An assessment and prognosis of water resources use in regions of the transboundary basin of the Ural River in the medium term

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Abstract. An assessment and medium-term prognosis of water resources use in the transboundary basin of the Ural River, and adjacent regions of the Russian Federation and the Republic of Kazakhstan were represented in the paper. Prediction of water consumption is one of the most significant water resources management tasks in the transboundary river basins. Under a water deficit of water resources in the Ural River basin in hydrological droughts, data on prospective water consumption allows estimating possible problems of regular water use and ways of their solution for neighboring states. Data on the dynamics of water consumption from 1995 to 2019 and materials of prognoses for socio-economic development of the region in the medium term were used to research and calculate expected water use values. Based on statistical methods, taking into account parameters scheduled of the dynamics of the population and economic development in the regions, we calculated prospective volumes of water resources use in the Ural River basin areas. Projection of water resources use is represented in several scenarios following prognoses of socio-economic development in the regions. As a result, the structural forecasts were worked out according to a type of water consumption: domestic and utility, industrial, irrigation, and agricultural water use for each region of neighboring countries by 2024.

1. Introduction

The Ural River's transboundary basin is geographically divided between the Russian Federation and the Republic of Kazakhstan. Problems of stable water consumption in the Ural River's transboundary basin are discussed in the Water strategies of neighboring states [1, 2]. In Russia, these problems are connected with a deficit of runoff during the hydrological drought. Still, in the Republic of Kazakhstan, they are linked with the apportioning of water and dependence on the neighboring state. For Kazakhstan, the Ural River basin is one of seven transboundary river basins. More than 80% of the Ural River runoff is formed in the Russian area, and water resources are 10% of the Republic's total surface water. In connection with it, the countries continue discussions to develop stable water consumption and work out inter-governmental programs to save the Ural River.

Within the adjacent states' areas, the Ural River basin is located in six regions with more than 4 million people (figure 1). Large industrial centers are forming an essential part of the regional economy placed on the Ural River and its inflows. The regions differ in size and a structure of the water resources' use in economic sectors. They independently decide their development in correspondence with state strategies and economic programs and targeted indicators in prognoses of socio-economic development. Strategies and programs are assumed long-term planning of
development for a decade and more, and projections are represented as a medium-term prospect of socio-economic development with plan numbers. The planned values of the economic growth in the regions allow forecasting the dynamics of water resources use in the medium-term potential. The study aims to calculate and estimate water consumption parameters in the transboundary basin of the Ural River for the medium-term prospects. The following tasks were formulated to achieve the goal: the water consumption dynamics and structure were analyzed for the last 25 years; strategies of adjacent states’ development and prognoses of socio-economic development in the regions were considered; projection data of water resources use was calculated for the medium-term prospect.

Figure 1. The regions of the transboundary basin of the Ural River.

2. Materials and Methods
Materials of the study included statistical data on actual dynamics and structure of water consumption parameters in subjects of the Russian Federation and the Republic of Kazakhstan for 1995-2019 [3, 4]. The observation period reflects changes in the economy of neighboring countries from the establishment of independent states to the present. Water consumption parameters for long-term periods belong to temporal rows. Therefore they were initially studied to reveal tendencies and stability of the given rows.

An assessment of future water resources’ use was made using data on officially published prognoses of socio-economic development of the Russian Federation and regions of the Republic of
Kazakhstan [3, 4]. Forecasts of socio-economic development are represented for a medium-term perspective by 2024. Estimating the population's medium-term dynamics, we used long-term prognoses on the RF subjects by 2030 of Rosstat (Federal State Statistic Service) and Office of National Statistics of RK. The predictions represent several scenarios for the RF subjects: conservative and basic variants. The traditional variant of the prognosis is based on moderate assessments of the economic growth dynamics, including considerable worsening of external financial terms. The basic variant was built on relevant influence on the economic development of changes in outer and inner factors under the current trends to resource use efficiency.

Calculation of prospective water resources' use for domestic and utility needs, industrial water consumption, and agricultural water supply with irrigation was conducted using the following predicted socio-economic indicators (table 1). Projection data on the population in regions were used to estimate domestic and utility needs (the dynamics, specific water consumption). Industrial needs were calculated using plans of shipped goods of own making, services in actually established prices, and the regions' industrial production index. The prognosis of water consumption for irrigation and agricultural water supply was based on farm products' perspective indicators and agricultural production index [5, 6].

