# Aspects of water use in Russia-Kazakhstan transboundary region

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**Abstract**. The study addresses the specific features of the use of water resources in the Russia-Kazakhstan transboundary region. It was found that over the past twenty years the studied region faced a significant reconfiguration of water use. The water consumption for agricultural purposes noticeably reduced, primarily due to a reduction in areas that receive inundation irrigation and regular irrigation. The subregions with relatively low indicators of water availability were established, which owes to insufficient renewable river run-off in conditions of significant water withdrawal for industrial and utility needs. Given the current demographic situation, the problem of guaranteed water supply may be exacerbated in Kazakhstan with a steady population growth. The results indicate that the socio-economic transformations in the Russia-Kazakhstan transboundary region affect the structure of water consumption, the water availability and the water use efficiency. The integrated water resources management within the Russian-Kazakhstan transboundary region should improve the water use efficiency in the water sector and take into account the hydroclimatic changes.

## 1. Introduction

Water is the most important natural resource that provides for various functions of modern society. Hence a sustainable and guaranteed supply of water resources to the economy and the population is an overriding priority in any country. The issues of using water resources are especially topical in transboundary regions—lasting territorial entities that incorporate a state border and, therefore, are distinct in their economic development [1]. The situation in a transboundary region is complicated if transboundary water bodies are the main sources of water for the countries located within such region [2]. Thus, over the past fifty years, more than 500 disputes have occurred all over the world, of which 37 developed into acute conflicts, including 21 followed by acts of war [3].

The Russia-Kazakhstan transboundary region, which includes twelve federal subjects of the Russian Federation and seven oblasts of the Republic of Kazakhstan (figure 1), has been developing as a single historical-geographical and socio-cultural space for the last three centuries [4]. What makes the water use issues topical here are the natural specifics of the transboundary region located mainly within the steppe zone. One of the hydroeconomic problems of the steppe zone is the guaranteed availability of fresh water to the population and the economy in the conditions of extremely uneven spatial and temporal distribution of surface runoff [5]. The border-straddling oblasts of the two countries with the minimum long-time average annual values of river run-off are Kurgan Region (3.5 $km^3$/year) and Chelyabinsk Region (7.4 $km^3$/year) in Russia and Kostanay Region (1.5 $km^3$/year) and Aktobe Region (3.2 $km^3$/year) in Kazakhstan. The steppe rivers of the studied region are characterized by significant

deviations from the long-time average annual river run-off, which is one of the key points in assessing the current and future water availability. Thus, the long-time annual variability ($C_v$) of the river runoff in the Russian regions varies from 0.08 (the Siberian regions) to 0.18–0.21 (the Volga and Ural regions) [6]. In this regard, the issues of sustainable use of water resources in certain oblasts of the Russia-Kazakhstan transboundary region are intensified not only by the hydroeconomic interests, but also by the hydroclimatic specifics of the water catchment areas.

Of particular interest is the use of water resources in the transboundary river basins because the complex natural-economic systems, united by common substance and energy flows yet separated by the state border, have been formed within them. It should be noted that the issues of efficient and rational use of water resources are particularly relevant for 'downstream' countries whose the sustainable regional development depends, among other aspects, on the quantity and quality of the river run-off from 'upstream' countries. An example of such river basin in the studied region is the transboundary basin of the Ural River where the Russian regions are 'upstream' for the Kazakhstani regions [5].

