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Water Use in Uzbekistan's Segment of the Zarafshan River: Analytical Review

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Abstract

The Zarafshan River is one of the main water supply sources for different sectors of Uzbekistan's national economy. The article aims to analyze water resources use in the Zarafshan River Basin, including calculating the amount of water that can be saved by introducing water-efficient irrigation technologies; testing the hypothesis of the possibility of restoring the Zarafshan's runoff as a tributary of the Amudarya River, as it was in ancient time; reviewing the experience of developed countries in injecting wastewater into deep aquifers, and the possibility of introducing the corresponding practices in Uzbekistan. The distance from the Zarafshan to the Amudarya was calculated based on the map, and turned out that today it is 127 km. The deployment of water-efficient technologies will allow saving enough water and calculating the water volume necessary for restoring the runoff. The study results show that the saved water will be enough to restore the Zarafshan's runoff, as well as to develop new irrigated land. The study findings likewise not only confirm the hypothesis of restoring the Zarafshan's runoff up to the Amudarya, thus increasing the river's water content, but also demonstrate that the saved water can be used to irrigate new farmland that can be further used for growing orchards and vineyards.

Key words: Zarafshan River, Amudarya River, water use, drip irrigation, wastewater injection, map, irrigation.

1. Introduction

As a natural resource, the Aral Sea Basin (ASB) provides material services and benefits for people, including raw materials, food, energy, wildlife resources, drinking water, air, as well as material goods. Thus, human health directly depends on ecosystem functions, services and condition. The biogeochemical cycle – which includes biogeochemical flows inside the system "air-dryland-hydrographic network-river valleys-Aral Sea" – serves the main mechanism for determining the state of ecosystems (Khodzhayev, Tashkhanova, 2016).

Excessive water use and discharge of wastewater into collector and drainage canals -- leading to salt accumulation and water pollution – are among the main unresolved problems (Yakubov, 2011).

Since ancient times, groundwater extraction has been done from shallow unconfined aquifers via the *kiarez* and wells, as well as with the help of animal towing power. In the 20^{th} century, they started developing deeper artesian aquifers for domestic and municipal water supply based on new well-drilling technologies (Franken, 2013).

Due to the relative constancy of river flow in the ASB and the rapidly growing population, water has been gradually becoming the main strategic resource in Central Asia. Over the past 75 years, the amount of water consumed per person has decreased 4.6 times in the area. Given that agriculture is the main water user, the question of how much water can be saved by introducing water-efficient technologies in agriculture and recirculated water supply systems in industry remains relevant.

In the Middle Ages, the Zarafshan River was a tributary of the Amudarya. Today, one of the challenges is that the latter does not reach the Aral Sea (Bologov, 2014). Restoring the runoff of the Zarafshan – since in ancient time it was one of the Amudarya's tributaries – might allow more Amudarya water reaching the Aral Sea. So, the main question is whether it is possible to restore the Zarafshan's runoff up to the Amudarya. The research aimed to test the hypothesis of the possibility of restoring the runoff of the Zarafshan River as a tributary of the Amudarya River (as it was in ancient time) to increase the water content of the latter and, thereby contribute to the overall improvement of the situation in the Aral Sea Basin by introducing water-efficient technologies, as well as calculating the distance from the mouth of the Zarafshan to the Amudarya.

2. Research area

2.1. Background

In Uzbekistan, the Zarafshan River flows through Samarqand, Navoiy and Buxoro (Bukhara) regions (Fig. 1.).

Since a number of districts inside the neighboring regions (Koson, Muborak, and Jizzakh) also use Zarafshan water resources, it appears reasonable to outline the boundaries of the constituencies through which the river flows. Samarqand Region is located in the Zarafshan River Basin in the central part of Uzbekistan. In the north, it borders on Nurata District of Navoiy Region, in the northwest – on Khatyrchi and Karmana Districts of Navoiy Region, in the west – on Qiziltepa District of Navoiy Region, in the south – on Qashqadaryo Region, specifically Koson, Muborak, Kitob and Chiroqchi Districts, in the east with the Panjakent

District of Sughd Region of the Republic of Tajikistan, in the northeast – on Jizzakh Region (Bakhmal, Gallaorol and Forish Districts). (Kulmatov et al., 2014).
The Kyzyl-Kum Plateau occupies the northwestern part of the region; the Nurata Mountain Ranges extend eastward; the region's southern part borders on the Zarafshan.

