Research paper

Hydroecological assessment of the Kazakh part of the Yertis River under conditions of industrial development

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ABSTRACT

This article analyzes the impact of climate in the conditions of industrial development on the flow and ecological condition of the Kazakhstan part of the river Yertis on the territory of East Kazakhstan (EKR), Abay and Pavlodar regions. The research is based on the analysis of data from the meteorological base of the Republican State Enterprise (RSE) «Kazhydromet» for the period from 2019 to 2023. The relationship between air temperature, precipitation and the flow of the river Yertis is shown. The results of the analysis showed that for the last 5 years there is a decrease in the flow of the river Yertis from China and the flow inflow to the territory of Russia. The water quality of the Irtysh River was assessed in the context of administrative regions. Water quality was assessed by 18 hydrochemical indicators in 14 sites on the border with the People's Republic of China in the area of Boran village; above and below major cities - Ust-Kamenogorsk, Semey and Pavlodar; Priirtyshskoye village on the border with the Russian Federation. The results of the assessment of the environmental condition of the Yertis River showed that the most polluted is the section of the river on the territory of East-Kazakhstan region.

1. Introduction

At present, climate change problems all over the world attract the attention of various specialists, including specialists in the field of rational use and protection of water resources. Climate change affects all aspects of water management, human life and has a significant impact on water bodies, especially on transboundary watercourses [1].

At present, the decline in water resources is a problem in the Central Asian region. The impact of climate change on water resources in Central Asia may be crucial for water availability and sustainable development of the countries [2,3].

The transboundary Yertis River is the largest tributary river on the planet, flowing into the Ob River, it forms the largest river system in Russia, the second largest in Asia and the seventh largest on Earth [4].

Currently, the Yertis River is experiencing increased anthropogenic impact. Anthropogenic impacts in the Chinese part of the Yertis River basin include industrial development, mining and agriculture in the Xinjiang-Uygur Autonomous Region, and the implementation of water flow transfer projects [5,6].

In the Kazakhstan part of the basin, anthropogenic impact is caused by wastewater from industrial enterprises, housing and communal services and agriculture in the East Kazakhstan, Abay and Pavlodar regions. In addition, three hydroelectric power plants (HPP) are involved in the Yertis River: Bukhtarminskaya, Ust-Kamenogorskaya and Shulbinskaya. Also, the factor of anthropogenic load changing the hydrobiological regime is water intake from the Yertis River through the Kanysh Satpaev Canal for economic activities. Water from the canal is supplied for water supply to industrial areas and agriculture in Central Kazakhstan, as well as to the Vyacheslav reservoir for water supply to the capital of Kazakhstan.

The Russian part of the Irtysh River basin is represented by the Omsk, Tyumen Oblasts and Khanty-Mansiysk Autonomous Okrug. A large number of small ponds and reservoirs have been created in the Russian part of the Irtysh basin. In the southern part there are centers of metallurgical, oil refining, chemical, machine-building industries. In the south-east there is the largest coal mine, and in the northern part there is oil and gas production [7]. Irtysh water resources are the only source of water supply for the southern agricultural areas and the city of Omsk.

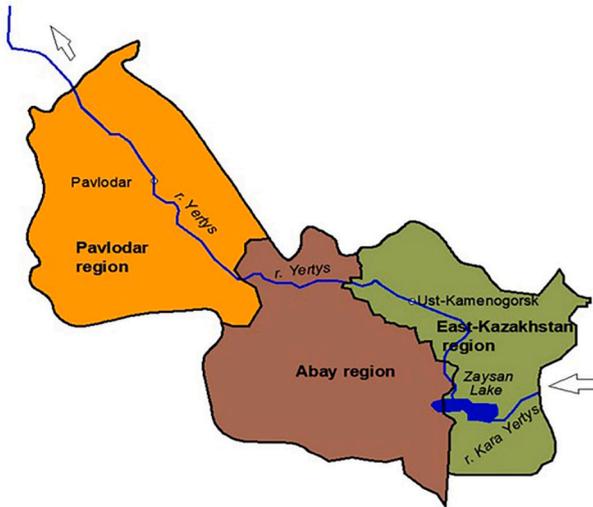**Fig. 1.** Map - scheme of the river basin of the Yertis River.

Fig. 2. Scheme of the Yertis River by administrative regions of the Republic of Kazakhstan.

Thus, the state of the Yertis River determines the ecological situation and plays a huge role in the life of the population of the three countries.

The problems of pollution of the transboundary river Yertis, assessment of the degree of pollution, runoff dynamics under climate change and anthropogenic load are covered in the works of many Kazakh and Russian scientists up to 2018 [8–13].

Comprehensive assessment of surface water runoff dynamics in the Irtysh River basin for the period from 1990 to 2019 in connection with climate change and urbanization was also dealt with by Chinese scientists [14].

The problems of water resources use of the Yertis River in the Russian-Kazakh transboundary region, as well as the impact of economic activity in China are covered in [15].
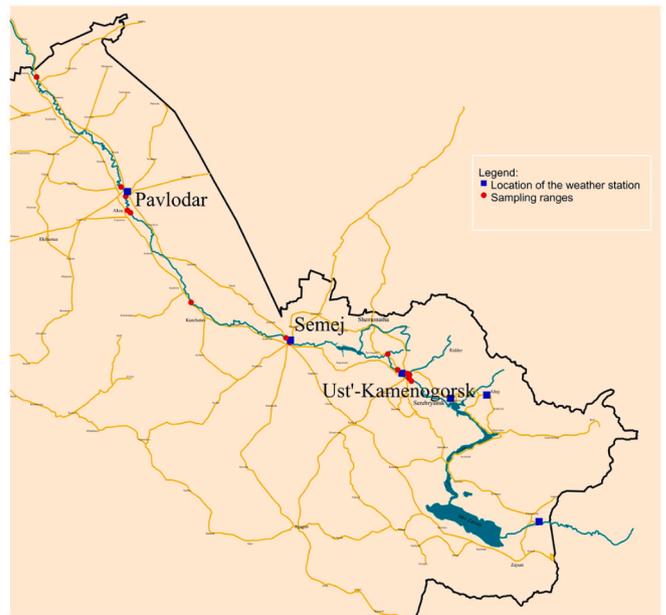
Fig. 3. A map of the location of the weather station and sampling station on the Kazakh part of the Yertis river.

Fig. 4. Graph of dependence of annual precipitation, air temperature and annual water discharge on the river in the section of the meteorological station «Boran».

Fig. 5. Graph of dependence of annual precipitation, air temperature and annual water discharge on the river in the section of the weather station «Zyryanovsk».

Fig. 6. Graph of dependence of annual precipitation, air temperature and annual water discharge on the river in the section of the weather station «Seleznevka».