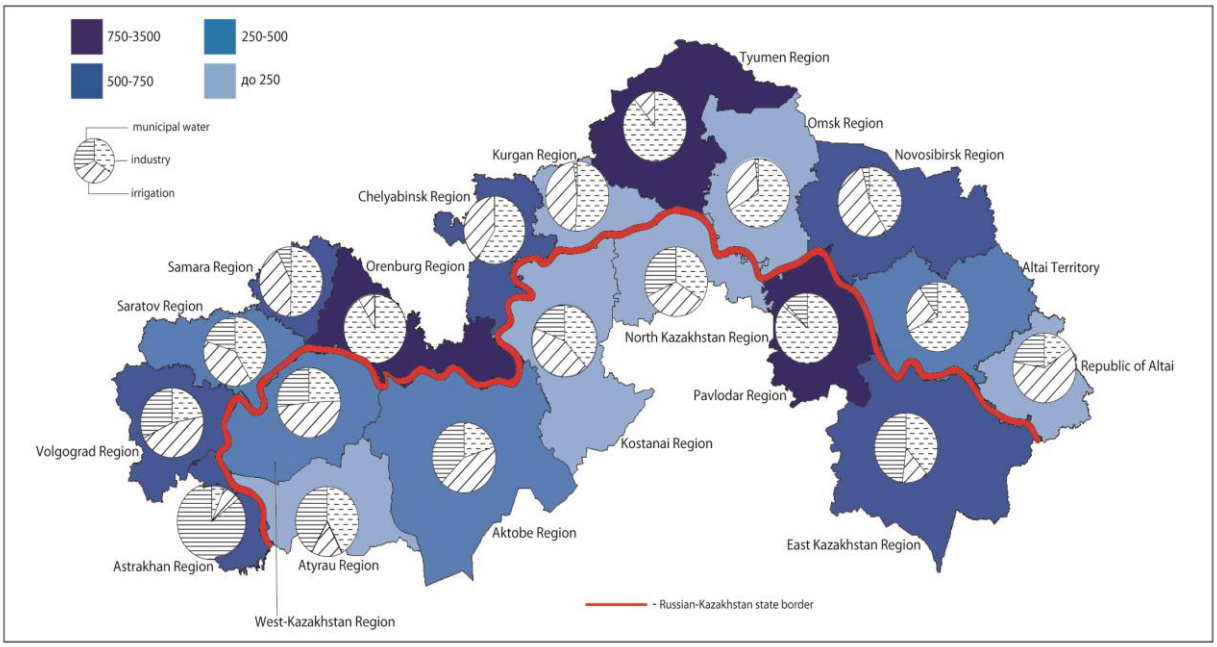


**Figure 1.** Total and sectoral use of fresh water in the Russian-Kazakhstan transboundary region, million $m^3$.

## 2. Materials and methods

The baseline data for the study were statistical data on the availability, use and protection of water resources in the regions of the Russian Federation and the Republic of Kazakhstan [7, 8]. A comparative assessment of water availability was carried out according to conventional methods commonly used in Russia and abroad. One of the common approaches is the Falkenmark water stress indicator: if the amount of renewable water in a country is below 1,700 $m^3$ per person per year, that country is said to be experiencing water stress [9]. However, this indicator reflects only water reserves, but does not take into account the demand for water resources, assuming that demand is uniquely determined by the size of the country's population [10].

An alternative approach is used to calculate the sustainability index, which is equal to the ratio of the volume of water withdrawn from natural sources to the total replenished volume of water [11]. With the sustainability index, if water consumption exceeds 20% of the renewable run-off, that country is said to be experiencing water scarcity; if it exceeds 40%, that country is said to be experiencing critical water scarcity. At the same time, the total volume of water can be regarded as either the internal replenished run-off, or the total run-off including the water run-off from external territories. In the

first case, the sustainability index may exceed 100% if a substantial part of the water run-off is formed outside the territory in question. This approach appears to be more expedient for the Russia-Kazakhstan transboundary region since the state border crosses a number of large river basins (the Irtysh River with its main tributary Tobol, the Ural River with Ilek) and, accordingly, the river run-off is formed beyond the national boundaries.

Another common approach to assessing the availability of water resources is the calculated indicator, which is the ratio of water consumption from surface sources to the long-time average annual river run-off. According to this method, if the ratio is less than 10%, there is low water scarcity; if from 10 to 20%, mild water scarcity; if from 20 to 40%, moderate water scarcity; if exceeding 40%, extreme water scarcity (water stress) [12].

The volumes of circulated and sequential water supply (million $m^3$), water losses during transportation (million $m^3$) and water intensity of the gross regional product (GRP) served as indicators of water consumption efficiency. The GRP water intensity is a fundamental indicator of the regional water consumption efficiency, reflecting the aggregate of changes in production processes in the water infrastructure, and its value primarily depends on the variability of electricity generation and irrigation water consumption [13].