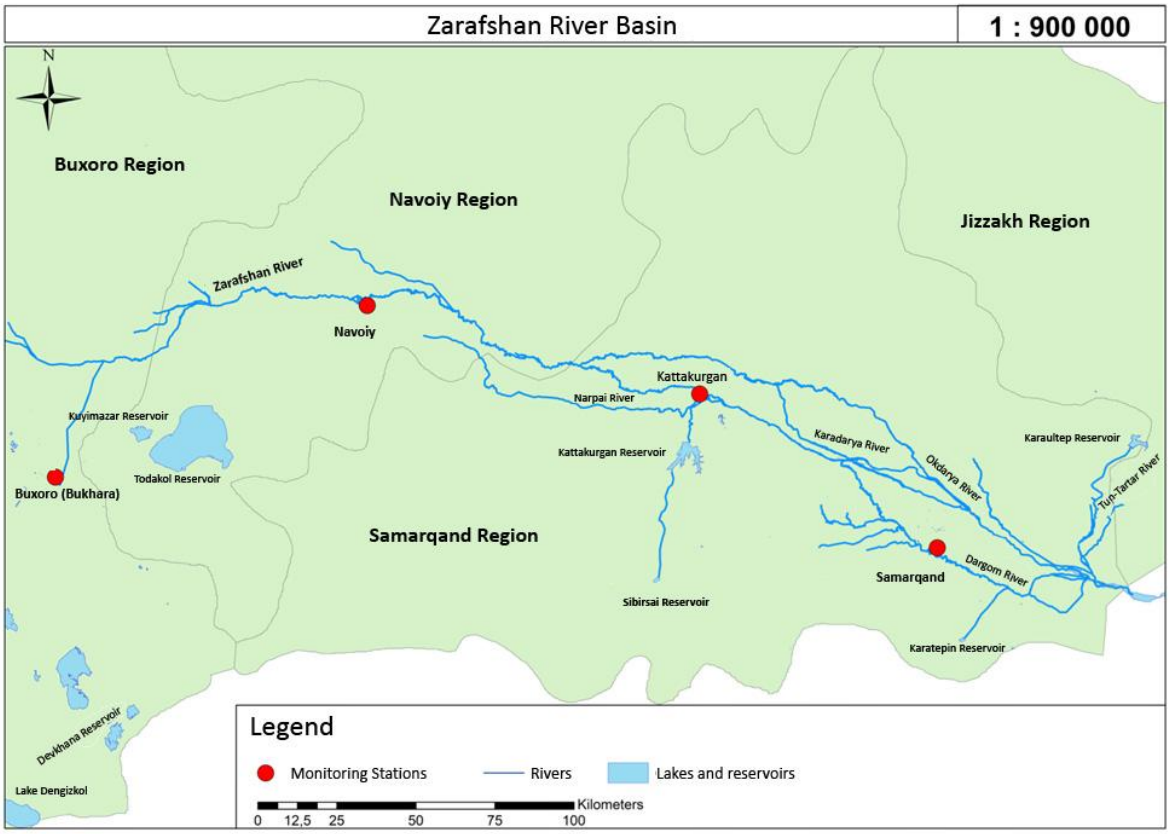

Figure 1. Zarafshan River Basin Map.

2.2. Climate

Since the Zarafshan's nourishment mainly consists of atmospheric precipitation and glacier melting, which in turn depends on climate peculiarities, the main climatic characteristics deserve attention. Geographically, Uzbekistan is located inside the Eurasian continent far from oceans and seas predetermining its sharp continental climate. For most of the year, it manifests itself in high summer temperatures, low rainfall, high evaporation, long and sultry summer; as well as significant daily and annual temperature fluctuationы, and relatively cold (for these latitudes) winters.