Fig. 7. Graph of dependence of annual precipitation, air temperature and annual water discharge on the river in the section of the weather station. «Ust-Kamenogorsk».

Fig. 8. Graph of dependence of annual precipitation, air temperature and annual water discharge on the river in the section of the weather station «Semipalatinsk».

An attempt to assess the existing risks and future prospects of the Yertis River from the point of view of the «ecosystem» approach, taking into account political issues, was carried out in [16].

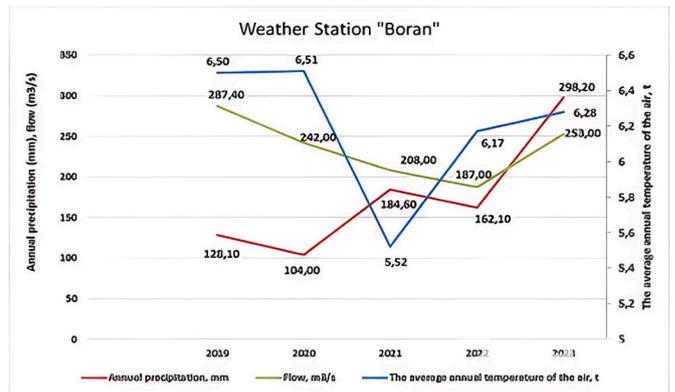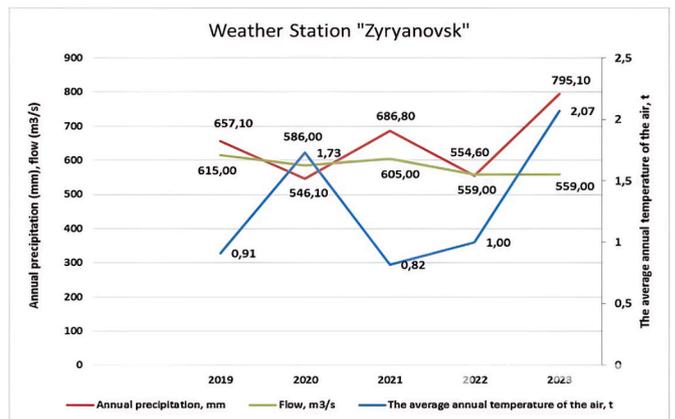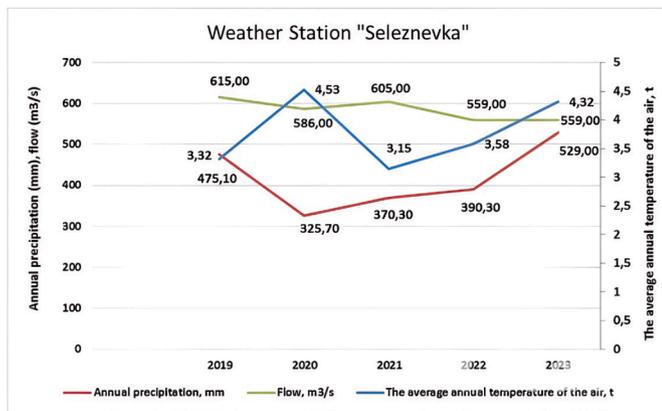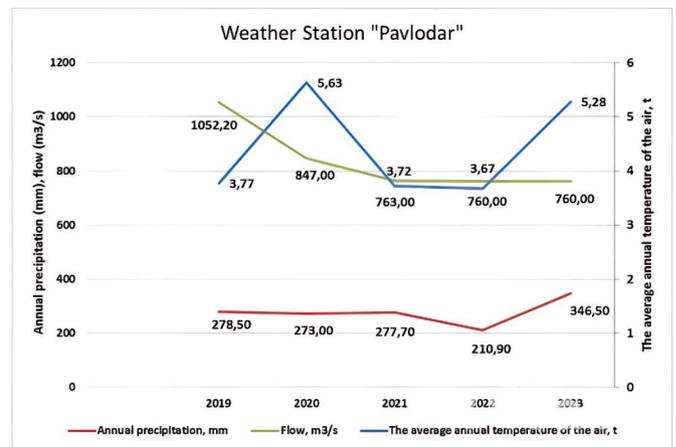The authors also considered the current challenges of natural and

Fig. 9. Graph of dependence of annual precipitation, air temperature and annual water discharge on the river in the section of meteorological station «Pavlodar».
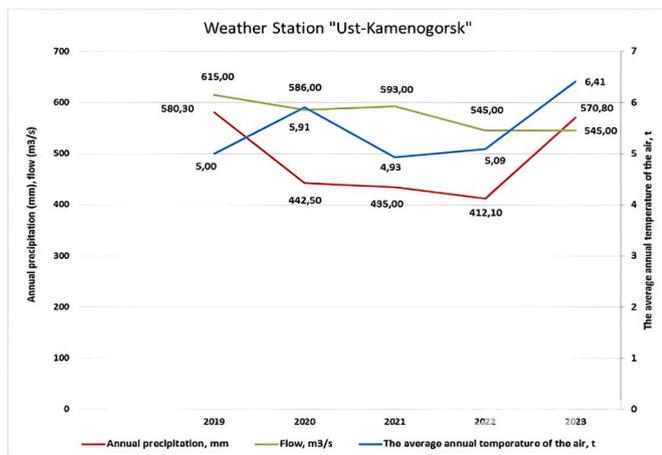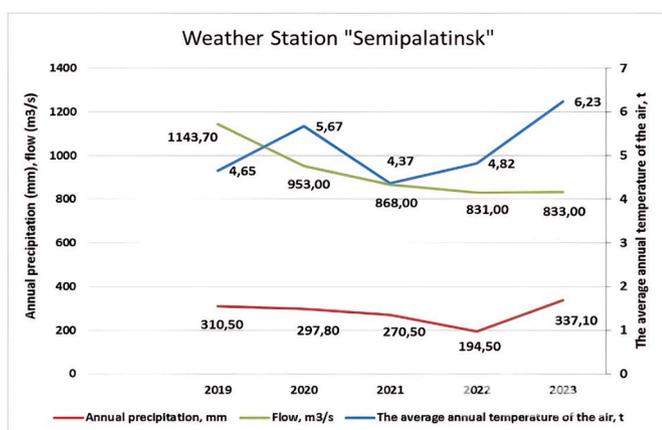
Table 1
Characterization of water use classes.