## 3. Results and discussion

For a long time, the dynamics and structure of water consumption in the studied transboundary region were determined by the socio-economic needs of the united Soviet state. From the early 1960s to mid-1970s water consumption had been steadily increasing [6, 14], which corresponded to the period of the most intensive economic development in the USSR. The period from 1975 to 1990 water consumption remain at about the same level, which can be explained by slowing economic growth and the introduction of water-saving technologies, especially in the industrial sectors [6]. In 1990s, the studied Russian and Kazakhstan regions experienced a significant reduction in water consumption in all water-consuming sectors of economy due to the general socio-economic crisis, although some regional differences could be observed. Thus, in the Lower Volga regions the volumes of irretrievable water consumption and losses noticeably reduced, for example, in Astrakhan Region by 3.4 times and in Volgograd region by 2.2 times [15]. For a more detailed assessment of the water consumption dynamics in the post-crisis period, the data on water use for various needs in the studied border-straddling oblasts were analysed (table 1).

**Table 1.** Dynamics of the structure of water consumption in the Russian-Kazakhstan transboundary region (%).
(I. – industrial, M. – municipal, A. – agriculturally water consumption)

| Region | 1995 | | | 2005 | | | 2015 | | |
|---|---|---|---|---|---|---|---|---|---|
| | I | M | A | I | M | A | I | M | A |
| Russian Federation | | | | | | | | | |
| Astrakhan Region | 10 | 7 | 83 | 22 | 11 | 68 | 6 | 8 | 85 |
| Orenburg Region | 84 | 8 | 8 | 90 | 9 | 1 | 91 | 8 | 1 |
| Chelyabinsk Region | 48 | 47 | 5 | 50 | 49 | 1 | 59 | 40 | 1 |
| Tyumen Region | 71 | 28 | 1 | 83 | 16 | 1 | 89 | 10 | 1 |
| Altai territory | 44 | 25 | 31 | 49 | 34 | 17 | 68 | 22 | 10 |
| Republic of Kazakhstan | | | | | | | | | |
| Western Kazakhstan Region | 2 | 5 | 93 | 2 | 6 | 92 | 24 | 49 | 27 |
| Aktobe Region | 10 | 21 | 69 | 8 | 9 | 73 | 20 | 42 | 38 |
| Atyrau Region | 25 | 12 | 63 | 49 | 10 | 41 | 42 | 16 | 42 |
| Kostanay Region | 11 | 18 | 71 | 24 | 42 | 28 | 38 | 43 | 19 |
| Pavlodar Region | 63 | 3 | 35 | 65 | 2 | 33 | 86 | 2 | 12 |

According to the data in table 1, over the past twenty years, a significant restructuring of water consumption has occurred in the studied region. Within the Russian oblasts, the most serious transformation took place in the agricultural sector, and the share of water used reduced to the minimum, except for Astrakhan Region, where the water consumption level of 1995 had been reached by 2015. The overall water consumption of the Kazakhstani region also decreased, primarily due to the reduction of water intake for inundation irrigation and regular irrigation in the agricultural sector. It should be noted that none of the Kazakhstani region has yet managed to achieve the pre-crisis level of agricultural water consumption. It is interesting to compare the data on industrial water consumption, which share has been steadily increasing in most studied border-straddling oblasts over the past twenty years.

The current structure of water consumption in the Russian-Kazakhstan transboundary region is characterized by the presence of clear intra-regional differences that can be attributed to climatic and socio-economic factors, as well as the history of economic management of the oblast territories. land development. In general, it can be noted that the Russian oblasts have a more heterogeneous structure of water consumption. In particular, Orenburg, Tyumen, and Novosibirsk Regions predominantly use of water resources for industrial needs. Most of the federal subjects of Russia consume relatively equal amounts of water for utility and industrial needs, except for Astrakhan Region where the water resources are mostly spent on agricultural needs. The current structure of water consumption in most Kazakhstani oblasts is still characterized by a significant proportion of the irrevocable use of water resources for regular and inundation irrigation.