The climate in the country is determined by its geographical location (in middle southern and subtropical zones in the north), solar radiation, air circulation and terrain. Air circulation plays an important role in the formation of Uzbekistan's climate, which in turn affects snow cover formation. In winter, Arctic cold air masses penetrate into the country's territory from the north and northeast, even reaching its southern borders. As a result, at times the weather is clear and cold. In winter, midlatitude air fronts and cyclones develop, and precipitation in the form of rain and snow fall over Uzbekistan's territory. In summer, the flat part of the country facilitates the local Turan tropical air mass. The air is saturated with fine dust, and becomes dry and hot. All these lead to the establishment of a low-pressure zone, stimulate entry of warm and humid air from the northwest and west. However, the air quickly heats up preventing precipitation. The hot air masses freeze in the mountains in the eastern part of the country – as a result, precipitation occurs in foothills and valleys (Prokhorov, 1997).

Temperature distribution. To get an idea of heat distribution in Uzbekistan, it is important to know the mean annual air temperatures at different sites. In Nukus, the mean annual air temperature is +10.8°C, in Tashkent it is +11.9°C, in Termez it is +17.0°C. In Uzbekistan, summer is dry and hot with July mean air temperature in the lowland country's section reaching +26-30°C rising up to +31°C, and up to +32°C in the south (Prokhorov, 1997).

The climate of Samarqand is subtropical intra-continental with clear seasonality. In winter, short (4-8 days) frost periods can be observed (with nighttime temperature falling down to -12°C, and rarely down to -20°C). Thaws are also observed in the course of winter, when the temperature rises from -5°C up to +6°C, and often even higher, sometimes reaching +12-15°C. Transition periods are short. Summer temperatures are registered already in late March. In summer, the daytime temperature is usually above +20°C averaging +15°C. Summer lasts from the second half of April to mid-October. In June and July, the daytime temperature often exceeds +40°C (Prokhorov, 1997).

The climate in Navoiy is dry sharply continental also with clear seasonality. In summer, the temperature may reach +54°C, and drops down to -18°C in winter. On average, winter lasts from mid-November to the first half of March. In winter, short frosts are registered (with nighttime temperature falling down to -12°C, and rarely down to -18°C). Summer temperatures are mainly observed in mid and late March, and in April. In June and July, the daytime temperature exceeds +40°C (Prokhorov, 1997).

The climate in Buxoro (Bukhara) is influenced by the local semiarid conditions with extremely low precipitation (156 mm/year). Based on the Koeppen-Geiger classification, the region's rank is BSk. The average air temperature in Bukhara is +15°C. The lowest amount of precipitation occurs in July (mean of 0 mm). In March, rainfall peaks with the mean of 33 mm. Mean air temperatures are the highest in July (+28.8°C). As a rule, January is the coldest month of the year with the mean temperature reaching +0.8° (Climate Data Portal).

Precipitation is mainly observed in the winter-spring period. The annual rainfall in plain areas amounts to 80-200 mm, in foothills zones – 300-400 mm, on the western and southwestern slopes of mountain ranges – 600-800 mm. On the territory of Uzbekistan, five natural ecosystems can be distinguished: desert plains, foothill semi-deserts and steppes, river and coastal zones, wetlands and deltas, and mountains. Desert plain ecosystems occupy the largest area (70%) of the total country's territory. The target area belongs to river and coastal as well as to desert plain ecosystems. Natural pastures occupy 50.1% of the total land area, irrigated land – 9.7%. All types of irrigated land are characterized by high salinity and low humus content.

As per climate indicators, it is possible to distinguish three main climatic zones in Uzbekistan: deserts and dry steppes, foothills and mountains (Chub, 2007).

The annual evaporation in Uzbekistan's plains exceeds precipitation several fold (in Tashkent – 3.5 times, in Nukus – 27 times). The wind is very strong. Northwester and westerly winds dominate across the country. In the northeastern part, northwestern and northeastern winds blow. Southwest winds also blow in the southern part of the republic (Chub, 2007).