Quality class	Characterization of water use categories
1	Waters of this water use class are suitable for all types (categories) of water use and correspond to the «very good» class
2	Waters of this water use class are suitable for all categories of water use except for domestic and drinking purposes. Simple water treatment methods are required for domestic and drinking water use
3	Waters of this water use class are undesirable for salmonid fish farming, and more effective treatment methods are required for their use for domestic and drinking purposes. For all other categories of water use (recreation, irrigation, industry) species of this class are suitable without limitation
4	Waters of this water use class are suitable only for irrigation and industrial water use, including hydropower, mining, and hydrotransport. In order to use waters of this water use class for household and drinking water use, intensive (deep) water treatment at water intakes is required. Waters of this water use class are not recommended for recreation purposes
5	Waters of this water use class are suitable for hydropower, mining, and hydrotransportation. Waters of this water use class are not recommended for other purposes

Table 2
Yertis River water quality class for 2019.

Name of water body	Water quality class	Name physical-chemical Substance	Unit of measurement	Physical and chemical content
Kara Yertis River (EKR)	Class 1	–	–	–
Yertis River (EKR)	Class 4	Suspended substances	mg/dm^3	11,2
Yertis River (Pavlodar region)	Class 1	–	–	–

anthropogenic, formal and institutional nature in the transboundary basin of the Yertis River [17].

Thus, taking into account the annual increase in the influence of climatic factors and anthropogenic impact, there is a need to have a scientifically sound assessment of the ongoing changes in the ecosystem of the Yertis River for the last 5 years in terms of water quantity and quality. The results of this assessment can be used to predict possible future changes.

Table 3
Water quality class of the Yertis River for the year 2020.

Name of water body	Water quality class	Name of physical and chemical substance	Unit of measurement	Physical and chemical content
Kara Yertis River (EKR)	Class 1	–	–	–
Kara Yertis River (EKR)	Class 4	Suspended substances	mg/dm^3	8,9
Yertis River (Pavlodar region)	Class 1	–	–	–

Table 4
Water quality class of the Yertis River for the year 2021.

Name of water body	Water quality class	Name of physical and chemical substance	Unit of measurement	Physical and chemical content
Kara Yertis River (EKR)	Class 1	–	–	–
Kara Yertis River (EKR)	Class 4	–	–	–
Yertis River (Pavlodar region)	Class 1	–	–	–

Table 5
Yertis River water quality information for the year 2022.

Name of water body	Water quality class	Name of physical and chemical substance	Unit of measurement	Physical and chemical content
Kara Yertis River (EKR)	Class 1	–	–	–
Kara Yertis River (EKR)	Class 1	–	–	–
Yertis River (Pavlodar region)	Class 1	–	–	–

Table 6
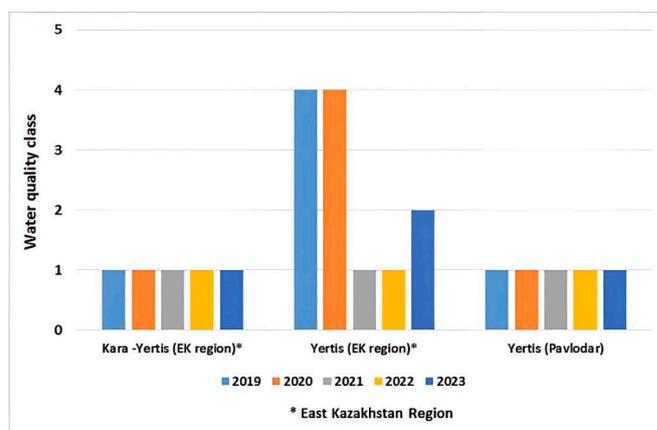Water quality of the Yertis River by quality class indicator for the year 2023.

Name of water body	Water quality class	Name of physical and chemical substance	Unit of measurement	Physical and chemical content
Kara Yertis River (EKR)	Class 2	Manganese	mg/dm^3	0,012
Yertis River (EKR)	Class 2	Manganese	mg/dm^3	0,012
Yertis River (Pavlodar region)	Class 1	–	–	–

The scientific novelty of this work consists in the assessment of the current ecological state of the Yertis River under the conditions of wastewater discharge and climate change impact.

2. Materials and methods

2.1. Study area

The Yertis River is an important water body not only for Kazakhstan,

Fig. 10. Water quality of the river Yertis in the context of administrative regions for 2019–2023.

but also for the entire Eurasia region. The Yertis River originates in China and flows through Kazakhstan and Russia. It is the left and largest tributary of the Ob River. The waters of the Ob and Irtysh flow into the Ob Bay in the Gulf of Kara Sea, which belongs to the Arctic Ocean (Fig. 1).

Up to the confluence with Lake Zaisan the river is called Kara - Yertis, on the rest of the territory of Kazakhstan - the river Yertis, and on the territory of the Russian Federation - the river Irtysh. Ecological monitoring of the river is carried out with the help of hydrological posts.

On the territory of Kazakhstan the river Yertis in the context of administrative regions is conditionally divided into three parts: Kara - Yertis river (East Kazakhstan region (EKR)), Yertis river (EKR), Yertis river (Pavlodar region). Until 2023, the territory of the current Abai oblast was part of the East Kazakhstan oblast (Fig. 2).

In the present study, hydrological and hydrochemical groups of indicators were analyzed, as they are the most widespread in the system of assessments of the ecological state of water bodies.

2.2. Study of the ecological condition of the Yertis River

Next author [8] studied the degree of pollution of the river Yertis for the period 1986 - 2011 with a step of 5 years in the sites: Kara Yertis River - Boran village (within the village); Yertis River - Ust-Kamenogorsk city (0.8 km below the HPP dam); Yertis River - Ust-Kamenogorsk city (22.2 km below the city); Yertis River - Semey city (0.8 km below the discharge from the city treatment facilities); Yertis River - Semey city (4 km above the city); Yertis River - Pavlodar city (0.5 km below the discharge from the municipal treatment facilities); Yertis River - Pavlodar city (22.2 km above the city); Yertis River - Priirtyshskoye village (at the water measuring station). Assessment of pollution degree was based on the combinatorial water pollution index (CWPI). Assessment of water quality in the river Yertis from 1986 to 1990 according to the CPIWI showed a high level of pollution. This is due to the period of most active and stable industrial production activities before the collapse of the USSR. And in the period from 2006 to 2011, the water quality assessment shows moderate level of pollution. This is explained by the modernization of treatment facilities and reduction of harmful discharges into the river Yertis and its tributaries.

Shenberger I.V. continued the study of water quality of the Yertis River in Kazakhstan and analyzed the composition and calculation of CWPI for the period from 1986 to 2015 [18]. Considering the period from 2006 to 2015, the water quality of the river Yertis, by economic - domestic criteria is at the level of «normative – clean», by fisheries – «moderately polluted».

Russian scientists in the article analyze the quality of river water under transboundary water use in different phases of the hydrological

Table 7
Summary table of background concentrations of pollutants in the Yertis River (EKR), mg/l (in the numerator data for 2020–2022 / in the denominator for 2021–2023) [28].

