was found at sites 6 and 7 downstream of Chelyabinsk. Water quality here is exposed to the industrial and household sewage of the city. The average annual nitrites content reaches the level of high pollution (>10 MPC), exceeding the MPC by 12 times, the ammonium nitrogen content exceeds the standards by approximately 4-6 times, phosphates - by 6-7 times.

Fig.4 shows the average annual exceedance of the content of organic substances and petroleum products in the Miass River and Argazinskoe and Shershnevskoe reservoirs. The highest content of easily oxidizable organic compounds (BOD_5) in water is registered at sites 2, 6 and 7, located downstream of the cities of Miass and Chelyabinsk. All the studied sites are characterized by the elevated concentrations of organic compounds resistant to oxidation (COD) with the values of 1.9-3.1 of MPC. Petroleum products are met sporadically, except sites 6 and 7.



Fig.1 Quick map of Miass river, Argazinskoe, and Shershnevskoe reservoirs

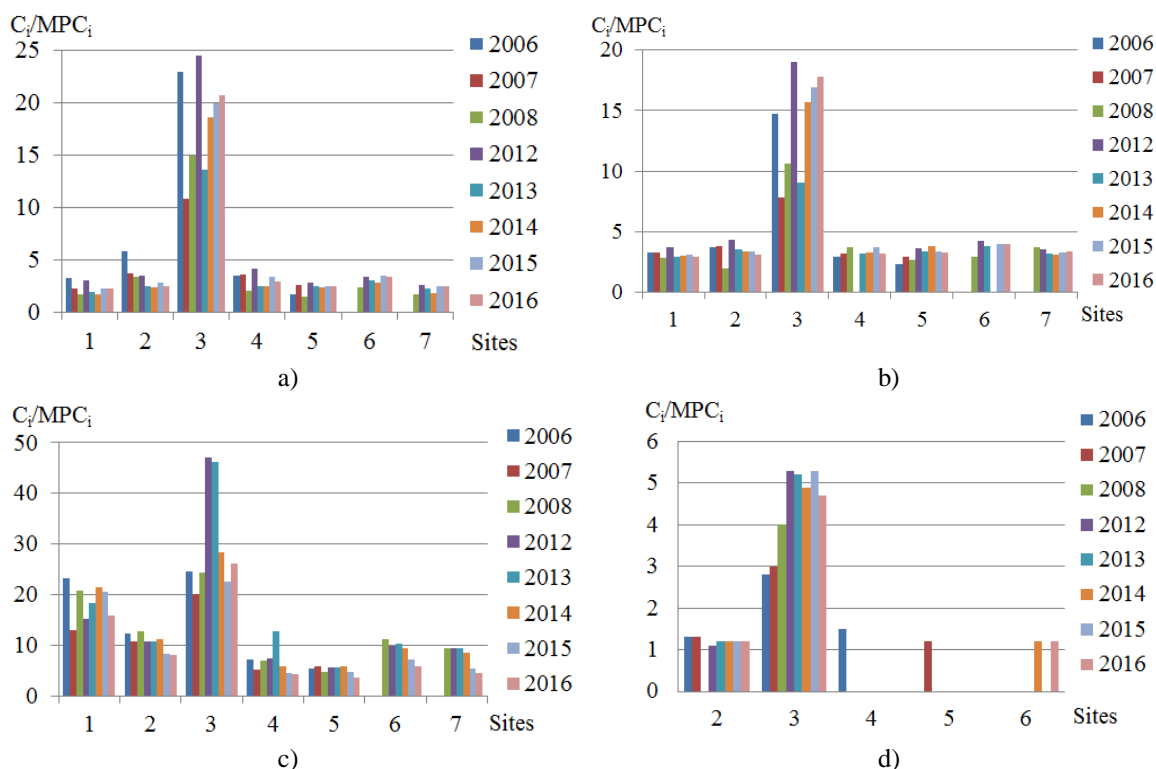


Fig.2 Diagrams of heavy metal content exceedance over MPC: a) Cu; b) Zn; c) Mn; d) Fe

3.2 High and Extremely High Pollution of the Studied Water-bodies and Rivers

Pollution episodes of high and extremely high character with the studied water bodies for 2006-2019 are reported on the site of Chelyabinsk centre for hydrometeorology and environmental monitoring monthly [22].