3. Research subject and method

3.1. Research subject

The Zarafshan flows through Tajikistan and Uzbekistan. In ancient times, it was a tributary of the Amudarya River, yet today the Zarafshan does not reach it and splits into branches in the Karakul Oasis. The Zarafshan River allows irrigating the land with rich cultural heritage (Kulmatov et al., 2014).

The Zarafshan River originates in the Zarafshan Glacier in Tajikistan at the merger of Mount Koksu at the intersection of the Turkestan and Zarafshan Ridges (altitude of approx. 2,800 m ASL). The river is over 870 km long. The highest runoff (250-690 m^3/s) is observed in July, and the lowest (28-60 m^3/s) in March (Kulmatov et al., 2014). At present, the river's length is 877 km (Prokhorov, 1972), including the 803 km (Mukhamedzhanov, 1978) section up to the Karakul Oasis, where it splits into branches. The total area of the Zarafshan River Basin is 41,860 km^2, including 17,710 km^2 in the mountain catchment zone. The mean annual runoff below the mouth of the Mogiendarya River amounts to 162 m^3/s. The highest (201 m^3/s) mean annual runoff was registered in 1973, and the lowest (112 m^3/s) in 1957. The river's annual maximum (250-690 m^3/s) runoff falls on July, and the lowest (28-60 m^3/s) on March. On January 31, 1928, the absolute minimum (24 m^3/s) discharge was recorded, and the absolute maximum (996 m^3/s) was recorded on May 31, 1964 (Aminov et al., 2003; Prokhorov, 1972). The mean annual water consumption at the Ravatkhoja Hydropower Plant (D5 Class HPP) near the Tajik-Uzbek border reaches its limit of 157.9 m^3/s, and is characterized by continuous flow dynamics (Groll et al., 2013).

To ensure the efficient use of the water withdrawn from the Zarafshan River, several hydroposts and artificial reservoirs (Kattakurgan and Kuyimazar) were built in the watershed

(Aminov et al., 2003). The Zarafshan connects with the Kashkadarya River via the Eskiankhor Canal (Aminov et al., 2003) and via the Iskityuyatartar Canal with the Sanzar River (Aminov et al., 2003).

Inside the Karakul Oasis, the Zarafshan River splits into several small branches – Taikyr, Gurdyush, Sarybazar, and Uygur – that were supplemented with a canal network in the course of economic activity (Aminov et al., 2003). Previously, distribution of the Zarafshan water was done through canals mainly located approx. 3 km from the town of Karakul. The Taikyr and Sarybazar Canals feed from the main river branches (Aminov et al., 2003). After the construction of the Amu-Karakul Canal, the former Zarafshan branches were connected with it as drainage canals. Currently, they feed mainly on the Amudarya water, although the possibility of obtaining water from the Zarafshan remains (Aminov et al., 2003).

3.2. Ground water quality

The ground water quality analyses performed by the Institute of Hydrogeology in the sections of the Zarafshan River Basin in Samarqand, Navoiy and Buxoro Regions revealed the following: in Samarqand ground water mineralization fluctuates between 0.118 and 1.032 g/L, i.e. water is suitable for drinking; in Navoiy, groundwater quality is not suitable for drinking due to high mineralization; the highest ground water salinity is observed close to the tailing dump of GMZ-1 (leach plant) and the sedimentary layer of Navoiyazot JSC. Water salinity there reached 4 MACs (maximum allowed concentration). In Buxoro, water salinity reaches 4.2 MACs. Water chemical composition is mainly sulphate-chloride, i.e. it is not suitable for potable water supply due to overall mineralization and hardness (Kulmatov, 2014).

3.3. River water use

Uzbekistan withdraws over 95% of the river's water, with Tajikistan on average withdrawing approx. 5-6% (Kulmatov et al., 2014). River water is mainly used for agricultural, municipal, power generation and industrial purposes (Fig. 2.).