№	Indicators	Background concentrations of pollutants, mg/L			MPC of harmful substances of water of fishery water bodies, mg/l
		Ust-Kamenogorsk city (0.8 km below the HPP dam) - №1	Ust-Kamenogorsk city (0.5 km below the discharge of the Condenser Plant) –№2	Ust-Kamenogorsk city (3.2 km below the Ulbi river, left bank) –№3	
		6579	6854	8286	background+0.25
		6,04	-	7,7	
1	Suspended solids	1537	1506	1673	–
		1,51	1,5	1,6	
2	BOD$_5$	9157	9104	9171	30
		8,97	8,99	9,3	
3	COD	8022	8035	7968	–
		8,03	-	7,98	
4	PH	0,019	0,019	0,025	0,05
		0,014	0,016	0,019	
5	Oil products	6474	6292	10,618	300
		6,4	-	16	
6	Chlorides	22,272	22,58	30,91	100
		23,4	-	37,53	
7	Sulfates	27,432	27,846	32,884	180
		28,7	29,2	35,6	
8	Calcium	7,72	8143	8902	40
		7,6	7,5	8,97	
9	Magnesium	0,123	0,142	0,58	0,5
		0,114	0,137	0,432	
10	Ammonium salts	0,506	0,504	2204	40
		0,492	0,53	2,02	
11	Nitrate nitrogen	0,506	0,504	2204	40
		0,492	0,53	2,02	
12	Nitrite nitrogen	0,005	0,006	0,044	0,08
		0,005	0,006	0,028	
13	Phosphates	0,029	0,02	0,742	0,25
		0,021	0,019	0,55	
14	Total iron	0,023	0,04	0,034	0,1
		0,028	0,04	0,046	
15	Copper	0,002	0,002	0,002	background+0,001
		0,002	0,002	0,002	
16	Zinc	0,005	0,005	0,009	0,01
		0,002	0,002	0,013	
17	Cadmium	0,0003	0,0002	0,0003	0,001
		-	0,0002	0,0003	
18	Manganese	0,006	0,008	0,012	0,01
		0,006	0,007	0,015	

regime of the Irtysh River for the period 1941 – 2018 [19]. River water quality under transboundary water use conditions is subject to changes under the influence of anthropogenic impact from industrial enterprises and deteriorates from the source to the mouth. The analysis showed that in 2017, the water quality of the Irtysh River flowing through the territory of the Republic of Kazakhstan in 79.3 % of samples is assessed as class IV «polluted». The value of specific combinatorial index of water pollution (SCIWP) in the site of Boran village and Ust-Kamenogorsk city is equal to 3.

The paper analyzes water quality at the border posts of the PRC (Boran village) and the Russian Federation (Priirtyshskoye village) from 2020 - 2022 by maximum allowable concentrations (MAC) and CWPI [20]. According to the data of surface water pollution monitoring of the Irtysh River for the study period the river is characterized by «moderate level of pollution».

Along with the water quality of the Irtysh River, scientists also analyzed water levels and water availability forecast.

The paper revealed the regularities of multi-year course of the annual runoff of the left-bank tributaries of the Irtysh River [21]. Based on the analysis, the authors assume that small left-bank rivers will not reach the Irtysh River and will eventually disappear.

Specialists of the National Research Tomsk State University in the works presented an analysis of the regime of maximum water levels of the Irtysh River, floodplain flooding conditions in the flat part of the catchment area and changes in the minimum flow of the Irtysh River,

within the Republic of Kazakhstan for the period from 1959 to 2010 [22, 23]. The work takes into account the operation of the Upper Irtysh cascade of reservoirs. It is shown that the regime of maximum and minimum water levels of the Irtysh River had significant changes compared to the natural regime.

Employees of the Institute of Water and Environmental Problems in the article analyzed the main transboundary problems in the basin, gave a forecast of water availability, water use and ecological state of the Irtysh River in the territory of the Russian Federation until 2030 [24]. According to the authors, as a result of economic activity in a significant part of the Irtysh River basin there was a decrease in surface water quality. In Kazakhstan in 2020, the quality of the river water at different sites varied from class 1 («very good») in Pavlodar region to class 4 («poor quality») in East Kazakhstan region. The main pollutants were suspended solids, iron and manganese.

Vinokurov Yu.I. and Krasnoyarova B.A. considered modern challenges of natural-climatic and civilizational nature in the transboundary basin of the Irtysh River [25]. The challenges are related to both climate change and formal-institutional incompleteness of institutions of ownership of natural resources. The authors conclude that measures are needed to strengthen interstate cooperation between Russia, Kazakhstan and China in the field of protection and use of water resources of the transboundary Irtysh River.

To analyze the dynamics of the Irtysh River runoff under climate change, the authors made a forecast of the expected changes in runoff

Table 8

Summary table of background concentrations of pollutants in the Yertis River (EKR), mg/l (in the numerator data for 2020–2022 / in the denominator for 2021–2023) [28].

N⁰	Indicators	Background concentrations of pollutants, mg/L			MAC of harmful substances of water of fishery water bodies, mg/l
		Ust-Kamenogorsk (3.2 km below the Ulbi River, right bank) –N⁰4	Ust-Kamenogorsk city (Praporshchikovo village) – N⁰5	Ust-Kamenogorsk (Predgornoye village) – N⁰6	
1	Suspended solids	12,035 / 11,1	14,628 / 10,8	11,902 / 12,5	background+0.25
2	BOD$_5$	1712 / 1,7	1514 / 1,6	1532 / 1,6	–
3	COD	10,073 / 9,9	8213 / 8,1	8,32 / 8,3	30
4	PH	7999 / 7,97	7973 / 9,96	8051 / 8,1	–
5	Oil products	0, 024 / 0,019	0,024 / 0,022	0,022 / 0,02	0,05
6	Chlorides	10,685 / 10,1	9516 / 10,1	7299 / 7,1	300
7	Sulfates	25,798 / 28,9	31,705 / 33,3	27,5 / 29,2	100
8	Calcium	32,111 / 32,2	33,169 / 34,6	32,721 / 32,1	180
9	Magnesium	8276 / 7,6	9,21 / 9,2	8927 / 8,3	40
10	Ammonium salts	0,174 / 0,185	0,19 / 0,243	0,192 / 0,196	0,5
11	Nitrate nitrogen	0,985 / 1,1	1148 / 1,37	0,944 / 0,932	40
12	Nitrite nitrogen	0,015 / 0,012	0,009 / 0,013	0,007 / 0,008	0,08
13	Phosphates	0,159 / 0,029	0,027 / 0,027	0,028 / 0,028	0,25
14	Total iron	0,126 / 0,138	0,098 / 0,115	0,085 / 0,09	0,1
15	Copper	0,002 / 0,003	0,002 / 0,003	0,005 / 0,006	background +0,001
16	Zinc	0,026 / 0,032	0,015 / 0,0135	0,062 / 0,063	0,01
17	Cadmium	0,001 / 0,0008	0,0004 / 0,0004	0,0005 / 0,001	0,001
18	Manganese	0,021 / 0,018	0,019 / 0,015	0,023 / 0,015	0,01

