Problems and trends in water resources use in the Russian-Kazakhstan transboundary region

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Abstract. This article considers the trends in use of water resources of transboundary rivers in the adjacent regions of Russia and Kazakhstan. The problems of transboundary water use in the river basins of the Ural and the Irtysh in the Russian-Kazakh region as well as the influence of economic activity in China are outlined. Among the regions under study, we identified those areas of the three countries whose water economy depends on the transboundary rivers of neighbouring regions or significantly regulates the hydrological regime of these rivers. To study and calculate water use trends, data on the water use from 2010 to 2019 was used. The structural specifics of water use are shown and the ratio of water consumption to available renewable water resources for the regions of Russia, Kazakhstan and the Xinjiang-Uygur Autonomous Region of China is determined. General trends and differences in water use in the water sectors of the transboundary river basins of the Ural and Irtysh have been identified.

1. Introduction

Nowadays due to increasing demand for water resources round the world, transboundary river basins face a particularly critical situation. The Russian Federation has a significant number of transboundary rivers due to the length of its borders. One of the longest state borders is the border with the Republic of Kazakhstan. Russia and Kazakhstan have two large transboundary river basins of the Ural and the Irtysh. The area of and the volume of water resources of the Ural and Irtysh river basins are not comparable, but each of them plays an important role in the socio-economic development of the Russian-Kazakh transboundary region and in the relations between the two countries. The upper reaches of the Irtysh River (the Black Irtysh River) are located in Xinjiang Uygur Autonomous Region of China, making it difficult to develop general decisions on the use of the transboundary Irtysh River.

The two river basins include more than half of the surface runoff resources of the Republic of Kazakhstan. The water resources of these basins are of critical importance for the water supply of industrial areas, cities and regions of Russia. More than 20 million people live in the regions of Russia and Kazakhstan on the territory of the transboundary river basins of the Ural and Irtysh. In the Xinjiang-Uygur Autonomous Region of China, more than 10 million people live in the upper part of the Irtysh basin (the Black Irtysh River) and the areas receiving water from it.

Problems in the Ural and Irtysh basins are identified in the water strategies of both states [1], [2]. Currently, only framework agreements on the use and protection of transboundary water bodies have been signed between the countries. During low-water periods, according to the agreements of the Russian-Kazakh commission in the Ural basin, the Russian side replenishes river runoff from the
reservoirs on the river to ensure stable water supply of the regions in the Republic of Kazakhstan. The regions of the Russian Federation located along the Irtysh and its transboundary tributaries also need a steady influx from the territory of the Republic of Kazakhstan. To date, there is no interstate agreement on regulating runoff and water separation between countries. The situation is complicated by the fact that there are no three-way agreements on the basin of the Irtysh. China and Kazakhstan have only bilateral cooperation agreements on the use and protection of transboundary rivers. Currently, water separation issues in the basin continue to be coordinated by specialists from the two countries [3], [4], [5], [6].

To promote further sustainable development between the countries, it is relevant to study trends in the use of water resources in the adjacent regions of the three countries. The water resources availability and the water stress indicators in the regions for the current water consumption level was analysed. As well were identified trends in water use over the past decade (figure 1).

![Figure 1. Adjacent regions of the transboundary basins of the Ural and Irtysh rivers.](image)

2. Materials and methods

Among the regions under study, we identified those whose water economy depends on the transboundary rivers of the neighbouring regions or significantly regulates the hydrological regime of these rivers [7], [8], [9], [10]. According to the purpose of the study, an array of data was collected for 6 regions of the Russian Federation, 9 regions of the Republic of Kazakhstan and 1 autonomous region of China. The study included information on total water resources, local runoff, reservoirs and statistical indicators for the actual water use pattern and structure in the constituent entities of the Russian Federation, the Republic of Kazakhstan and China during the period from 2010 to 2019 [11], [12], [13]. To determine the ratio of water consumption to available renewable water resources, indices for water use of local and total runoff were calculated. If the value of the indicator is less than
10%, it indicates that there is no water stress; if the indicator is between 10% and 20%, there is a little shortage of water; if it is 20%-40%, the shortage is moderate; if the indicator exceeds 40%, it means a high level of water scarcity (water stress) [14]. Statistical methods were applied to analyse changes and trends in water use. Water use indicators for the multi-year period are a type of time series; therefore, they were first investigated to point out trends and the stationarity in these series.