High and extremely high pollution levels for Mn content were registered in some months (January-April) 1-5 times a year in site 1 (Fig.5). Such a situation could be explained by exceeding natural Mn content, which is typical for South Ural. 2014 is the peak for water pollution, then there is a tendency to decrease both high pollution and extremely high pollution episodes, as well as average exceedance of Mn content over the standards. High pollution levels for nitrites were registered 1-3 times a year in site 2 (downstream the Miass city). Nitrites, products of oxidation of the usual component of household sewage (ammonium), predominate in winter and spring (Fig.6) when self-purification in the river is less intense.

At site 3, high and extremely high pollution was registered for Cu, Zn and Mn (Figs.7,8). For Cu, there is a predominantly high average annual

pollution level (> 30 MPC, Fig.8), episodes of HP occur 1-2 or 5-7 times a year (Fig.7). In 2009-2013, Mn was predominantly frequent in HP and EHP episodes (6-10 times a year) with a further decrease (Fig.7). Up to 2010, high pollution episodes were more frequent, since then water quality was deteriorating, and in 2017-2018 MPC values reached 58 (Fig.8). Moreover, separate episodes of the MPC exceedance by 60-127 times were revealed. The most adverse situation is about Zn content. At the initial stages of monitoring (2006-2009), the exceedance of maximum concentrations of HP and EHP criteria was 3-6 times a year, and it could be defined as a high level of water pollution with Zn (Fig.8). And then such cases became monthly (9-12 times a year) and water pollution level was characterized at that period as extremely polluted (Fig.7). The Sak-Elga River is the main pollutant in this site. The by-pass channel is being built now in the framework of the project «Clean Water» [24]. The channel will divert clean water through the cascades of water bodies into the Argazinskoe reservoir near the city of Karabash. A dam and a storage pond (a hydrobotanic ground) will be built on the territory where the Sal-Elga River runs through the city of Karabash and the dumps of the copper smelter.

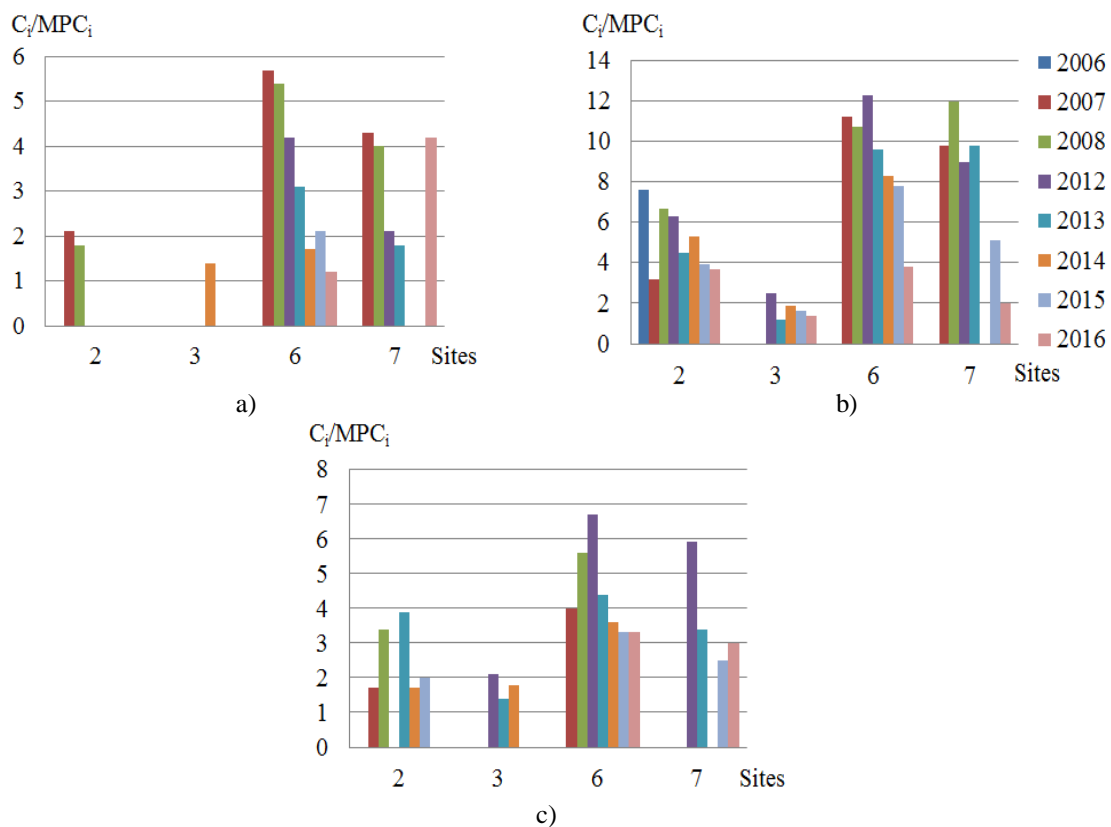


Fig.3 Diagrams of biogenic element content exceedance over MPC: a) NH_4^+ , b) NO_2^- , c) PO_4^{3-}