under the influence of climate change in the Kazakhstan Altai region from 1936 to 2017 [26]. The authors of the work state that the total flow of the Irtysh River across the catchment area in the period up to 2030 will decrease by 10 %, and in the period up to 2040 the flow will increase by 10 – 15 %, returning to normal. This is explained by changes in precipitation. The authors conclude that the problem of the Irtysh River basin is not in the expected decrease in runoff due to global warming, but in the increasing water withdrawal. They also note the lack of proper accounting and scientific substantiation of all components of the water balance.

The staff of the Institute of Geography carried out water management calculations. Retrospective (1980…1989, 1990…1999, 2000…2010 and 2010…2015) and forecast water balances were drawn up [27]. According to the authors' forecasts, in 2030…2040, some water users within Kazakhstan will start to experience water deficit in the Yertis River basin. It is also expected to reduce the flow to the Russian Federation. In the following years, the intensification of intensive development of water consumption in the flow formation zone (China) and in the middle reaches (Kazakhstan) is the worst-case scenario, when water scarcity will be aggravated by 2050.

2.3. Data and methods used to assess the ecological status of the Yertis River

Assessment of the ecological status of the Yertis River was carried out by analyzing the flow and water quality for the period 2019 - 2023 for 8

hydrological sites of meteorological stations («Boran», «Zyryanovsk», «Seleznevka», «Ust-Kamenogorsk», «Semipalatinsk», «Pavlodar») of the observation network. These sites are located on the territory of East Kazakhstan, Abay and Pavlodar regions.

Studies of flow dependence of the Yertis River are based on the statistical method of analyzing data from the meteorological database of RSE «Kazhydromet» (air temperature, precipitation, annual water discharge) [28].

Assessment by water quality class was carried out according to the information bulletin on the state of the environment of the Republic of Kazakhstan of the Department of Environmental Monitoring of RSE «Kazhydromet» [28].

Water quality studies were based on the data of background information of the site of RSE «Kazhydromet» [28]. Water quality was assessed by 18 hydrochemical indicators: suspended solids, BOD$_5$, COD, pH, oil products, chlorides, sulfates, calcium, magnesium, ammonium salts, nitrate nitrogen, nitrite nitrogen, phosphates, total iron, copper, zinc, cadmium, manganese. Background concentrations of pollutants on the Yertis River sites up to 2020 in the database of RSE «Kazhydromet» are not available.

Analysis of the obtained data, study of the relationship between climatic, hydrochemical indicators and the amount of runoff was carried out using graphical methods.

Table 9

Summary table of background concentrations of pollutants at the Yertis River sites in Abay and Pavlodar regions, mg/l (in the numerator data for 2020–2022 / in the denominator for 2021–2023) [28].

№	Indicators	Background concentrations of pollutants, mg/L				MAC of harmful substances of water of fishery water bodies, mg/l
		Semey city (4 km above the city) – №7	Semey city (3 km below the city) –№8	Mayskoye village (Pavlodarsk region) – №9	Aksu city (3 km upstream of SDPS* waste water discharge –№10	
1	Suspended solids	6,4	6528	11,052	11,226	background+0.25
		6,4	6,7	10,3	10,6	
2	BOD$_5$	2144	2282	1727	1745	–
		2,1	2,2	1,7	1,7	
3	COD	8398	9,12	8881	8744	30
		8,6	9,3	9,6	9,5	
4	PH	7809	7763	8028	8003	–
		7,7	7,7	8,1	8,03	
5	Oil products	0,015	0,018	0,016	0, 017	0,05
		0,015	0,017	0,016	0,016	
6	Chlorides	9179	9533	8,1	6,93	300
		9,3	9,7	8,5	6,9	
7	Sulfates	27,642	27,04	30,454	29,433	100
		26,02	26,3	30,3	29,6	
8	Calcium	29,24	29,947	28,688	28,215	180
		29,5	30,2	28,3	27,7	
9	Magnesium	8,56	7819	7034	7155	40
		7,97	7,5	7,01	6,99	
10	Ammonium salts	0,119	0,197	0	0,167	0,5
		0,087	0,125	0	0,192	
11	Nitrate nitrogen	1356	1496	0,296	0,25	40
		1,3	1,3	0,267	0,196	
12	Nitrite nitrogen	0,012	0,013	0,01	0,009	0,08
		0,01	0,011	0,014	0,012	
13	Phosphates	0,097	0,113	0,019	0,02	0,25
		0,071	0,086	0,02	0,02	
14	Total iron	0,069	0,07	0,067	0,07	0,1
		0,067	0,07	0,067	0,07	
15	Copper	0,002	0,003	0,002	0,002	background +0,001
		0,003	0,004	0,002	0,002	
16	Zinc	0,007	0,008	0,002	0,002	0,01
		0,007	0,009	0,002	0,0017	
17	Cadmium	0,0001	0,0003	0	0	0,001
		0,0002	0,0003	0	0	
18	Manganese	0,012	0,015	0,004	0,004	0,01
		0,011	0,014	0,004	0,004	

SDPS* - State district power station.

3. Results

3.1. Analysis of changes in annual precipitation, average annual air temperature and annual river discharge

The study examined precipitation dynamics and temperature changes, and graphically showed the relationship between climatic factors and the flow of the Irtysh River. Studying the dependence of climatic changes and runoff was carried out on the river Yertis in the section of weather stations «Boran», «Zyryanovsk», «Seleznevka», «Ust-Kamenogorsk», «Semipalatinsk» and «Pavlodar».

Fig. 3 shows the map - scheme of location of the weather station and sampling sites in the Kazakhstan part of the Ertis River basin.

Figs. 4-9 show graphs of dependence of annual precipitation, average annual air temperature and annual water discharge of the river Yertis for the last 5 years.

Fig. 4 shows data on the meteorological station «Boran».

At the weather station «Boran», the graph shows that the annual precipitation increases every year. From 2019 - 2020, there was a decrease in annual precipitation from 128.1 to 104.0 mm (decreased by 18.8 %). From 2020, a spike was noticed to 184.6 mm in 2021 (increased by 77 %). From 2021 to 2022 there was no significant decrease in annual precipitation and from 2022 to 2023 there was a sharp increase in annual precipitation from 162.1 to 298.2 mm (increased by 83.9 %). There was an average 12 % decrease in annual streamflow from 2019 to 2022 and an increase of 35.3 % from 2022 to 2023. The average annual

temperature was between 5.52 and 6.51 °C (an increase of 0.99 °C).