|                      | 2018 | 2020 | 2022 | 2024 |
|----------------------|------|------|------|------|
|                      | Real | Conserv. | Basic | Conserv. | Basic | Conserv. | Basic |
| **Domestic and utility** |      |      |      |      |      |      |      |
| Orenburg region      | 84.6 | 83.4 | 85.0 | 82.2 | 85.4 | 80.8 | 86.0 |
| Chelyabinsk region   | 206.0 | 204.2 | 204.6 | 203.5 | 204.1 | 202.0 | 203.2 |
| The Republic of Bashkortostan | 177.8 | 176.4 | 176.6 | 175.4 | 176.0 | 173.0 | 174.5 |
| **Industrial**       |      |      |      |      |      |      |      |
| Orenburg region      | 889.6 | 983.8 | 984.7 | 1067.5 | 1074.6 | 1153.7 | 1168.9 |
| Chelyabinsk region   | 528.8 | 579.0 | 597.0 | 569.3 | 622.8 | 577.8 | 669.0 |
| The Republic of Bashkortostan | 391.0 | 439.8 | 442.6 | 489.9 | 497.7 | 543.0 | 554.8 |
| **Irrigation, livestock and rural** |      |      |      |      |      |      |      |
| Orenburg region      | 36.4 | 40.9 | 41.7 | 44.6 | 49.5 | 48.9 | 58.3 |
| Chelyabinsk region   | 43.2 | 42.3 | 42.7 | 43.2 | 44.1 | 44.8 | 46.1 |
| The Republic of Bashkortostan | 161.6 | 174.3 | 174.5 | 189.2 | 193.8 | 207.8 | 217.9 |

The calculation was based on the current indicators of specific water consumption per one person in a year, reservoir capacity of industrial and agricultural production in value terms in the established prices as of 2018. According to the prognosis of the average annual index of prices, anticipated monetary socio-economic indicators were led to the price level of 2018.

3. Results and Discussion
In the regions of adjacent states of the Ural River basin, the total water intake of freshwater was 3089.3 million m³ in 2019. Water resource use is distributed in the following way: industrial – 1826.7 million m³ (59.2 %), domestic and utility – 545.4 million m³ (17.6 %), irrigation, livestock and rural – 130.4 million m³ (4.2 %), other needs 586.5 million m³ (19 %). In 2019, the most volume of the total water resource's use and water used for industrial needs and domestic and utility purposes were
noticed in the regions of the Russian part of the basin. Still, the volume of water consumption for irrigation and agricultural water supply was higher in the regions of the Republic of Kazakhstan.

During 1995-2019, adjacent states' regions cut down water consumption of fresh water at 57.5%, for irrigation, livestock and rural at 94.5%, for domestic and utility and industrial needs at 48.4 % and 36%, respectively. In the Russian Federation, the water use of freshwater has been reduced by 43.5% for the last 25 years. However, there were no structural changes, and consumption was reduced considerably for the economic sectors.

There is a trend to reduce water consumption for principal purposes in the dynamics of temporal rows for the observation period. The most water consumption decrease was in irrigation, livestock and rural at 95%, domestic and utility water use reduced at 52.4%, and industrial – at 37% — the area of irrigated lands shortened for this period that reflected water consumption for agriculture. Domestic and utility water use reduced due to natural decline in the population, and legislative solutions concerning a transition of water supply payment to the account of used water. Water consumption for industrial needs reduced at the expense of the decline of electric power output in TPS, especially in Orenburg region. In Chelyabinsk region and the Republic of Bashkortostan, we can notice water consumption's long-term stability for industrial needs (figure 2).

![Figure 2](image-url)

**Figure 2.** Type of water use in Russian regions in million cubic meters (MCM): (a) – Total, (b) – Industrial, (c) – Domestic and Utility, (d) – Irrigation, livestock and rural.

In the Republic of Kazakhstan, the total water consumption reduced by 69%, the structure of water use changed from 1995 to 2019. Water consumption for industrial needs exceeded water intake for irrigation and agricultural water supply. Trends on the principal types of water use for the examined period have differently directed dynamics with significant amplitude in long-term water consumption parameters (figure 3).

For the studied period, industrial water use in regions increased by 20%, reflecting the formation and growth of production in the areas, especially in Atyrau region. Domestic and utility water
consumption reduced by 17%, but a rising trend increased in the last decade. The urban population growth and connection of small settlements to the central water supply promote freshwater use by the population. Water consumption for irrigation, pastures watering, livestock and rural reduced by 88%.

Figure 3. Type of water use in Kazakhstan regions in million cubic meters (MCM): (a) – Total, (b) – Industrial, (c) – Domestic and Utility, (d) – Irrigation, livestock and rural.

The reduction is connected with a decrease in regularly irrigated lands and especially limans and flooded hayfields. The most reduced areas of practically irrigated lands happened in West-Kazakhstan and Atyrau regions at 78 % and 92 %, respectively [7, 8, 9].

According to the conducted calculation of expected indicators in the medium-term prospect, the total growth of water resource's use will be noticed in the regions of the Russian Federation and the Republic of Kazakhstan connected with the predictable increase of the economy in the all studied areas (table 1, 2).