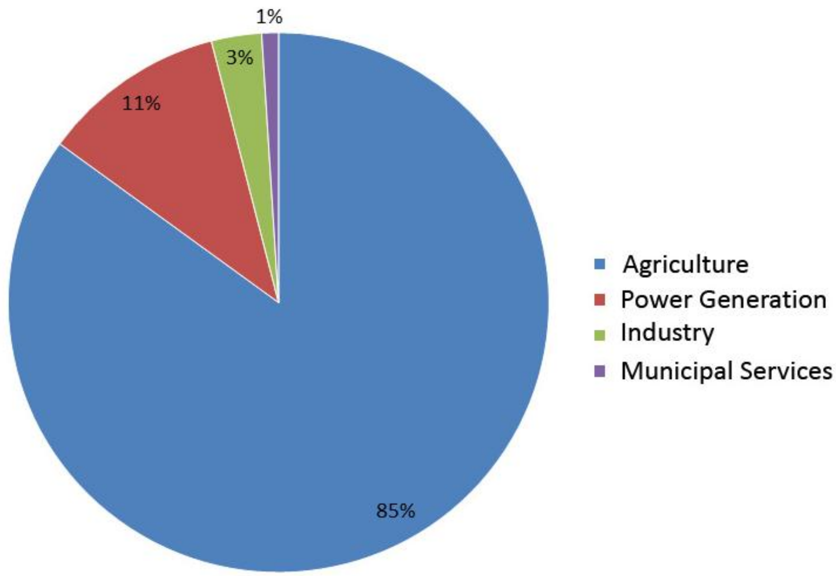

Figure 2. Water use by sectors in the Zarafshan River Basin (Kulmatov et al., 2014).

The total area of irrigated land in the Zarafshan Valley, excluding the irrigated farmland in Tajikistan, is 559.6 thous. hectares (Abduraimov, 2017), including 67% in Samarqand Region, 16% in Navoiy Region, 8.6% in Jizzakh Region, and 8.4% in Kashkadarya Region (Abduraimov, 2017).

The main crops grown in the Zarafshan Valley include cotton, cereals and vegetables. Despite the overall soil fertility, cotton still requires a lot of water and on average needs 600-700 kg of water per kilogram of dry mass of plants, including fruit organs. (Mamatov, 1992). About 42% of the total working population living in the valley are engaged in agriculture. In the Zarafshan Valley, there is a significant discrepancy between water demand and supply. Whereas the river originates in Tajikistan, the lion's share of irrigated land is located in Uzbekistan. The Zarafshan's runoff in Uzbekistan is managed by the Ministry of Agriculture and Water Management. In percentage terms, 70.2% are allocated for Samarqand Region (hosting 67% of the valley's irrigated land); 13.1% go to Navoiy Region (hosting 16% of the valley's irrigated land); 7.4% for Jizzakh Region (hosting 8.6% of the valley's irrigated land); and 9.3% for Kashkadarya Region (7.8% of the irrigated land), respectively (Abduraimov, 2017).

In the upper parts of the valley, the actual amount of water consumed can exceed the set limits; and be significantly below the set limits in its lower sections (Abduraimov, 2017).

In Samarqand Region, the annual water consumption for irrigation amounts to 2.4-2.5 km^3. Based on the data of the national Ministry of Water Resources and Agriculture, in 2002 the drainage and wastewater discharge amounted to 1.23 km^3; in 2003 – 1.46 km^3; and in 2004 –

1.50 km^3 (Kulmatov et al., 2013). Industrial wastewater intended for injection into subsurface formations, usually contains dissolved minerals and salts, organic compounds, mechanical impurities and pathogenic organisms (bacteria).

On average, the amount of water used is 2-4 km^3 per year. Broken down by regions, water consumption is as follows: whereas the total amount of water used for irrigation in Navoiy Region during 2002-2005 had increased from 1.67 km^3 to 1.88 km^3, the water flow in the collector network had grown from 0.75 km^3 to 0.88 km^3 (Kulmatov et al., 2013).