Fig. 5 shows data on the weather station «Zyryanovsk».

At the weather station «Zyryanovsk», the graph shows that in the period 2019 - 2020 there was a decrease in annual precipitation from 657.1 to 546.1 mm (decreased by 17 %). From 2020 increased to 686.8 mm in 2021 (increased by 20.4 %). From 2021 to 2022, there was a decrease in annual precipitation from 686.8 to 554.6 mm, and from 2022 to 2023, there was an increase in annual precipitation from 554.6 to 795.1 mm (increased 43.4 %). There was an observed annual change in river discharge from 2019 to 2021 by an average of 5 % and no significant change was observed from 2022 to 2023. The average annual temperature was between 0.91 and 2.07 °C (an increase of 1.16 °C).

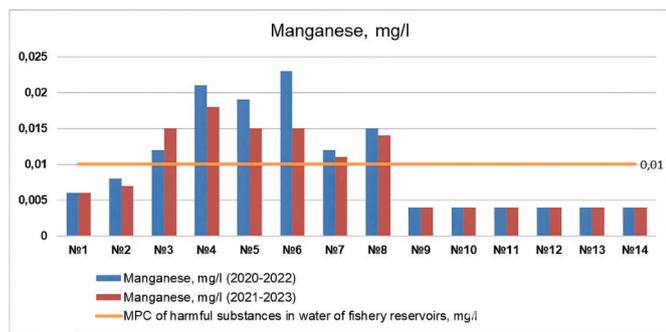Fig. 6 shows data on the weather station «Seleznevka».

At the weather station «Seleznevka», the graph shows that in the period 2019 - 2020 there was a decrease in annual precipitation from 475.1 to 325.7 mm (decreased by 31.4 %). From 2020 increased to 370.3 mm in 2021 (increased by 13.7 %). There was a slight increase in annual precipitation from 2021 to 2022, and from 2022 to 2023 there was an increase in annual precipitation from 390.3 to 529.0 mm (increased 35.5 %). There was an observed annual change in river discharge from 2019 to 2021 by an average of 5 % and no significant change was observed from 2022 to 2023. The average annual temperature was between 3.15 and 4.32 °C (an increase of 1.17 °C).

At the weather stations «Zyryanovsk» and «Seleznevka», which are located in mountainous areas, the air temperature is lower and the annual precipitation is higher.

Table 10
Summary table of background concentrations of pollutants at the Yertis River sites in Abay and Pavlodar regions, mg/l (in the numerator data for 2020–2022 / in the denominator for 2021–2023) [28].

№	Indicators	Background concentrations of pollutants, mg/L				MAC of harmful substances of water of fishery water bodies, mg/L
		Aksu city (0.8 km downstream of SDPS wastewater discharge) – №11	Priirtyshskoye village - №12	Pavlodar city (22 km above Pavlodar city) – № 13	Pavlodar city (1 km below Pavlodar city) – №14	
1	Suspended solids	0	0	0	0	background+0.25
		0	0	0	0	
2	BOD$_5$	1839	1779	1702	1,82	–
		1,8	1,7	1,7	1,8	
3	COD	9209	9654	8841	9449	30
		9,95	10,5	9,5	10,1	
4	PH	8004	8056	8005	8,05	–
		8,04	8,1	8,04	8,08	
5	Oil products	0,018	0,017	0,017	0,017	0,05
		0,017	0,017	0,016	0,016	
6	hlorides	7,32	7988	6965	7866	300
		7,4	8,2	7,1	7,7	
7	Sulfates	30,128	30,265	28,964	30,276	100
		29,9	30,9	28,9	31,1	
8	Calcium	28,296	28,566	28,02	28,75	180
		27,8	28,3	27,4	28,1	
9	Magnesium	7131	7666	7085	7614	40
		7,2	7,4	6,9	7,8	
10	Ammonium salts	0,171	0,183	0,162	0,179	0,5
		0,186	0,196	0,184	0,2	
11	Nitrate nitrogen	0,253	0,273	0,247	0,276	40
		0,207	0,456	0,208	0,24	
12	Nitrite nitrogen	0,01	0,009	0,009	0,01	0,08
		0,013	0,016	0,012	0,014	
13	Phosphates	0,02	0,023	0,02	0,024	0,25
		0,021	0,024	0,021	0,026	
14	Total iron	0,07	0,067	0,066	0,069	0,1
		0,069	0,065	0,066	0,069	
15	Copper	0,002	0,002	0,002	0,002	background +0,001
		0,002	0,002	0,002	0,002	
16	Zinc	0,002	0,002	0,002	0,002	0,01
		0,002	0,002	0,002	0,002	
17	Cadmium	0	0	0	0	0,001
		0	0	0	0	
18	Manganese	0,004	0,004	0,004	0,004	0,01
		0,004	0,004	0,004	0,004	

Fig. 11. Comparative analysis of the background concentration of manganese in the water of the Yertis River with the fishery MAC.
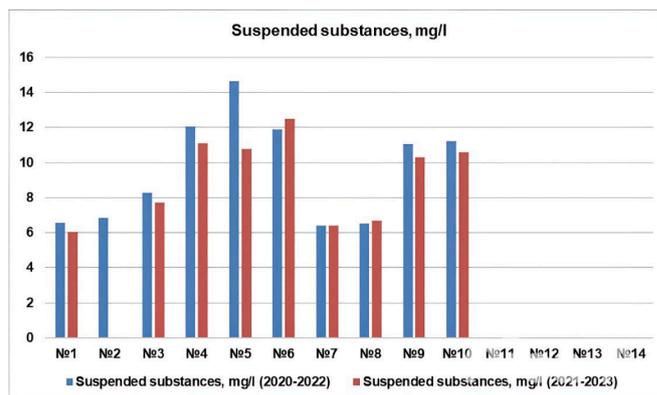
Fig. 12. Analysis of the background concentration of suspended solids in the water of the Yertis River.

Fig. 7 shows data on the weather station «Ust-Kamenogorsk».

At the weather station «Ust – Kamenogorsk» the graph shows that in the period 2019 - 2020 there was a decrease in annual precipitation from 580.3 to 442.5 mm (decreased by 23.7 %). From 2020 there was a slight decrease to 435.0 mm in 2021. From 2021 to 2022, there was also a similarly slight decrease in annual precipitation, and from 2022 to 2023, there was an increase in annual precipitation from 412.1 to 570.8 mm (increased by 38.5 %). There was an annual decrease in annual streamflow from 2019 to 2021 with an average decrease of 6.4 %, and no change was observed from 2022 to 2023. The average annual

temperature was between 5.00 and 6.41 °C (an increase of 1.41 °C).