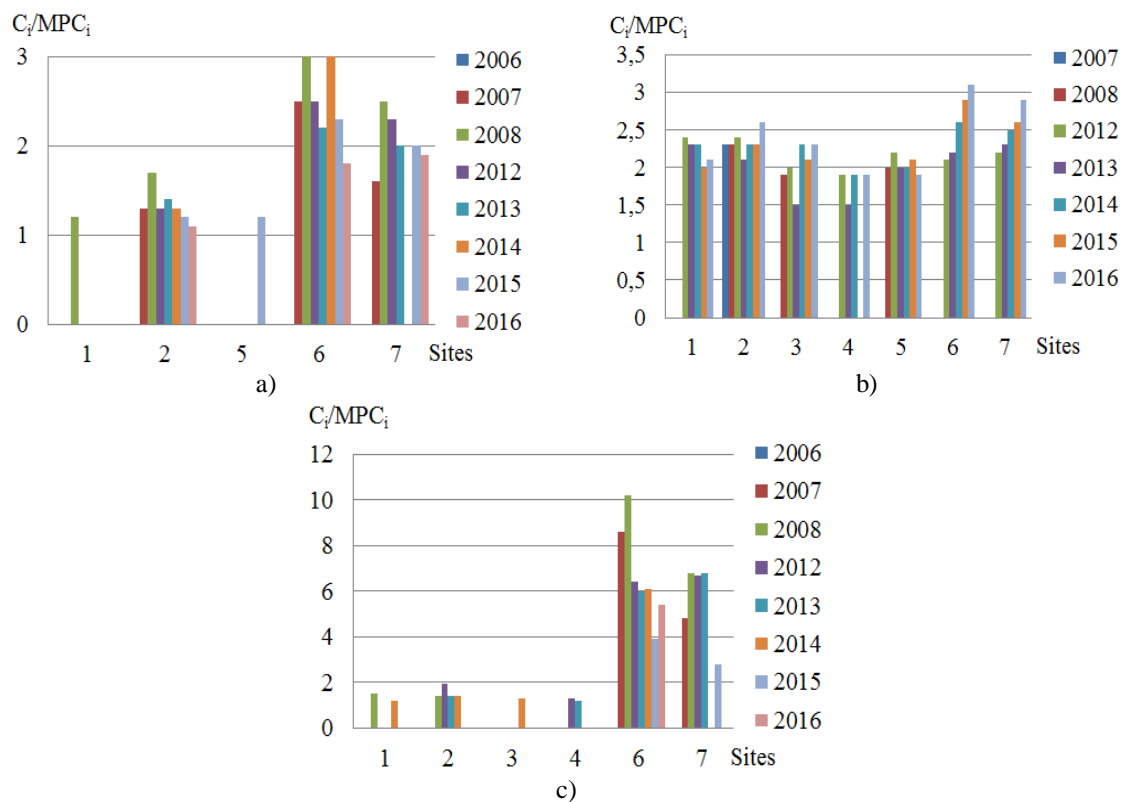


Fig.4 Diagrams of organic substances content exceedance over MPC: a) BOD_5 , b) COD, c) oil pipeline

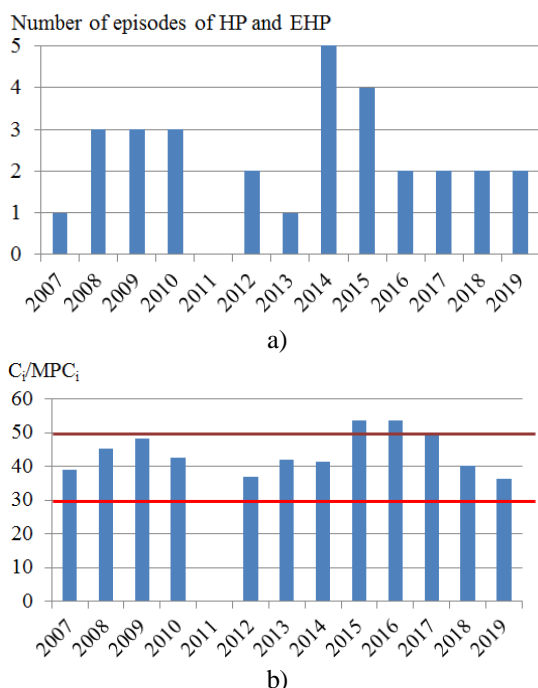


Fig.5 High and extremely high values of water pollution by Mn (s. 1): a) number of episodes of NP and EHP; b) average values of HP (red line) and EHP (brown line)