3. Results and discussion
Transboundary rivers, crossing borders with the Republic of Kazakhstan are the Ural and Irtysh (including the Tobol and the Ishim), and the source of the Irtysh river (the Black Irtysh) lies in China. More than 70% of the area of these basins lies in Russia with the exception of the Ishim River (where only 18% of the basin area belongs to Russia). The main transboundary rivers include large tributaries of the Ural – the Ilek and the Or, the Tobol and the Ubagan, most of the flow of which is formed on the territory of Kazakhstan.

The total inflow of the transboundary rivers, which is formed outside the Russian Federation, exceeds the outflow outside the country (in 2018, the inflow exceeded the outflow by 7 times). The Irtysh and Ishim rivers get a significant amount of inflow on the territory of Kazakhstan (37, 9 km³ in 2018), while the Ural River has the greatest outflow (4.4 km³ in 2018). Regions differ significantly in the water resources availability of both local and total surface runoff (including transit flows from other territories). The regions of the Republic of Kazakhstan (table 1) have the fewest water resources.

| Region            | The average annual volume of surface runoff (total), km³ | Annual per-capita water availability, in 1,000 cubic meters | Local runoff use (water stress) index in 2019 | Total water use (water stress) index in 2019 |
|-------------------|----------------------------------------------------------|------------------------------------------------------------|-----------------------------------------------|---------------------------------------------|
| Russian Federation|                                                          |                                                            |                                               |                                             |
| Kurgan region     | 3.5                                                      | 4.1                                                        | 7.1                                           | 2.2                                         |
| Omsk region       | 41.3                                                     | 20.9                                                       | 3.0                                           | 0.4                                         |
| Orenburg region   | 12.7                                                     | 6.3                                                        | 22.0                                          | 13.0                                        |
| Republic of Bashkortostan | 34.2                                                  | 8.4                                                        | 3.1                                           | 2.2                                         |
| Chelyabinsk region| 7.4                                                      | 2.1                                                        | 13.2                                          | 11.8                                        |
| Tyumen region     | 583.7                                                    | 161.5                                                      | 0.1                                           | 0.2                                         |
| Republic of Kazakhstan |                                      |                                                            |                                               |                                             |
| Akmol region      | 8.73                                                     | 13.2                                                       | 14.0                                          | 2.7                                         |
| Kostanay region   | 1.54                                                     | 1.8                                                        | 5.3                                           | 5.1                                         |
| North Kazakhstan region | 2.21                                                | 3.0                                                        | 3.4                                           | 2.9                                         |
| Pavlodar region   | 1.02                                                     | 1.9                                                        | 32.9                                          | 24.5                                        |
| Karaganda region  | 29.12                                                    | 38.8                                                       | 6012.0                                        | 10.3                                        |
| East Kazakhstan region | 1.78                                               | 1.3                                                        | 93.5                                          | 89.8                                        |
| Xinjiang Uygur Autonomous Region | 35.65                                           | 26.1                                                       | 2.0                                           | 1.6                                         |
| China             |                                                          |                                                            |                                               |                                             |

Table 1. Water availability and use in the Russian-Kazakhstan transboundary region.
In the Ural basin the West Kazakhstan and Atyrau regions are the most dependent on transit river runoff from other regions; in the Irtysh basin the Pavlodar and Karaganda regions of the Republic of Kazakhstan are the most dependent ones. Large reservoirs and canals, which provide water supply to industrial and agricultural areas, play a significant role in the sustainability of the region's water industry. Reservoirs in the Ural basin can hold up to 1/3 of the average annual flow of the river. The cascade of reservoirs in the upper part of the Irtysh River can accumulate about 60% of the average annual flow at its full capacity. The construction of reservoirs, an extensive network of canals and the runoff transfer have changed the hydrological regime of the rivers. The area of the industry relying on the water resources of these rivers exceeds their basins.

In 2010-2019, the total fresh water consumption in the adjacent regions of the transboundary basins of the Ural and Irtysh rivers decreased by 12%, while irrigation and agricultural water use went down by 18.6%, domestic and industrial water use fell by 11.3% and 15.8%, respectively. Over the past decade the regions of the Russian Federation saw a decrease of fresh water use by 25.6%, while in the Republic of Kazakhstan it decreased by a mere 5%. Structural changes in water use did not take place, but water consumption in water sectors decreased significantly (table 2).