In Kashkadarya Region, in recent years water intake from basin rivers amounted to 4.2-4.5 km^3. Due to the lack of water resources during the irrigation season, the Eskiankhor Canal (1955) was built to transport water from the Dargom Canal (Zarafshan River Basin) and supply it to the Kashkadarya River via the Chimkurgan Reservoir (Chembarisov et al., 2018). The share of water from the Zarafshan River Basin consumed in Kashkadarya Region is 8.4%, i.e. 0.38 km^3 in absolute figures.

Water from the Zarafshan River comes to Jizzakh Region via the Sanzar Canal with the discharge of 4 m^3/sec or 14,400 m^3/h (Aminov et al., 2003), i.e. Jizzakh Region consumes 0.13 km^3/year of the Zarafshan's water. Adding the figures, it becomes obvious on average 4-5 km3 of water are withdrawn from the Zarafshan River every year.

3.4. Surface water quality

The analytical review of water consumption of the Zarafshan River's resources should include an assessment of pollution dynamics, as it affects river water quality. The dynamics of water pollution with petrochemicals along the river's course is presented in Fig. 3. below. During the study period, the river's petrochemical pollution was low. For instance, phenol content in the samples collected below the city of Samarqand was 1.2-2 times higher than the corresponding MAC. Long-term data on water mineralization change in the Zarafshan River are provided in Fig. 4. A constant increase – from 1.0 to 1.7 MAC – of mineralization along the river course was observed during the study period. The maximum mineralization (1.7 MAC) was detected at the line gauge below the city of Navoiy (Kulmatov et al., 2014). The chemical reactions taking place due to the injected water (waste) interacting with the aquifer cause precipitation, emission of heat, gases, etc., which – combined with bacterial growth – may cause partial well absorption and performance degradation (Goldberg, 1994).

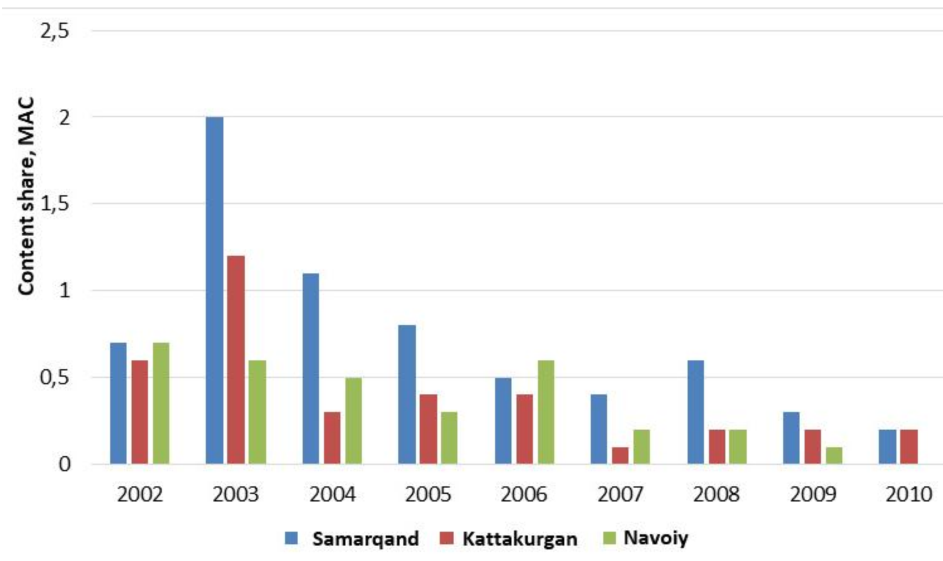

Figure 3. Dynamics of petrochemical water pollution along the Zarafshan River (Kulmatov et al., 2014).

