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TEMPORAL CHANGES IN HYDROCHEMICAL REGIME OF TRANSBOUNDARY IRTYSH RIVER

Burlibajewa D. M., Opp Ch., Kirwiel I. **Zmiany reżimu hydrochemicznego transgranicznej rzeki Irtysz**. Irtysz płynie przez obszar trzech państw: Chińskiej Republiki Ludowej, Republiki Kazachstan i Federacji Rosyjskiej. Stanowi największy dopływ rzeki Ob. Obecnie ważnym zagadnieniem jest nie tylko ilość wody w tej rzece (Irtyszu), ale przede wszystkim jej jakość. Zatem przedstawiono charakterystyki współczesnych zmian reżimu hydrochemicznego rzeki Irtysz. W analizach uwzględniono szeregi obserwacyjne o zróżnicowanych długościach: 1) punkt Boran – 1941–2009 r. (ogólna mineralizacja wody), 1963–1996 r. (chemiczne zużycie tlenu), 1976–2009 r. (metale ciężkie); 2) punkt Semej (dawny Semipałatyńsk) – 1965–2010 r. (ogólna mineralizacja wody), 1965–1996 r. (chemiczne zużycie tlenu), 1984–2009 r. (metale ciężkie); 3) punkt Semijarka – 1957–1996 r. (ogólna mineralizacja wody), 1963–1996 r. (chemiczne zużycie tlenu), 1968–1996 r. (metale ciężkie).

Бурлибаева Д. М. Опп Х., Кирвель И **Временная динамика гидро-химического режима трансграничной реки Иртыш**. Река Иртыш течет по территории трех стран: Китая, Казахстана и Российской Федерации. Является самым большим притоком Оби. В настоящее время существенным вопросом выступает не только количество воды в Иртыше, но – прежде всего – ее качество. Так, в данной статье даются характеристики современного состояния изменений гидрохимического режима реки Иртыш. Для анализа взяты ряды наблюдений различной протяженности: 1) с. Боран – 1941–2009 гг. (общая минерализация воды), 1963–1996 гг. (химическое потребление кислорода), 1976-2009 гг. (тяжелые металлы); 2) г. Семей – 1965–2010 гг. (общая минерализация воды), 1965–1996 гг. (ХПК), 1984–2009 гг. (тяжелые металлы); 3) с. Семиярка – 1957–1996 гг. (общая минерализация воды), 1963–1996 гг. (ХПК), 1968–1996 гг. (тяжелые металлы).

Key words: hydrochemistry, hydrochemical regime, the Irtysh river, Kazakhstan
Słowa kluczowe: hydrochemia, reżim hydrochemiczny, rzeka Irtysz, Kazachstan
Ключевые слова: гидрохимия, гидрохимический режим, река Иртыш, Казахстан

Abstract

The Irtysh river flows through the territories of three countries: People's Republic of China, the Republic of Kazakhstan, and the Russian Federation. The Irtysh river is a major tributary of the Ob river. Therefore, not only a question of quantity, but especially quality of water is very important at present time. In this paper changes in hydrochemical regime of the Irtysh river are presented. River sections of varying lengths are taken for analyses: 1) the village of Boran, in 1941–2009: total dissolved salts (TDS), in 1963–1996: chemical oxygen demand (COD), in 1976–2009: heavy metals; 2) city of Semey – in 1965–2010: TDS, in 1965–1996: COD, in 1984–2009: heavy metals, 3) Semiyarka village – in 1957–1996: TDS, in 1963–1996: COD, in 1968–1996: heavy metals.

INTRODUCTION

Ecology of the present time is a complex of different sciences, because environmental problems are very difficult, and include relations between systems of living organisms and inanimate nature.

Chemical processes are the basis of life, to control the dynamic equilibrium of the biosphere, it is necessary to understand chemical processes occurring in different systems (CHIBISOVA, DOLGAN, 1998).

At present hydrochemical studies have become one of the most important parts of environmental survey in the context of domestic activities. Water quality control and its future condition prediction are the main aims of environmental protection policy.

Physico-geographical characteristics of the Irtysh river basin

Relief

Kazakhstan part of the Altai mountains has mainly mountainous relief with a great variety of surface forms and very complex orographic structure.

Orographic structure of this territory represents folded mountainous region with altitudes from 200 to 4500 m a.s.l. The right bank of the Irtysh river is characterized by general rise of ridges and bottom of valleys from the NW to E and SE to the main mountain sites of the Altai. The western (left) part is characterized by gradual rise of altitude – from hills and low mountain areas of Kazakh rolling (undulated) country in the north and west to midland and mountainous relief in the south. The other characteristic feature of the landscape is domination of mountain ranges that are oriented to the W and NW.

The five geomorphological regions in the western part of the area (the left bank of the Irtysh river) may be distinguished:

1) hills of Kazakh rolling (undulated) country,
2) Chingiz-Tau and Saur-Tarbagatai ridges,
3) Zaisan depression,
4) the Irtysh territory plain,
5) Kalbinsky ridge.

Hills region is located in the NW part of the area. The surface of this region has been formed by weathering of ancient mountain ranges up to the plain stage, with small mountains and hills. Low (500–600 m a.s.l.) hills, often grouped into ridges, alternate with isolated low raises and vast plains.

In the NE hills smoothly change to the Irtysh plain and in the SW are surrounded by low mountain range of Chingiz-Tau.

Chingiz-Tau range is a horst rise of Kazakh undulated country. It extends from the NW to SE for more than 200 km, and stands up above surrounding terrain at 500–600 m a.s.l. (abs. height up to 1 150 m). The structure of the ridge is asymmetric – the NE slopes are highly dissected and steep, and the SW consist of three hollow steps. Kanchingiz parallel ridge moves away from Chingiz-Tau to the north, and Akshatau ridge (1 300 m a.s.l.) – to the south. The whole Chingiz-Tau range is characterized by alternation of low linear mountains and hills, separated by wide valleys. In the SE Chingiz-Tau is connected with Tarbagatai ridge by the hill zone.