Overall, water consumption domestic and utility needs continues to fall in regions of the Russian Federation following the demographic prognosis. According to the basic scenario of the regional demographic forecast for Orenburg region, the population increase will be noticed in the medium-term prospect. According to the basic scenario, the total population number will be 98.7 % of 2018's level, and, according to the conservative variant, it will be 96.9 %, respectively. According to the traditional scenario of the development, reduction of the population number is expected in Chelyabinsk region at 2 %.

In the Republic of Kazakhstan's studied regions the population number's growth will be noticed that will reflect in an increase of domestic and utility water consumption in the medium-term prospect. The population's total number will increase at 3.2 %; the most growth will be seen in Atyrau region - at 10.7 %.

In the production and agro-industrial complex, the RF regions plan to keep the existing production structure with increasing output for the medium-term prospect. According to the basic variant, industrial water consumption will increase in the Russian Federation subjects at 25% according to the
conservative scenario and at 32% according to the basic variant. The increase in absolute values will be only 10.5 million m$^3$, compared with the growth of more than 100 million m$^3$ in other regions. The growth is conditioned by increased production of the metallurgical sector, electric power generation on TPS, mineral resources treatment, chemical production.

**Table 2.** Real and prognostic water resources' use in the regions of the Republic of Kazakhstan (mln. m$^3$).

| Fresh water consumption | 2018 Real | 2020 Prognosis | 2022 Prognosis | 2024 Prognosis |
|-------------------------|-----------|----------------|----------------|----------------|
| **Domestic and utility** |           |                |                |                |
| Aktobe region           | 36.0      | 36.2           | 36.7           | 37.2           |
| West-Kazakhstan region  | 23.0      | 23.2           | 23.4           | 23.5           |
| Atyrau region           | 24.0      | 24.9           | 25.8           | 26.6           |
| **Industrial**          |           |                |                |                |
| Aktobe region           | 12.0      | 12.2           | 12.9           | 13.5           |
| West-Kazakhstan region  | 11.0      | 11.1           | 11.8           | 12.8           |
| Atyrau region           | 96.0      | 112.2          | 126.6          | 140.6          |
| **Irrigation, livestock and rural** | | | | |
| Aktobe region           | 18.0      | 22.0           | 22.6           | 23.5           |
| West-Kazakhstan region  | 19.0      | 13.7           | 16.6           | 19.8           |
| Atyrau region           | 71.0      | 76.7           | 97.6           | 118.0          |

Correction of the values of water resource's use for industrial needs is possible due to reducing global prices at products of such sectors and decreased output, updating of production with an increase of efficiency of resources' use, including water.

In the Republic of Kazakhstan's studies regions, the growth of industrial water consumption will reach 35% to 2024 of 2018's level (table 3). The growth is connected mainly with production increase in mining and mineral resources processing (Aktobe region), the oil and gas sector (West-Kazakhstan and Atyrau regions).

Regarding agricultural water supply and irrigation, water resources' use in the RF subjects according to the conservative and basic variants of socio-economic development, the growth will be similar to industrial – 25% and 33.6% respectively by 2024. But it will be seven times lower in the absolute values and will not change the structure of total water consumption according to the volume of used water. The most increase of water use for such needs is predicted in the Republic of Bashkortostan due to plans to intensify agricultural production in all farms to enter into the five best RF regions on the agricultural output.

Orenburg region plans to restore and bring to the irrigation systems full power that demands increasing water resources' use for irrigation. Chelyabinsk region realizing the agro-industrial complex development program will bring in exploitation 80 ha of irrigated lands at the expense of reconstruction and building of new meliorated systems.

In the regions of the Republic of Kazakhstan, the total growth of agricultural water supply, irrigation, and watering of pastures will be 50% by 2024. Restoration of the water-meliorated economy happens under updating of an irrigated network and infrastructure, transit to drop irrigation. The most growth is forecasted in Atyrau region. Overall, the growth of water resources' use in absolute values is compared with the Russian Federation subjects.

4. Conclusion
As a result of the conducted analysis of retrospective parameters of water consumption and its structure in the regions of adjacent states in the Ural River basin, significant changes are reflecting socio-economic processes of these countries for the examined period. A decrease in water resource
use in all sectors of the economy has been noticed for the last 25 years in countries except the Republic of Kazakhstan. Industrial water consumption increased and transformed the structure of water use in the country. Stabilization of water consumption has been seen in the water use dynamics for the last time. The prognosis of water consumption values on the basis of medium-term socio-economic plans of the regional development proves the established trends. The growth of total water consumption will be by 2024 in the prospect. A decrease is predicted only for the domestic and utility water supply in the Russian Federation regions due to the population's natural decline. We should consider and correct water use's values following changes of prognoses of socio-economic development in connection with the current situatations.

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