**Table 2.** Comparative assessment of water availability of the Russian-Kazakhstan transboundary region.

| Region | Falkenmark Index, $m^3$/year/people | Sustainability index,% | Water stress, % | River flow, $km^3$/year |
|---|---|---|---|---|
| Russian Federation | | | | |
| Astrakhan Region | 259761,6 | 0,3 | 0,3 | 264,6 |
| Volgograd Region | 110921,8 | 0,3 | 0,2 | 282,4 |
| Saratov Region | 109224,8 | 0,3 | 0,2 | 271,7 |
| Samara Region | 83500,3 | 0,3 | 0,3 | 267,7 |
| Orenburg Region | 4724,5 | 13,0 | 14,0 | 9,4 |
| Chelyabinsk Region | 2626,8 | 8,6 | 6,3 | 9,2 |
| Kurgan Region | 8237,6 | 0,9 | 0,8 | 7,1 |
| Tyumen Region | 183825,1 | 0,6 | 0,5 | 672,8 |
| Omsk Region | 29097,1 | 0,3 | 0,3 | 57,4 |
| Novosibirsk Region | 25292,3 | 0,9 | 0,8 | 70,3 |
| Altai territory | 26081,1 | 0,6 | 0,7 | 61,7 |
| Republic of Altai | 198156,6 | 0,2 | 0,02 | 43 |
| *Russian Federation* | *30251,1* | *1,6* | - | *4441* |
| Republic of Kazakhstan | | | | |
| Atyrau Region | 11350,4 | 4,2 | 3,2 | 6,5 |
| Western Kazakhstan Region | 13811,0 | 6,8 | 4,0 | 12,0 |
| Aktobe Region | 3890,4 | 13,8 | 9,8 | 3,2 |
| Kostanay Region | 1701,7 | 8,9 | 5,7 | 1,5 |
| North Kazakhstan Region | 1748,9 | 6,1 | 5,1 | 33,5 |
| Pavlodar Region | 38503,3 | 10,7 | 10,7 | 29,1 |
| East Kazakhstan Region | 25728,7 | 1,7 | 1,5 | 35,9 |
| *Republic of Kazakhstan* | *8267,8* | *16,8* | - | *146,1* |

Water resources are renewable components of the environment, and due to this fact the water availability indicators are not steady-state characteristics. The variability of this indicator is determined, first of all, by the spatial and temporal transformations of river runoff in modern climatic conditions. In addition, the availability of water resources directly depends on the socio-economic situation in a particular region, i.e. on population dynamics, technological innovations in industry, etc. As a result, the problem with satisfaction of water demand arises only if the physical water supply in a certain period of time is insufficient to meet all needs [10]. At the same time, despite certain 'plasticity' of the water availability indicator, in many regions of the world the problem of the fresh water scarcity is only aggravating. Given this trend, several approaches to the assessment of water availability were developed. They differ from each other in socio-economic and hydrological indicators used in the calculations (table 2).

The conducted assessment shows that within the Russia-Kazakhstan transboundary territory, most oblasts have relatively high levels of water availability. First of all, this observation refers to the Russian oblasts located along the lower reaches of the Volga River (Astrakhan, Volgograd, Saratov and Samara regions) and in the south of Western Siberia (Tyumen, Novosibirsk and Omsk Regions, the Republic of Altai, Altai Territory). Water availability in Orenburg and Chelyabinsk Regions is slightly lower, which is associated with insufficient amounts of renewable river run-off in conditions of significant water withdrawal for industrial and utility needs. In Kazakhstan, the most critical situation with guaranteed water supply to the population and the economy can be observed in Kostanay, North Kazakhstan and Aktobe Regions. Moreover, taking into account the current demographic situation, the problem of guaranteed water supply may be exacerbated in Atyrau, Aktobe and West Kazakhstan Regions that show steady population growth.