### Table 2. Trends in the water use in the Russian-Kazakh transboundary region from 2010 to 2019.

| Region                      | Change/Average annual increase (decrease) |
|-----------------------------|------------------------------------------|
|                             | Total         | Industrial   | Domestic     | Irrigation, agricultural |
| **Russian Federation**      |              |              |              |                          |
| Kurgan region               | 5.5 / 0.94   | 5.0 / 0.6    | -25.3 / -3.2 | -44.2 / -6.2             |
| Omsk region                 | -45.3 / -5   | -46.3 / -5.8 | -35.0 / -4.4 | -46.7 / -0.5             |
| Orenburg region             | -14 / 2      | -7.2 / 2.3   | -32.9 / -4.2 | -0.4 / 2.7               |
| Republic of Bashkortostan   | -0.4 / 0.5   | -12.0 / -0.8 | -16.5 / -1.5 | -35.1 / -3.3             |
| Chelyabinsk region          | -25.5 / -3.1 | -19.3 / -1   | -36.9 / -4.9 | -31.7 / -3.4             |
| Tyumen region               | -31.4 / -4   | -24.3 / -2.7 | -39.1 / -5.3 | -36.0 / -4.4             |
| **Republic of Kazakhstan**  |              |              |              |                          |
| Aktope region               | -20.5 / 5.4  | -52.0 / -3.9 | -12.2 / -0.4 | -82.7 / 19.7             |
| Atyrau region               | -16.0 / -1.5 | 3.2 / 1.3    | 41.7 / 5.6   | -31.2 / -1.9             |
| West Kazakhstan region      | -48.2 / -0.8 | -95.2 / 8.2  | 4.5 / 2      | 0.0 / 4.3                |
| Akmola region               | 8.2 / 1.1    | 11.1 / 2.1   | -5.7 / -0.5  | 60.0 / 6.4               |
| Kostanay region             | -12.2 / -0.1 | 55.6 / 5.9   | 66.7 / 7.1   | -73.2 / -9.6             |
| North Kazakhstan region     | 346.4 / 31.5 | 985.7 / 88.7 | 12.5 / 1.5   | -78.9 / -14              |
| Pavlodar region             | 1.5 / 1.2    | -0.4 / 0.1   | -11.1 / -1.27| 9.5 / 24.6               |
| Karaganda region            | -14.8 / -1.5 | -19.0 / -1.9 | -17.6 / -1.7 | 15.2 / 2.5               |
| East Kazakhstan region      | 4.9 / -0.1   | -10.4 / 1.5  | -10.6 / 1.5  | -74.8 / 16.4             |
| Xinjiang Uygur Autonomous Region | 3.9 / 0.4 | 28.6 / 2.8   | 21.3 / 2.3   | 0.2 / 1.0                |
In the regions of the Republic of Kazakhstan the trends in water use vary. There is a significant increase in industrial water consumption in the North Kazakhstan and Akmola regions in the Irtysh basin. In the constituent entities of the Russian Federation, the domestic and industrial uses of water resources see a general trend towards a decrease in water consumption. Due to the growth of the urban population and the development of a centralized water supply network for settlements in the Akmola and North Kazakhstan regions, the volume of domestic water consumption increased.

In the Ural basin there is a substantial reduction in industrial water use in the Orenburg region. Industrial water use is largely determined by the generation of electricity at thermal power stations for industrial enterprises. In irrigation and agricultural water supply, there is a general decrease in both Russia and Kazakhstan.

4. Conclusion

Based on the results of the retrospective analysis of water use indicators and water use structure in the Russian-Kazakh transboundary region, we established that regions continue to differ significantly in terms of in water use in the transboundary basins. In some regions, water consumption exceeds the resources of local surface runoff and is significantly dependent on transit flow. In the basin of the Ural and the Irtysh rivers, water-related environmental problems may arise during low-water periods, when water intake from transit rivers increases and the dilution of wastewater in these watercourses decreases. The transboundary nature of both river basins has a significant impact on the development of the water economy of the adjacent regions of the three countries. The legal framework for cooperation between the countries in terms of use and protection of transboundary rivers is currently being developed. The fluctuations in the hydrological regime of these rivers as well as any initiatives to build reservoirs on the territory of one of the countries provoke a strong reaction from a neighbouring state.

In terms of water use trends, there is a general decrease in water consumption in Russia and Kazakhstan, while China sees a steady growth. There are trends to increase water consumption in the Republic of Kazakhstan and China. In the socio-economic development programs of the regions, industrial and agricultural production indicators are projected to increase, which will affect the increase in current water consumption. Consequently, already in the adjacent regions of the transboundary river basins of the Ural and the Irtysh projects to construct new reservoirs and to transfer runoff from other river basins are being developed.

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