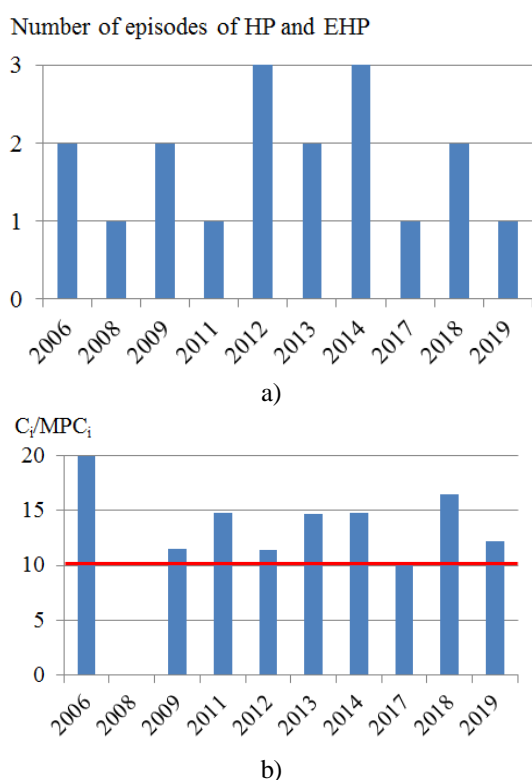


Fig.6 High values of water pollution by nitrites (s. 2): a) number of episodes of HP; b) average values of HP (red line)

4. CONCLUSION

The Miass River and the cascade of Argazinskoe and Shershnevskoe reservoirs are the main sources of water for some cities of the Chelyabinsk region including Chelyabinsk. The river is under a significant anthropogenic impact along all its length. The environment of water bodies has been monitoring for more than 10 years with chemical pollution indices that exceed the environmental security standards being registered. Heavy metals and biogenic substances are the main pollutants for the river.

An increasing Cu, Zn and Mn content in the water has been marked both in the Miass River along its length and in the reservoirs since 2006. The upper pool of Argazinskoe reservoir where the Sak-Elga River very dirty water enters is characterised by the maximum content of the metals. Episodes of high and extremely high levels of these metals are recorded annually at this site.

Constant water pollution by biogenic elements is typical for the stretches of the river downstream of the cities of Miass and Chelyabinsk, which is caused by inefficient industrial sewage treatment before it is run-off into the Miass River. The episodes of HP and EHP by nitrites were registered till 2016-2017. The situation has been improved recently. Currently, some measures within the project «Clean Water» are planned to improve water quality in the studied water bodies. The recommendations for water quality protection: upgrading of the sewage treatment plant, expansion of water protection zones, increase environmental penalties.

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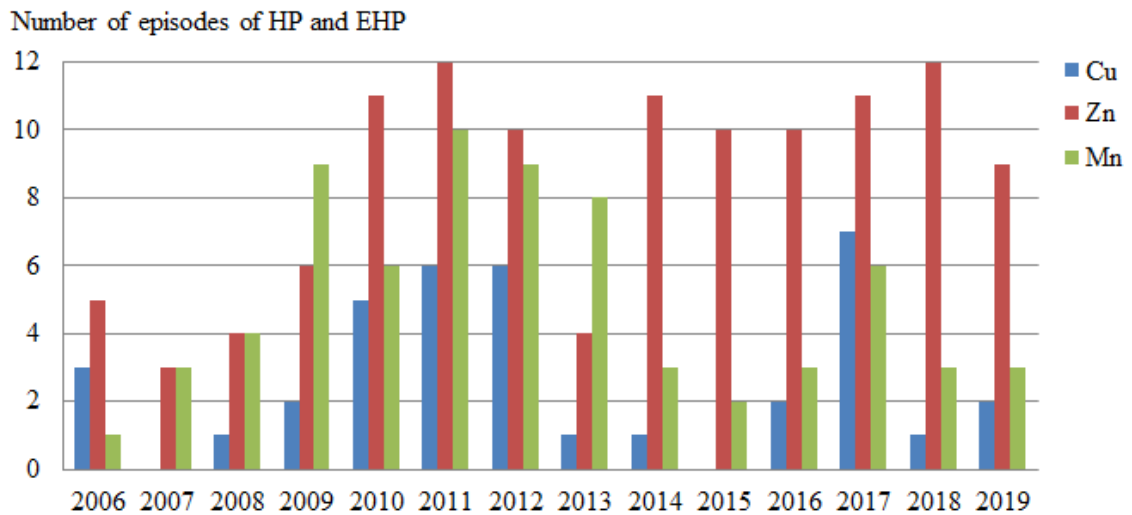