Achieving sustainable water supply in the studied region is difficult unless developing programs for the efficient use of water resources are implemented by both countries. To assess the efficiency of water use within the studied border-straddling oblasts, the following indicators were selected: GRP water intensity, water consumption and water discharge (use of fresh and recycled water in production, water loss during transportation) (table 3).

According to the author's calculations using the statistical data, the indicators of water intensity of the economy of the Russian Federation and the Republic of Kazakhstan differ significantly. To start with, it is important to note a rather high level of water intensity of Kazakhstan's GDP, which is 3.4 $m^3$/kRUB. Such resource intensity of the economy of the Republic of Kazakhstan can be explained by the significant water consumption for irrigation of farming land and flooding of pastures. Hence one of the target indicators of the State Policy is a 33% reduction in water consumption per GDP unit as compared to 2012. At the same time, noteworthy is that the use of water resources in the Kazakhstani oblasts has become more efficient, except for Pavlodar Region where a multi-sectoral industrial complex was developed with focus on power generation and production of alumina.

The water intensity of Russia's GDP is significantly lower and comparable to the indicators of some developed countries (1.14 3.4 $m^3$/kRUB). In the regional aspect, adequately efficient use of water resources is observed in the Republic of Altai, Kurgan and Omsk Regions. The maximum water intensity of the oblast economy was found in Astrakhan Region (2.28 $m^3$/kRUB), due to a high share of agricultural water consumption, and in Orenburg Region (1.70 $m^3$/kRUB), due to the operation of Iriklinskaya GRES that annually consumes 2 $km^3$ of water from Iriklinskoye reservoir for cooling of power units. Also, in the Russian regions circulated and sequential water supply solutions prevail over once-through solutions, which is generally indicative of the majority of the subjects of the Russian Federation.

**Table 3.** Indicators of water use efficiency in the Russian-Kazakhstan transboundary region.

| Region | Water consumption, mill $m^3$ | Water content gross regional product, $m^3$/ thousand rubles | Volumes of circulating and re-sequential water supply, mill $m^3$ | Water loss during transportation, mill $m^3$ |
|---|---|---|---|---|
| Russian Federation | | | | |
| Astrakhan Region | 730 | 2.28 | 512 | 27 |
| Volgograd Region | 593 | 0.81 | 1376 | 202 |
| Saratov Region | 488 | 0.79 | 7281 | 80 |
| Samara Region | 719 | 0.58 | 3026 | 67 |
| Orenburg Region | 1315 | 1.70 | 1672 | 27 |
| Chelyabinsk Region | 581 | 0.50 | 8251 | 105 |
| Kurgan Region | 54 | 0.30 | 303 | 14 |
| Tyumen Region | 3497 | 0.61 | 9582 | 41 |
| Omsk Region | 185 | 0.36 | 1345 | 41 |
| Novosibirsk Region | 578 | 0.66 | 867 | 37 |
| Altai territory | 410 | 0.84 | 868 | 23 |
| Republic of Altai | 80 | 0.23 | 8 | 1 |
| Republic of Kazakhstan | | | | |
| Atyrau Region | 227 | 0.28 | 242 | 41 |
| Western Kazakhstan Region | 504 | 1.14 | 4 | 34 |
| Aktobe Region | 427 | 1.01 | 31 | 4 |
| Kostanay Region | 83 | 0.35 | 546 | 8 |
| North Kazakhstan Region | 53 | 0.34 | 5 | 3 |
| Pavlodar Region | 3038 | 10.12 | 4153 | 12 |
| East Kazakhstan Region | 538 | 1.34 | 332 | 51 |

## 4. Conclusion

The findings indicate a significant impact of the socio-economic processes in the Russia-Kazakhstan transboundary region on the structure of water consumption, water availability and efficiency of water use. The key water management problem of the studied region is the guaranteed availability of fresh water to the population and the economy in the conditions of extremely uneven spatial and temporal distribution of river run-off. Accordingly, the integrated management of water resources within the Russia-Kazakhstan transboundary region should rely on increasing the efficiency of water use in all water-intensive sectors of economy and taking into account the ongoing climate changes.

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