Fig. 8 shows data on the weather station «Semipalatinsk».

At the weather station «Semipalatinsk» the graph shows that in the period 2019 - 2020 there was a decrease in annual precipitation from 310.5 to 297.8 mm (decreased by 19.6 %). From 2020 there was a slight decrease to 270.5 mm in 2021. From 2021 to 2022 there was a decrease in annual precipitation to 194.5 (decreased 28.1 %) and from 2022 to 2023 there was an increase in annual precipitation from 194.5 to 337.1
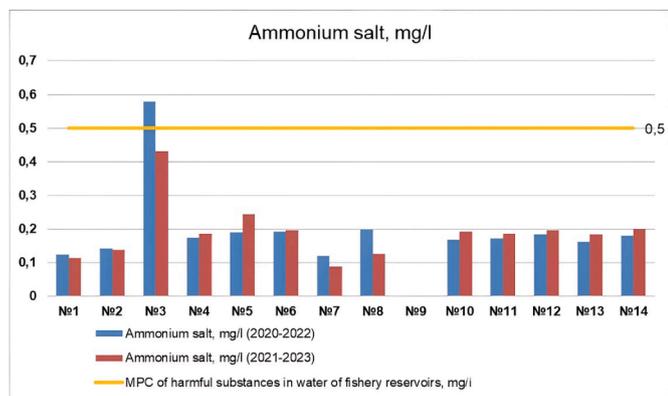
Fig. 13. Comparative analysis of background concentration of salt ammonium in water of the river Yertis with fishery MAC.
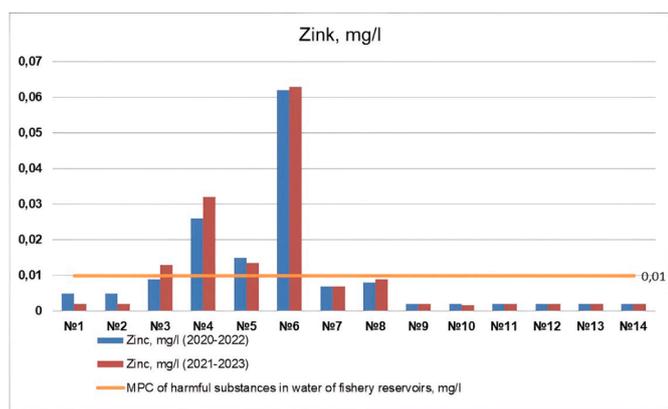

Fig. 14. Comparative analysis of background zinc concentration in the water of the river Yertis with fishery MAC.
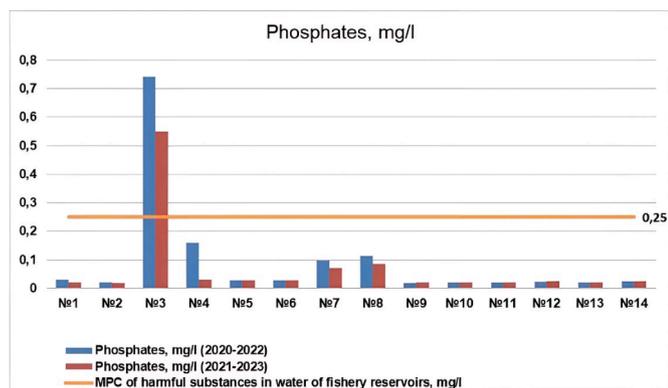

Fig. 15. Comparative analysis of background phosphate concentration in the water of the river Yertis with fishery MAC.

mm (increased 73.3 %). There was an annual decrease in stream discharge from 2019 to 2022 with an average decrease of 9.9 % and an increase of 0.24 % was observed in 2023. The average annual temperature was between 4.65 and 6.23 °C (an increase of 1.48 °C).

Fig. 9 shows data for the weather station «Pavlodar».

At the meteorological station «Pavlodar» on the graph shows that in the period from 2019 - 2021 values of annual precipitation is uniform and ranged from 273.0 to 278.5 mm. From 2021 to 2022 there was a sharp decrease in annual rainfall from 277.7 to 210.9 mm (decreased by 24 %) and from 2022 to 2023 there was an increase in annual rainfall

from 210.9 to 346.5 mm (increased by 64.3 %). There was an annual decrease in river discharge from 2019 to 2023 with an average decrease of 9.93 %. The average annual temperature was in the range of 3.77 - 5.28 °C (increase of 1.51 °C).

All weather stations show a decrease in annual discharge of up to 10 % and an increase in air temperature of >1 °C.

3.2. Water quality assessment of the Yertis River

The main normative document for assessing the water quality of water bodies of the Republic of Kazakhstan is the «Unified system of classification of water quality in water bodies» (hereinafter - Unified Classification) [28]. The Unified System of Classification of Water Quality in Water Bodies (hereinafter - the Classification) is divided into five water use classes with gradual transition from the 1st class of waters of «best quality» to the 5th class of «worst quality». Characteristics of water use classes according to the «Unified system of water quality classification in water bodies» of the RK are presented in Table 1.

Tables 2 through 6 below summarize the water quality class of the Yertis River under the Unified Classification for the years 2019 through 2023.

Tables 2 and 3 show that water quality in the rivers Kara Yertis (EKR) and Yertis (Pavlodar region) belongs to class 1, and the river Yertis (EKR) to class 4 and exceeded MAC for suspended solids.

As can be seen from Tables 3 and 4, in comparison with 2020, water quality in the Kara Yertis River (EKR), Yertis River (Pavlodar region) has not changed significantly, and the Yertis River (EKR) has improved (transition from class 4 to class 1).

As can be seen from Tables 4 and 5, compared to 2021, water quality in the Kara Yertis (EKR) and Yertis rivers has not changed significantly and belongs to class 1.

As can be seen from Table 6, in comparison with 2022, water quality in the Yertis River has changed. The water quality in the Kara Yertis and Yertis Rivers (EKR) has gotten worse. It used to be very clean (class 1) but now it's moderately polluted (class 2). Tests also showed higher-than-allowed levels of manganese in the water.

The summary analysis on water quality of the Yertis River by administrative regions for 2019–2023 is presented in Fig. 10.

The water quality class in the Kara Yertis River (EKR) and Yertis River (Pavlodar) in the period from 2019 to 2023 was - 1. The water quality class in the Yertis River (EKR) in 2019 and 2020 is 4, in 2023 is 2, and in 2021 and 2022 is 1.