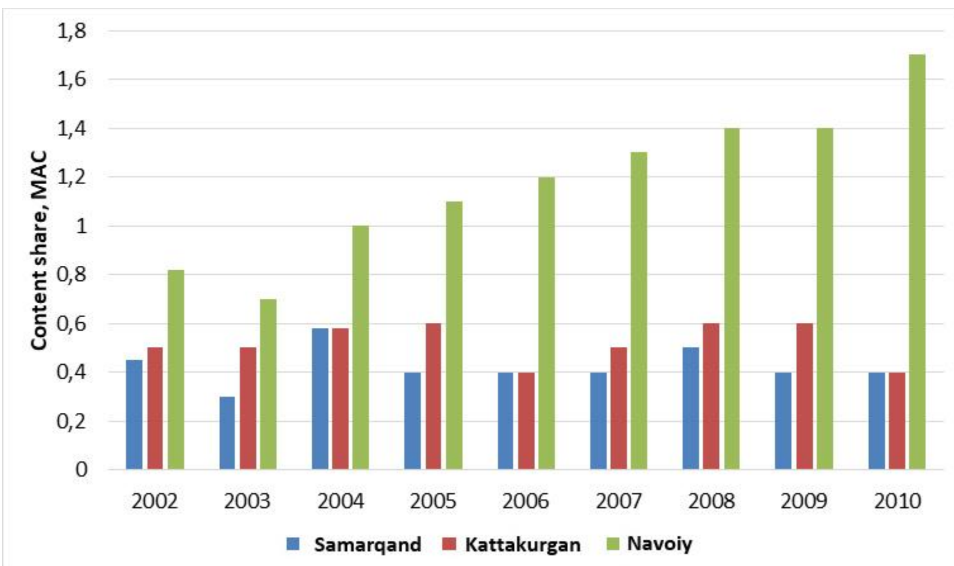

Figure 4. Dynamics of water mineralization change in the Zarafshan River (Kulmatov et al., 2014).

3.5. Research methodology

For the study, a formula-based analytical processing method was chosen. Interactive analytical processing is a data processing technology that involves the preparation of summarized (aggregated) information based on large multidimensional structured data arrays. Technology implementations are components of Business Intelligence software solutions (IT

Term Definitions, 2011). The analysis was carried out by map-based measuring of the distance between the Zarafshan River mouth and the Amudarya River (Fig. 5.).

In addition, the volume of water used for agriculture in each of the target regions was considered, and the total water volume was calculated, which can be saved by way of introducing drip irrigation. Also, the width of the canal via which it might be possible to transport the saved water to the Amudarya River was calculated. In addition, the garden area which can be irrigated using the water saved after the introduction of drip irrigation (in case the hypothesis of bringing the Zarafshan to the Amudarya is not confirmed) was calculated.

Maps are commonly used for getting spatial information. The distance from the Zarafshan to the Amudarya can be also measured using maps. This model of distance calculation was chosen, since today there is no literature providing information about the distance between the target points; a straight line was drawn because it gives the shortest distance between them. The question arises: why not restoring the ancient buried river channel? The answer is simple: since the Zarafshan River was a tributary of the Amudarya River in great antiquity, by today this channel, unfortunately, has not been preserved. The point where the Zarafshan River splits into three branches was located on the map and connected to the nearest point of the Amudarya River.