Fig.7 Episodes of HP and EHP by metals (s. 3)

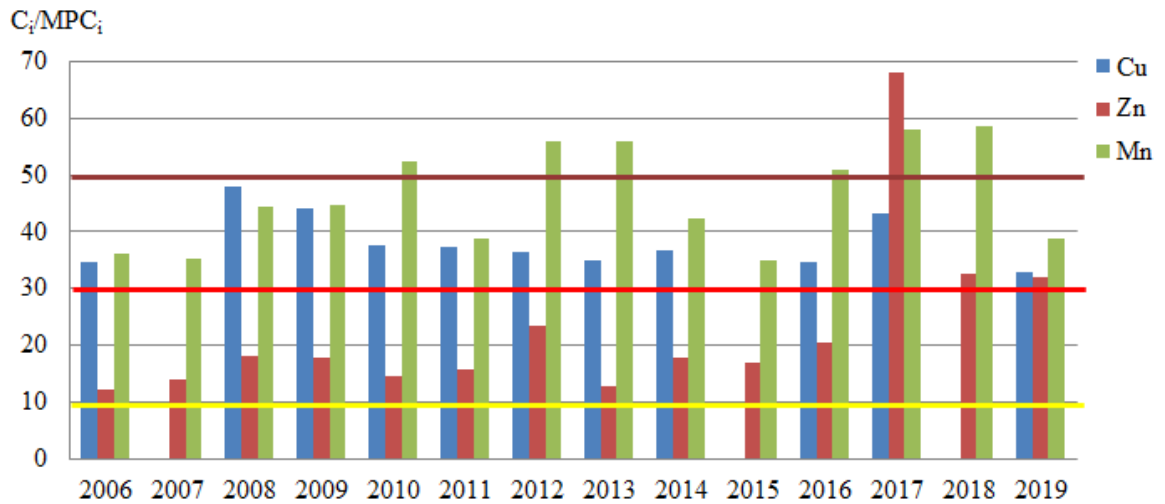


Fig.8 Average values of HP and EHP by metals (s. 3): yellow line - HP level for Zn, red line - HP level for Cu and Mn, Brown line - EHP level for Zn, Cu, Mn

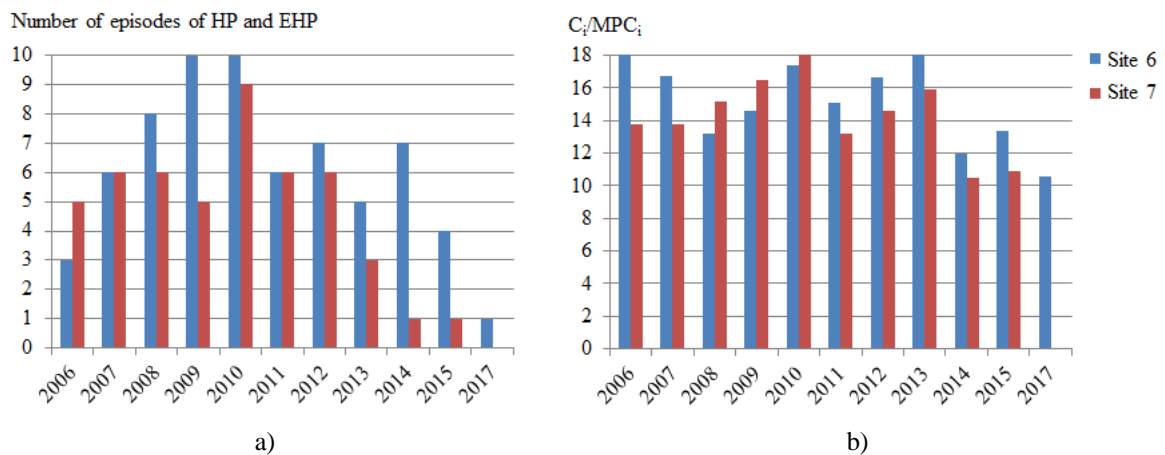


Fig.9 Average HP values by nitrites (sites 6 and 7): red line - HP level

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