Saur-Tarbagatai ridge is located in latitudinal direction in the extreme south of territory and enters into it only by the northern slopes. This middle-mountain massif of extensive Chiliktinskaya valley (1 000–1 400 m a.s.l.) is divided into ranges of Tarbagatai and Saur. The predominant altitude of monolithic Tarbagatai ridge is 2 000–2 500 m a.s.l., and only in the central part its height increases up to 3 000 m.

The highest point of Saur range is Mustau mountain (3 816 m a.s.l.) located in the eastern part. In the centre altitudes are 2 200–3 000 m, and to the west they are lower (1 800–2 000 m). In the NW from the Saur low ridge Manrak is separated by the Uidene river valley.

Zaisan hollow is a vast depression surrounded by the mountains of Southern Altai, Saur-Tarbagatai and Calba. Its borders are clearly expressed in the north and south. To east a continuation of the valley is a vast valley of the Black Irtysh river, and to west it smoothly passes into hills of the Central Kazakhstan. The depression has a character of flat plains (abs. altitude of Zaisan lake is 380 m). The surface is slightly sloping to the center of the hollow, where Zaisan lake is located. Endorheic hollows, occupied by ephemeral salt or swamped lakes are also present here.

The Irtysh plain. This area is characterized by low undulate or hilly relief and low altitudes (mostly less than 200 m abs.). Closed dish-shaped endorheic depressions occupied by small lakes are often found here. There are lots of sandy ridges separated by wide shallows. To the north the Irtysh plain smoothly changes into Kulundinskaya steppe, and its continuation to the SE is the Altai foothills.

Kalbinsky ridge is the left continuation of the Altai mountain ranges. To the east it gets behind Narymsky ridge like coulisses, it's a cause of a deep bend of the Irtysh river valley. Next the ridge stretches in latitudinal direction to the Char river valley, where it deviates to the NW and ends with a series of low ridges 40–60 km from the Irtysh river.

To the E and S of Kalba there are numerous mountain ranges of the Altai. Five types of geomorphological landscapes are clearly distinguished on the Altai territory by the nature of the terrain and other natural features:

1) high Alpine landscape with developed glacial forms
2) ancient peneplain or ancient surfaces of flattening;
3) middle-mountain erosion relief;
4) low-mountain erosion relief;
5) intermontane valleys and foothills with a predominance of accumulative relief forms.

The Southern Altai is an area of intensive lifting and tectonic faulted, in huge trough of it there are valleys of the rivers Narym and upper part of Bukhtarma. The mountains go down to the SW and end by a sharp bench 30–40 km from the Black Irtysh river. Sarymsakty, Tarbagatai, Narym ridges enter this territory by southern slopes.

Climate

Part of the Altai Mts on the territory of Kazakhstan characterized by continental climate. Due to its remoteness and isolation by mountain systems the warm and humid air masses from the Atlantic Ocean are transformed, and arrive here with loss of the most humidity. Air masses from the Arctic Ocean are cold and dry. Hills and plain areas of the left bank of the Irtysh river are especially dry. The western, northern peripheral and central highlands of the Altai are characterized by the highest humidity. The Altai climate is generally much milder, than in the neighbouring areas, the ummer is cool and the winter is relatively warm.

Air temperature. The average annual air temperature varies from -3.0 to -3.6°C in the SW plain areas close the large water reservoirs (lakes Teletskoye and Zaisan), to -6 to -7°C in mountainous areas. In plain, foothills, and low-mountain areas the increase of average annual air temperature from the N to S, and from the E to the W may be observed.

The summer in most parts is warm in spite of relatively low average temperature of all the territory. The average temperature of the warmest month (July) everywhere (except high mountains) exceeds 15°C, reaching 20–22°C in dry steppes and semi-deserts of the SW and W areas.

In the summer temperature gradually decreases with altitude. Temperature gradient in July for mountainous areas is -0.5 to -0.7°C per 100 m. The average July temperature does not exceed 6–10°C near to the glaciers. In mountain steppes July temperature amounts to 13–15°C.

The coldest month is January. The distribution of January temperature depends on macrocirculation factors and relief. In the W and SW of the territory winter is slightly warmer, than in the other parts. The average January temperature ranges here from –14 to -19°C.

Precipitation. Orography and altitude have great influence on the precipitation distribution in the Altai Mts and the Upper Irtysh. Rainfall is the most evenly distributed in flat areas of Irtysh plain, Zaisan depression and Kazakh hills. Its quantity on the slopes of Chingiz-Tau, Kalbinski ridge, and Saur-Tarbagatai greatly changes depending on the altitude and orientation of slopes.

Average annual precipitation in the Kazakh hills and Irtysh plain amounts to 250–300 mm for multiannual period, and in Zaisan depression – is 180–200 mm. In most raised parts of Chingiz-Tau northern slope annual precipitation can reach up to 350 mm, and in Saur-Tarbagatay it increases from 300 mm in foothills to 500–600 mm in the middle mountain belt and high mountains.

Relation between precipitation in liquid and solid form changes with increasing altitude of the area – on flat parts rainfall dominates, and at altitudes above 3100–3400 m only snow falls.

Monthly maximum of precipitation is observed mostly in June or July. However there is a specific feature of this territory – the second maximum (Zaisan depression, Southern Altai) that can exceed the summer one.

Number of days with precipitation increases with rise of altitude and in plain and foothill areas – from the SW to NE.

Snow cover is ditributed unevenly. It is due to low precipitation in the winter on plain, hilly areas, and intermontane depressions. At the same time there is a lot of snow on mountain slopes. Snow transfer by wind also plays significant role.

The first snowfalls and unstable snow cover in the NW areas are observed in October, in the NE foothill areas appear in September, and in the Altai highlands – in the late August–early September. The stable snow cover is formed, as a rule, around 20–30 days later. Duration of stable snow cover varies from 135–150 days in lowland, low mountainous, and hilly areas to 170 days in the NE foothills of Altai.

The greatest thickness of snow cover is equal 16–20 cm (plain areas of the Upper Irtysh and Altai), whereas in winters with little snow it is only 3–5 cm.

Hydrography

The area is characterized by developed hydrographic network. The main waterway is the Irtysh river. All rivers belong to the basin of the Kara Sea.