Further analysis was conducted to determine pollutants (marker pollutants) at all sites located on the Yertis River. Tables 7, 8, 9 and 10 present data on background concentration and MAC of harmful substances of water of fishery water bodies for 18 indicators of pollutants of the Yertis River.

Based on the data of Tables 7, 8, 9 and 10 graphs on background concentration of pollutants in the river Yertis exceeding the values of MAC of harmful substances of water of fishery water bodies, mg/l are constructed (Figs. 11-15).

Fig. 11 presents a comparative analysis of background concentration of manganese in the water of the river Yertis with MAC of fishery water (MAC$_{fw}$).

Data analysis (Fig. 11) shows exceedance of MAC$_{fw}$ = 0.01 mg/l in the following sites: Ust-Kamenogorsk city (3.2 km below the Ulbi River, left bank); Ust-Kamenogorsk city (3.2 km below the Ulbi River, right bank); Ust-Kamenogorsk city, Praposhchikovo village); Ust-Kamenogorsk city (Predgornoye village); Semey city (4 km above the city); Semey city (3 km below the city, 0.8 km below the wastewater discharge from the city treatment facilities).

Fig. 12 shows the graph of background concentration of suspended solids.

Fig. 13 presents a comparative analysis of the background concentration of saline ammonium in the water of the Yertis River with the fishery MAC.

Data analysis (Fig. 13) shows exceedance of $MAC_{fw} = 0.5$ mg/l in the site of Ust-Kamenogorsk town (3.2 km below the Ulbi River, left bank).

Fig. 14 shows a comparative analysis of background zinc concentration in the water of the Yertis River with fishery MAC.

Data analysis (Fig. 14) shows exceedance of $MAC_{fw} = 0.01$ mg/l in the following sites: Ust-Kamenogorsk town (3.2 km below the Ulbi River, right bank); Ust-Kamenogorsk town (Praposhchikovo village); Ust-Kamenogorsk town (Predgornoye village).

Fig. 15 presents a comparative analysis of background phosphate concentration in the water of the Yertis River with fishery MAC.

Data analysis (Fig. 15) shows an exceedance of $MAC_{fw} = 0.25$ mg/l at the site of Ust-Kamenogorsk town (3.2 km below the Ulbi River, left bank).

According to the results of analysis of data in Table 7 and Figs. 11-15, an exceedance of the following pollutants was detected in the river Yertis: manganese, nitrite nitrogen, saline ammonium, zinc, phosphates mainly at the sites of Ust-Kamenogorsk town (3.2 km below the Ulbi River, left and right banks). These exceedances are explained by the influence of the right tributary of the Ulbi River, into which wastewater is discharged by such industrial enterprises as: Ust-Kamenogorsk Titanium and Magnesium Plant JSC (Joint-Stock Company); «Ulba Metallurgical Plant» Joint-Stock Company («UMP» JSC); LLP «Kazzinc», Ust-Kamenogorsk metallurgical complex.

4. Discussion

The analysis of the results showed that in the period from 2019 - 2023, for all weather stations there is a decrease in annual water discharge within up to 10 % and an increase in air temperature by >1 0C.

In general, this phenomenon is confirmed and coincides with the forecasts of the authors in [26], which states that in the period up to 2030 there will be a decrease in total runoff by 10 %. According to the forecast of the same authors, the next decade, in the period up to 2040 runoff will increase by 10–15 %, returning to normal.

Analysis of the results obtained on the basis of data from Kazgidromet posts showed that the excess of polluting components is observed in the territory of East Kazakhstan region, where a significant share of mining and metallurgical industry of non-ferrous metals is concentrated. On the territory of Pavlodar region, where metallurgy and energy enterprises are also located, water quality in the river Ertis is higher. This is due to the fact that industrial wastewater is discharged into the waste accumulator 'Balkyldak'.

Thus, the environmental problem for the Irtysh River is the increasing anthropogenic load associated with the industrial development of the region. This is explained by increasing water withdrawal from the river by industrial and agricultural enterprises, inefficient use of water resources in water supply and irrigation systems.

5. Conclusion

The article considers the dynamics of changes in temperature, annual precipitation and their impact on the flow of the river Yertis for the period from 2019 to 2023. The instability of the water balance of the Yertis basin due to a decrease in river runoff (decrease in annual water flow from 5 to 9.93 %) is noted. In addition, there is an increase in air temperature by >1 °C.

The performed review of statistical data on water quality of the Yertis River for the last years allowed to identify the most polluted sections of the Yertis River: nitrite nitrogen content exceeds in the site of Ust-Kamenogorsk city (3.2 km below the Ulbi River, left bank);

- zinc content exceeds in three sites: Ust-Kamenogorsk town (within the town limits, 3.2 km below the confluence of the Ulbi River, right bank); Ust-Kamenogorsk town (within the limits of the village of Praporshchikovo, 15 km below the confluence of the Brazhy Creek);

Predgornoye village (within the limits of the village of Predgornoye, 1 km below the confluence of the Krasnoyarka River);
- manganese content exceeds in six sites: Ust-Kamenogorsk town (3.2 km below the Ulbi River, left bank); Ust-Kamenogorsk town (3.2 km below the Ulbi River, right bank); Ust-Kamenogorsk town, Praporshchikovo village); Ust-Kamenogorsk town (Predgornoye village); Semey town (4 km above the town); Semey town (3 km below the town, 0.8 km below the wastewater discharge of municipal treatment facilities).
- The phosphate content exceeds in Ust-Kamenogorsk town (3.2 km below the Ulbi River, left bank);
- ammonium salt content exceeds in the site of Ust-Kamenogorsk town (3.2 km below the Ulbi River, left bank).

Mainly the excess of polluting components is observed in the site of Ust-Kamenogorsk city (3.2 km below the Ulbi River) and it is explained by the location of treated wastewater outlets of such industrial enterprises as: Ust-Kamenogorsk Titanium and Magnesium Plant JSC (Joint-Stock Company); «Ulba Metallurgical Plant» Joint-Stock Company («UMP» JSC); LLP «Kazzinc», Ust-Kamenogorsk metallurgical complex.

The results of this study can be further used to solve the problem of sustainable management of water resources of the Yertis River.

CRediT authorship contribution statement

Valentina Kolpakova: Supervision, Methodology. **Yuliya Yeremeyeva:** Writing – original draft, Conceptualization. **Samal Anapyanova:** Visualization, Data curation. **Gulnaz Mamyrbekova:** Investigation. **Roza Nurekenova:** Visualization. **Laura Utepbergenova:** Data curation. **Zhanbolat Shakhmov:** Writing – review & editing. **Aleksej Aniskin:** Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The data that contributed to the findings and conclusions of this study are available upon reasonable request from the authors.

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