Lakes and artificial reservoirs constitute a significant element of the landscape. The largest lakes are Markakol, Teletskoye, and Zaisan; artificial seas (reservoirs) are Bukhtarma and Ust-Kamenogorsk.

Swamps are relatively rare because geographical conditions of the East Kazakhstan are not propitious for swamp formation. They are rarely found in highlands of the Altai, in floodplains and river deltas.

Glaciers are typical element in the landscape of the Altai and Saur Mts. In Altai, and Saur-Tarbagatay there are many snow patches. Total number of glaciers exceeds 300, area of glaciation amounts to almost 100 km^2 and volume of ice reaches 4 km^3 the East Kazakhstan.

Hydrographic structure of the river network of Kazakhstan part of the Altai Mts is result of river network of Kazakhstan part of the Altai Mts is most sparse hydrographic network (0.10–0.15 km/km^2).

Kazakh hills transit sections of rivers and shallow riverbeds of occasionally functioning watercourses are present, whereas in Zaisan depression and Irtysh plain there are many dry riverbeds, gullies and arheic depressions filled by drying lakes.

In Chingiz-Tau, Tarbagatai, and Saur slopes density of river network increases to 0.40–0.50 km/km^2 with altitude growth, number of rivers with constant water flow also rises.

The Irtysh river is the largest river in Kazakhstan, and it is the Chingiz-Tau, Tarbagatai, and Saur slopes density of river network increases to 0.40–0.50 km/km^2 with altitude growth, number of rivers with constant water flow also rises.

The Irtysh river is the largest river in Kazakhstan, and it is SW slopes of the Mongolian Altai (China), and before flowing into Zaisan lake is named the Black Irtysh. The total length of the Irtysh river is 4 248 km; length of the Black Irtysh amounts to 672 km, length of the Irtysh river from lake Zaisan to inflow to the Ob river – 3 501 km. The total area of the Irtysh river basin is 1 595 000 km^2. On Kazakhstan territory the Irtysh river (Black Irtysh) flows as high-water river (average annual water discharge is around 300 m^3/s), in Semey city point the discharge trebles to 900 m^3/s. It should be noted that about 90% of the water volume increase of the Irtysh river is because of the right-bank tributaries flowing down from the mountain ranges of Kazakhstan Altai. The largest right-bank tributaries are: Bukhtarma, Ulba and Uba.

Fig. 1. Irtysh river basin and location of researched hydrochemical points on the Irtysh river:
1 – Black Irtysh river – the village of Boran, 2 – Irtysh river – city of Semey (4 km above the city), 3 – Irtysh river – Semiyarka village

Rys. 1. Dorzecze Irtysza i lokalizacja hydrochemicznych punktów badawczych na rzece:
1 – Czarny Irtysz – wioska Boran, 2 – Irtysz – miasto Semej, 3 – Irtysz – wioska Semijarka

Data on major rivers of the Irtysh basin (average annual water flow rate greater than 5 m^3/s) are presented in table 1.

Reservoirs on the Irtysh river. The Irtysh river basin is one of the largest industrial and agricultural areas of the Republic of Kazakhstan. As a consequence, the flow of the river is mostly regulated. The Irtysh river has 3 large artificial reservoirs formed by dams of Bukhtarma HPP, Ust-Kamenogorsk HPP, and Shulba HPP (fig. 1).

Below the mouth of the Bukhtarma river Irtysh flows in narrow canyon with almost steep slopes of 200–300 m height, the length of the canyon is 90 km. In the canyon below the Bukhtarma mouth the dam

Table 1. Characteristics of major tributaries of the upper course of Irtysh river and their basin area
Tabela 1. Charakterystyka głównych dopływów górnego biegu Irtysza i ich zlewni

Rivers	Flows into (from what bank – r/l)	Basin area, km^2	River length, km	Average annual water discharge, m^3/s
Kara-Kaba	Kaba (r)	3 040	154	40,6
Ak- Kaba	Kaba (l)	1 570	106	18,4
Kalzhyr	Black Irtysh (r)	2 980	123	21,5
Kurchum	Bukhtarma reservoir (r)	5 900	218	62,1
Naryn	Bukhtarma reservoir (r)	2 850	95	15,2
Bukhtarma	Bukhtarma reservoir (r)	15 500	405	243
Ulba	Irtysh (r)	5 090	98	98,0
Small Ulba	Ulba (l)	2 300	112	53,1
Uba	Irtysh (r)	9 950	286	170
Kendirlik	Bukhtarma reservoir (l)	4 310	174	9,8
Bazar	Disappears	4 450	149	5,3
Kokpekty	Bukhtarma reservoir (l)	10 100	217	5,5
Large Bukon	Bukhtarma reservoir (l)	4 150	181	12,2

of Bukhtarma HPP was built. Formed reservoir included Zaisan lake. This reservoir is one of the largest in CIS. Bukhtarma reservoir is a reservoir of multiannual flow regulation. Its area is 5 500 km^2 and its volume amounts to 50 km^3.

In 1963 the Ust-Kamenogorsk HPP was built below the canyon. Water volume of the reservoir at normal level is 0,655 km^3. Reservoir is backed river part with length of 90 km – before the dam of Bukhtarma HPP. There are weekly and daily flow regulations, and the reservoir is used for energy production.

The dam of Shulba HPP was built 4 km above Semey city and below Old Shulba village; surface area of river-bed reservoir is 255 km^2, its volume amounts to about 3 km^3. The surface area reduces two times when water is released.

Water regime of the river. The Irtysh river belongs to the type of rivers with the spring flood. River feeding is mixed: upstream part is fed mainly by mountain-snow and glaciers, in the downstream part sources are snow and by ground water. In spite of differences in feeding and flow formation the main phase of all rivers of the Upper Irtysh basin is flood, during which a large part of annual runoff is observed, there are also maximum values of water discharge and water level.

Flood period. River flood in plain, hills and low-mountain of the Upper Irtysh begins on average in the first decade of April. In years with the early spring floods are observed in the second or third decade of March, and sometimes even in the first decade of March. Late flood begins in mid-April. Flood rise of the Irtysh rivers basin is fast, in 10–15 days it reaches its maximum, and after 15–20 days the flood ends.

Small rivers with glacier feeding are characterized by extended multi-step flood. Flood peak on glacial rivers is observed on average in the third decade of July, the earliest date (May 25) is on rivers of the Bukhtarma river basin. In years with late summer the main wave of flood raising of mountain rivers is observed in mid-August.

Flood recession on glacial rivers (contrary to rivers with the spring flood) is shorter than rising. The reason here is decrease of air temperature and not exhaustion of feeding sources (snow and ice). The recession of flood on glacial rivers ends in the second-third decade of September. The total duration of flood varies around 40–60 days.

Winter low water period. Duration of winter low water period is on average 140–150 days (November to March). Minimum flow is observed in January-February, sometimes in December (*Surface water resources...*, 1969; BURLIBAYEV, MURTAZIN, TURSUNOV, 2006).

MATERIALS AND METHODS

Analysis was performed by calculation and plotting of changeable average value of a particular chemical element. The concentration of a particular substance for ten-year period is calculated with equation:

$$C_{\mathrm{i}\,av10} = \frac{\sum_{1}^{10}(C_{i1} + C_{i2} + C_{i3} + ... + C_{i10})}{10} \quad (1)$$

when $C_{i\ av\ 10}$ – average concentration of the i-th element in a particular period (flood, low water) for the ten-year period; $C_{i\ 1,\ 2,\ 3\ ...\ 10}$ – average concentration of the i-th element in a particular period for the first (second, third ... tenth) year of this decade.

Averaging was performed for ten-year period, for example, total dissolved salts TDS of the flood period is averaged from 1940 to 1949, then it is averaged from 1941to 1950, next from 1942to 1951, etc.

This method allows to smooth or mitigate maximum values that can be caused by a single discharge of substances in water. When it has been considered in the long-term period it was possible to estimate actual change in concentration of a particular element, excluding the possibility of consideration of peak concentrations. Trend lines are built to identify dynamics of changes, they also help to see these changes more clearly.

It should be noted that the dynamics of concentrations of substances is considered in different periods of water regime – flood period, flood period together with transition to low-water period, and autumn-winter low-water period. Such attitude is correct because during the various phases of water regime concentrations of substances are different. For example, the lowest concentrations are observed during flood period, because of dilution by meltwater, and the highest concentration is in low-water period, when water level in the river is low (ALEKIN, 1970).

In this paper, as a criterion for surface waters quality assessment, following parameters were chosen:

- *total dissolved salts (TDS)* – usually expressed in mg/dm^3 or mg/l or ppm (‰);
- *chemical oxygen demand (COD)* is amount of oxygen, consumed for the chemical oxidation of the water containing organic and inorganic compounds undergoing oxidation. COD is expressed in mg/l of atomic oxygen;
- *copper* in natural waters originates from waste water from metallurgical and chemical industries;
- *zinc* – in natural waters results from processes, occurring in nature, as rock weathering and dissolution of minerals, as well as from industrial wastewater (ZENIN, BELOUSOVA, 1988).

To identify the long-term chemical dynamics of Irtysh river, three points were selected (fig. 1):
1 – Kara (Black) Irtysh river – the village of Boran;
2 – Irtysh river – city of Semey (4 km above the city);
3 – Irtysh river – Semiyarka village (phot. 1 and 2).

The following periods of observations were taken into account.

TDS – observation period: 1) Black Irtysh river, Boran, 1941–2009; 2) Irtysh river – Semey, 1965–2010; 3) Irtysh river – Semiyarka, 1957–1996;

COD – observation period: 1) Black Irtysh river, Boran, 1963–1996; 2) Irtysh river, Semey, 1965–1996; 3) Irtysh river, Semiyarka , 1963–1996;

Heavy metals– observation period: 1) Black Irtysh river, Boran, 1976–2009; 2) Irtysh river, Semey, 1984–2009; 3) Irtysh river, Semiyarka, 1968–1996.

Photo 1. Irtysh river valley – general view (http://news.gazeta.kz/art.asp?aid=382853)
Fot. 1. Dolina Irtysza – widok ogólny (http://news.gazeta.kz/art.asp?aid=382853)

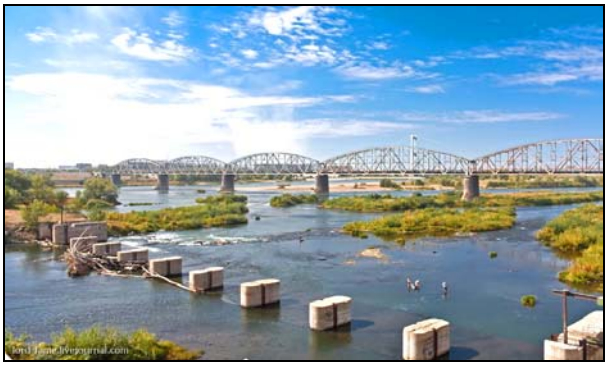

Photo 2. Irtysh river at Semey town (phot. by lord_fame.yvision.kz – http://www.chagan.ru/forum1/viewtopic.php?p=32031&sid=4ba7c0a8aef6a6e198994af0c91f2dce)
Fot. 2. Irtysz w m. Semej (d. Semipałatyńsk) (fot. lord_fame.yvision.kz – http://www.chagan.ru/forum1/viewtopic.php?p=32031&sid=4ba7c0a8aef6a6e198994af0c91f2dce)

The points are selected basing on continuity of data series to estimate the temporal variation of hydro-chemical regime. The data for such long period are representative because the method of determining the concentration of chemical components in water has not been changed.

RESULTS AND DISCUSSION

Results of hydrochemical analyses, made in these points, are presented below.

TDS during the flood time (from April to July)

In these period TDS increase tendency is indicated clearly. This tendency exists in all three points during rather long term.

Significant TDS increase is indicated at Boran point on Kara (Black) Irtysh. TDS has increased here by 1.6 times in 1941–2008 (from comparison of TDS equal 97 mg/dm^3 in 1941–1950 and TDS equal 156 mg/dm^3 in 1999–2008 . The trend line analyses has shown increase by 2.4 times, from 68 mg/dm^3 to 160 mg/dm^3).

At Semey point TDS has increased by 1.1 times (it was 142 mg/dm^{3}in 1965–1974 and 158 mg/dm^3 in 1998-2007. The trend line has increased by 1.2 times (from 140 mg/dm^3 to 163 mg/dm^3).

At Semiyarka point, in 1957–1996 TDS has increased by 1.1 times (from 154 mg/dm^3 in 1957–1966 to 166 mg/dm^3 in 1987–1996), but change in the trend line is insignificant.

This significant increase of TDS at Boran point on the Black Irtysh river is connected with increase of returned water volume (water after irrigation) in the territory of the People's Republic of China (PRC), where recent agricultural activity growth is noticed. This impact is less harmful for the Semey and Semiyarka points because water reservoirs (Bukhtarma, Ust-Kamenogorsk and Shulba) are situated one by one, and part of pollutants is sedimented here.

TDS during winter low water period (from November to February)

Similarly as during the flood time, during winter low flow period significant TDS increase by 1.7 times is found at Boran point on the Black Irtysh river in 1952–2008 (from 110 mg/dm^3 in 1952–1961 to 189 mg/dm^3 in 1999–2008). In the trend line increase is more significant, 1.9 times: from 100 mg/dm^3 to 190 mg/dm^3).

In two other river points there are not significant changes during 50 years. It is connected with TDS control by use of water reservoirs, where every winter, big volume of water is discharged, that makes TDS stable.

Chemical oxygen demand (COD) during the flood time (from April to July)

COD at Boran point, compared with decade average index, increased by 1.1 times (from 17.9 mg/dm^3 in 1963–1972 to 20.0 mg/dm^3 in 1987–1996). In the trend line increase is more significant – 1.4 times (from 14.1 mg/dm^3 to 19.9 mg/dm^3, period of time is the same).

At the Semey point COD has increased by 1.2 times (from 17.1 mg/dm^3 in 1965–1974 to 21.0 mg/dm^3 in 1986–1996); in the trend line has increased by 1.3 times.

At Semiyarka point COD increased by 1.2 times (from 18.6 mg/dm^3 in 1963–1972 to 22.0 mg/dm^3 increase is more significant: 1.8 times (from 13.0 mg/dm^3 to 22.8 mg/dm^3).

Chemical oxygen demand during winter low water period (from November to February)

COD at Boran point compared with decade average index, increased by 1.9 times (from 7.2 mg/dm^3 in 1970–1979 to 13.5 mg/dm^3 in 1987–1996); in the trend line increase is 2 times (from 8.7 mg/dm^3 to 17.0 mg/dm^3).

At Semey point COD has increased by 1.1 times (from 14.0 mg/dm^3 to 15.0 mg/dm^3) in the trend line only.

At Semiyarka point there is the same change, increase by 1.1 times in the trend line (from 13.8 mg/dm^3 to 15.5 mg/dm^3).

The above results show that the concentrations of oxidizable organic substances at all research points has increased.

Heavy metal ions water pollution

Copper ions content during the flood time (from April to July) (fig. 2). At Boran point Cu concentration has decreased by 1.6 times (comp. with average indices); in the trend line decrease is 1.7 times.

At Semey point decrease is significant, two times according to average indices at the beginning and at the end of research; in the trend line there is 2.5 times decrease.

At Semiyarka point situation is opposite: there is copper ions concentration increase by 1.2 times; in the trend line increase is the same. It should be noticed, that in 1977–1990 significant copper ions concentration increase took place here, concentration was 9.0–10.0 μg/dm^3.

Copper ions concentration during winter low water period (November to February) (fig. 3). At the Boran point copper ion concentration increased by 1.9 times (comp. with average indices); in the trend line increased by 2.7 times.

At the Semey point there was significant decrease by 2.3 times (compared with average indices; in the trend line there is 2.7 times decrease.

At the Semiyarka point situation is opposite: copper ions concentration increased by 1.4 times, according to average indices at the beginning and at the end of research period, in trend line increase is

1.5 times. As in the previous case, at this point rather significant increase of copper ions concentration was found in 1976–1987, when concentration was equal 6.0–6.5 μg/dm³.

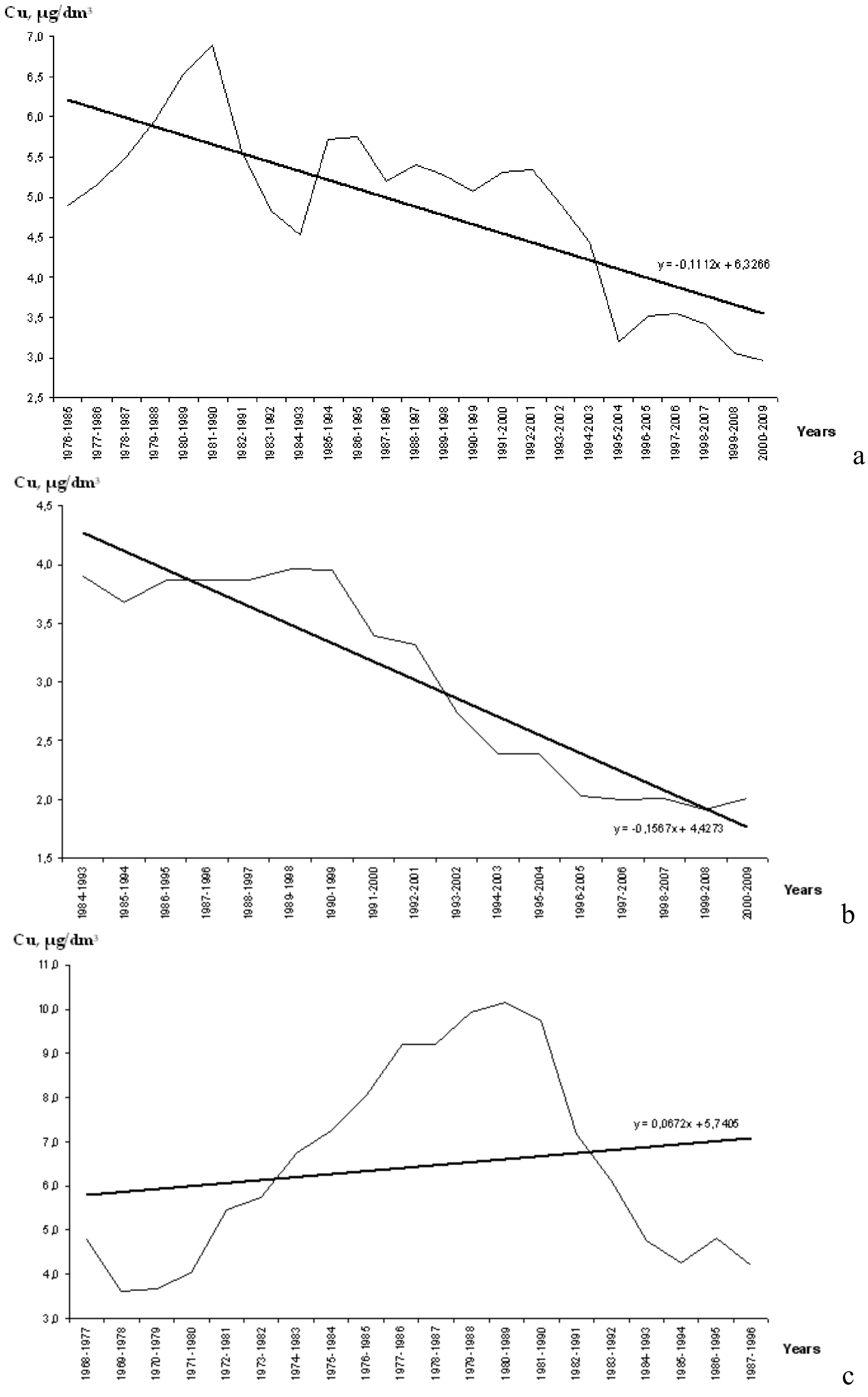

Fig. 2. Changes of the average decade copper ions concentration during the flood time, at different points: a – Boran, b – Semey, c – Semiyarka

Rys. 2. Zmiany średnich dekadowych stężeń jonów miedzi podczas wysokich stanów wody w Irtyszu: a – Boran, b – Semej, c – Semijarka

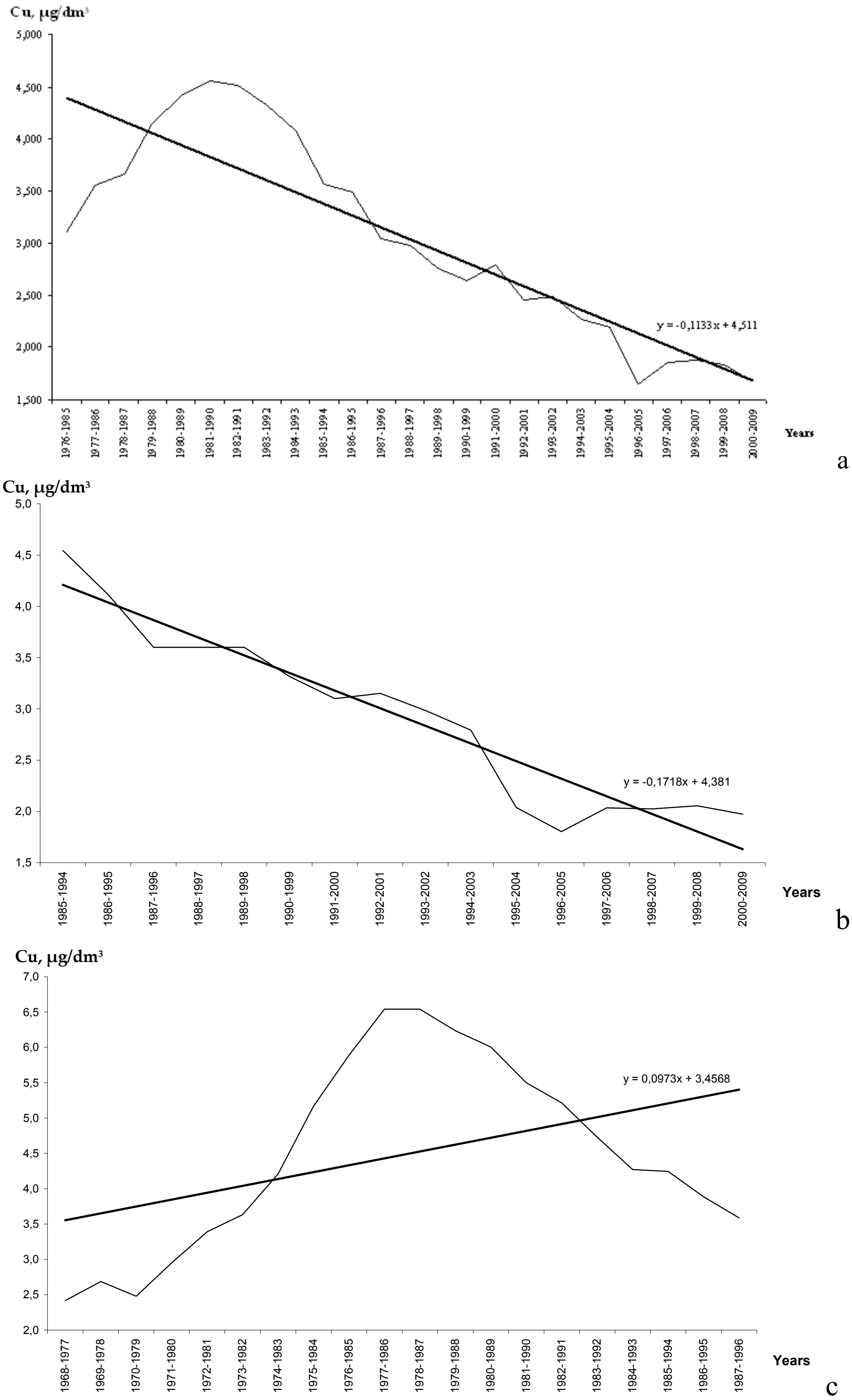

Fig. 3. Changes of the average decade copper ions concentration during the winter low water period, at different points: a – Boran, b – Semey, c – Semiyarka

Rys. 3. Zmiany średnich dekadowych stężeń jonów miedzi podczas niskich stanów wody w Irtyszu:: a – Boran, b – Semej, c – Semijarka

<u>Zinc ions concentration during the flood time (from April to July)</u> (fig. 4). At the Boran point Zn decreased by 2.4 times (comp. with average indices); in the trend line decrease is 2.5 times.

At Semey point decrease is by 3.8 times, according to average indexes in the beginning and in the end of survey period; in the trend line there is 5.2 times decrease.

At Semiyarka point situation is as with Cu: there is 2.1 times increase, as compared with average indexes; in the trend line increase is by 3.2 times.

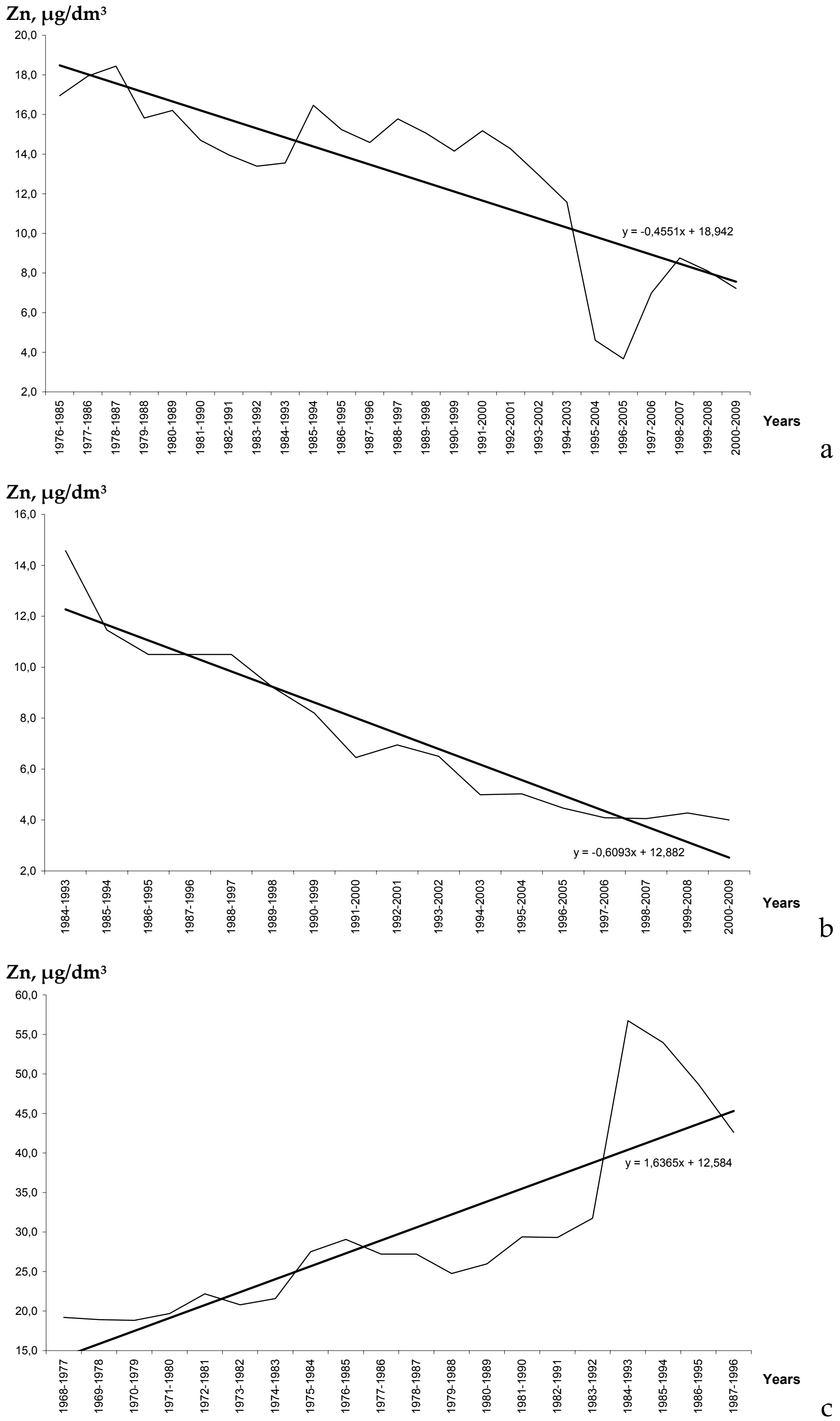

Fig. 4. Changes of average decade zinc ions concentration during the flood time, at different points: a – Boran, b – Semey, c – Semiyarka

Rys. 4. Zmiany średnich dekadowych stężeń jonów cynku podczas wysokich stanów wody w Irtyszu: a – Boran, b – Semej, c – Semijarka

Zinc ions concentration during the winter low flow period (November to February) (fig. 5). At the Boran zinc ion concentration decreased by 1.6 times (as compared with average indices); in the trend line increased by 1.9 times.

At the Semey point zinc ion concentration decreased by 2.1 times, according to average indices; in the trend line there is 1.8 times decre-ase.

At the Semiyarka point Zn has increased 1.6 times; in the trend line increaseis by 1.4 times.

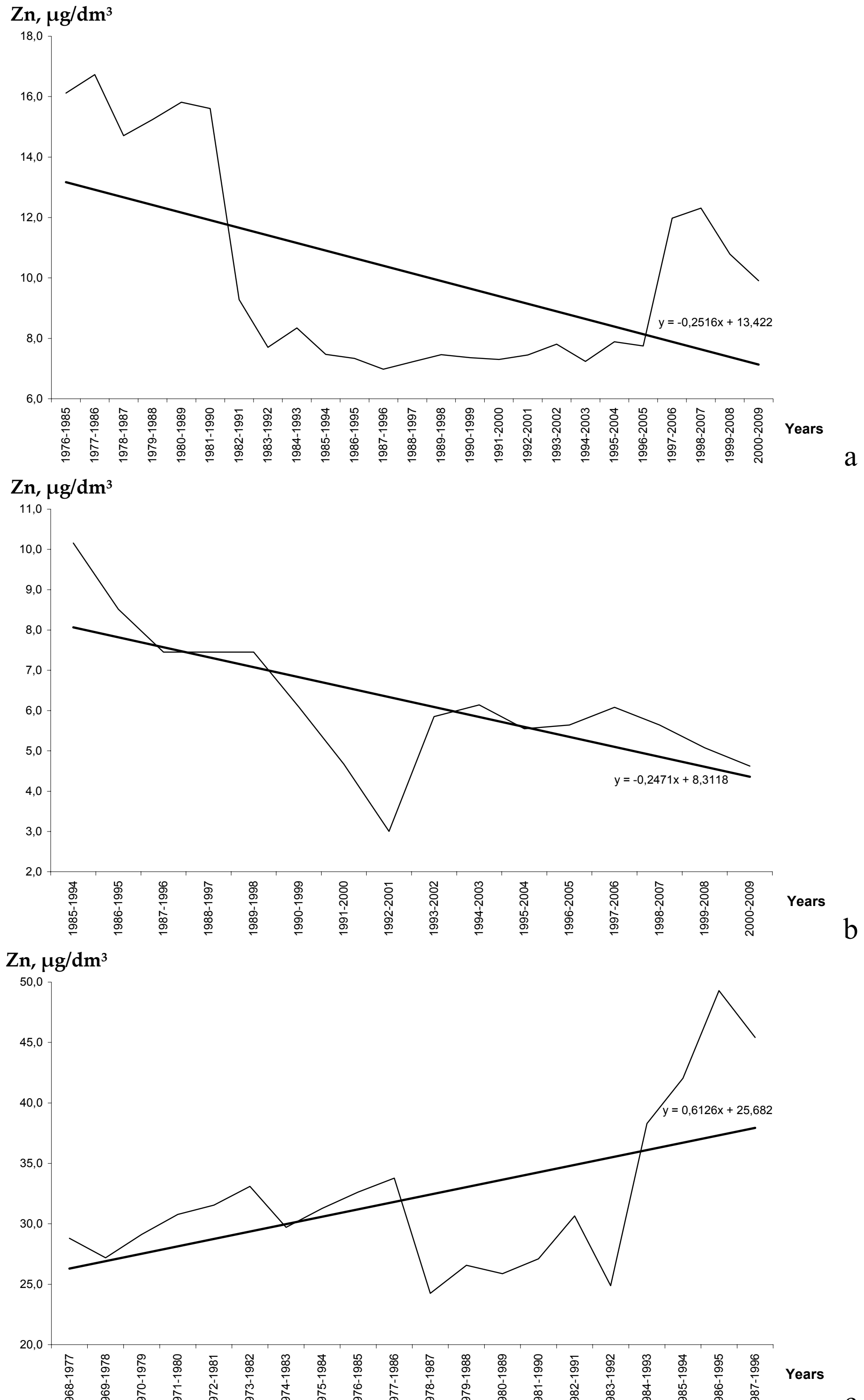

Fig. 5. Changes of the average decade zinc ions concentration during the winter low water period, at different points: a – Boran, b – Semey; c – Semiyarka

Rys. 5. Zmiany średnich dekadowych stężeń jonów cynku podczas zimowych niskich stanów wody w Irtyszu: a – Boran, b – Semej, c – Semijarka

CONCLUSIONS

Changes of hydrochemical regime take place when water resources are decreasing and the rise of anthropogenic pollution of waters is observed.

The main results obtained in this research are: parallel quantitative change of water resources, increase of total dissolved salts (TDS) concentration in river, decrease of oxygen concentration in water, increase of heavy metal concentration. In the Irtysh river the most considerable increase of TDS occurs at Boran village. This is the first point of observation in the Republic of Kazakhstan, it is clear that it reflects the anthropogenic influence of People's Republic of China. The results show that at all three observation points in different periods (flood and winter low water) there is an increase of TDS. The COD growth is also noticeable at all three points in flood period, as well as in winter low water period. However, in the case of heavy metals, the picture is mixed. In the first and second points (Boran and Semey) a decrease of heavy me-tals in water is observed, but in Semiyarka point there is a noticeable increase of it. The decrease is a result of the fact that in China and in Kazakhstan heavy metals particles precipitate in reservoirs. And at Semiyarka point this significant increase is caused by the fact that this area is one of the most developed regions.

This change of hydro-chemical regime can be explained by large anthropogenic pressure on the basin territory. This is an industrial region of the Republic of Kazakhstan. There are a lot of factories in some regions (in Kazakhstan) there is a navigation on the Irtysh river, navigation on the river is also well developed in Russia.

Another cause of changes in hydrochemical regime is the construction of reservoirs: Bukhtarma, Ust-Kamenogorsk, and Shulba. These artificial objects undoubtedly change not only the hydrological regime of the river but also have a great influence on chemical composition of water. Flowing river regime changes in slow mode of a reservoir, and, as result, deposition of particles of chemical compounds and their accumulation in the bed load of the reservoir are occurs here.

The Irtysh river flows through the territories of three countries: People's Republic of China, the Republic of Kazakhstan, and the Russian Federation. Therefore, not only a question of quantity, but especially quality of water is very important at present time. The Irtysh river is the main water artery supplying Central Kazakhstan. At this moment there is another problem – water providing to Astana city (the capital of Kazakhstan) by the Irtysh river. Because in the near future the Ishim river (which is the main source of drinking water for Astana city at present) will not be able to meet the needs of rapidly growing city. As a result of this, there is a question about launching of the second stage of the channel Irtysh–Karaganda named after K. Satpayev. This, of course, will also affect the quality of the Irtysh river water, as the Ishim river is a tributary of the Irtysh river and flows into it on the territory of the Russian Federation.

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