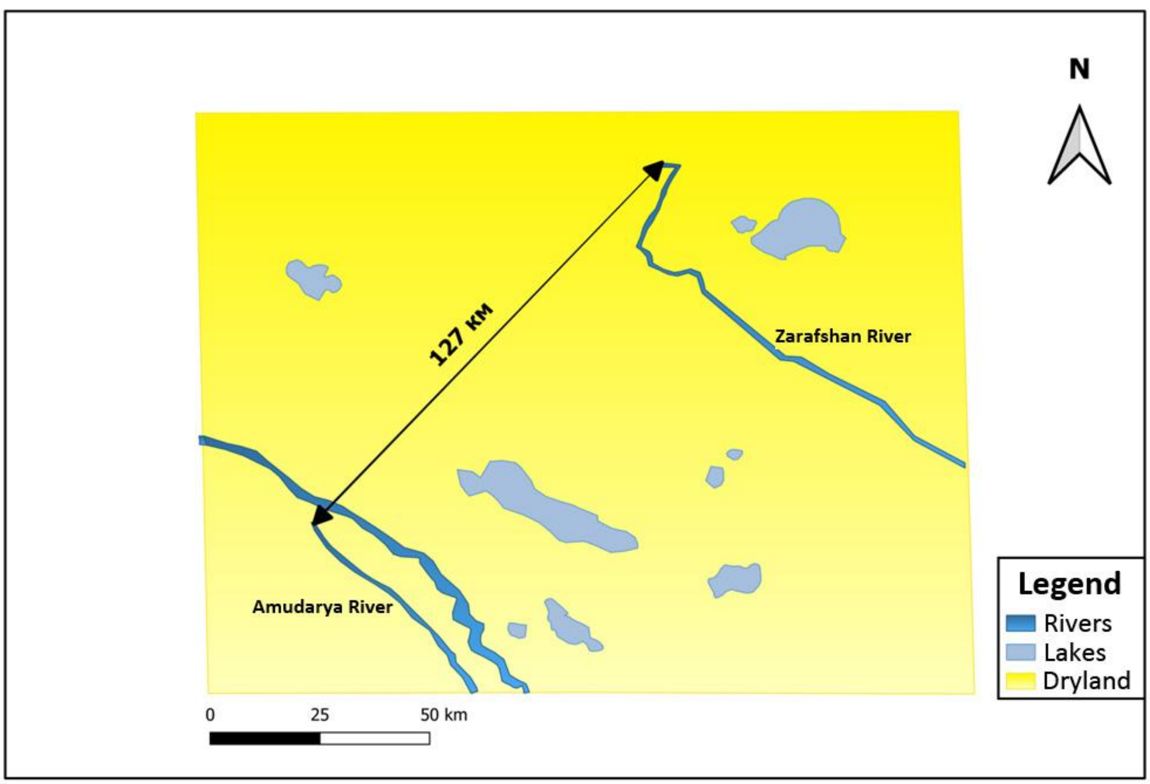

Figure 5. Distance between the mouth of the Zarafshan River and the Amudarya River.

The amount of water used for agriculture calculated during the study amounted to 4-5 km^3 (Kulmatov et al., 2014; Aminov et al., 2003; Chembarisov et al., 2018).

Considering that water saving thanks to drip irrigation depends on crops – 51% for cotton, 55% for maize (grain), 49.5% for wheat (soft), 51.5% for wheat (hard), and 31% for vegetables (tomatoes, cucumbers) (Pulatov et al., 2014), it is possible to calculate water consumption before and after the introduction of this irrigation technology (Table 1.). Thus, if on average 47.6% of the total 4-5 km^3 can be saved due to the deployment of drip irrigation, then in absolute terms it amounts to 2 km^3.

Table 1. Water consumption prior to and after introduction of water-efficient technologies.

Region	Prior to introduction of water-efficient technologies, km^3	After introduction of water-efficient technologies, km^3
Samarqand	2.5	1.19
Navoiy	1.88	0.89
Kashkadarya	0.38	0.18
Jizzakh	0.13	0.06
Total:	**4.89**	**2.32**

The volume of water required to fill the distance from the Zarafshan to the Amudarya (127 km) can be calculated as per the following formula:

$$V=X*B*H,$$

where *V* – water volume,
X – distance between the Zarafshan and the Amudarya,
B – river width,
H – river depth.

X = 127 km,
B = 100 m,
H = 4 m,
V = 127,000*100*4=50,800,000 m^3 or 0.51 km^3.

Based on the above calculations, it can be concluded that the hypothesis of restoring the Zarafshan runoff as a tributary to the Amudarya is confirmed, as only 0.51 km^3 are required to do it. The amount of water that will be lost due to evaporation and infiltration is currently unknown.

4. Research findings and discussion

4.1. Republic of Uzbekistan

The study results show that most of the water resources are used in agriculture. To date, the vast majority of farmers are using the conventional – furrow-type – irrigation system associated with significant evaporation and infiltration leading to large water losses. Introduction of modern water-efficient technologies (drip irrigation) in agriculture may allow saving up to 2-3 km^3 of water annually. The calculations executed within the framework of the research show that such saving will generate enough water both for the development of new farmland and restoration of the Amudarya runoff. Water-efficient technologies will allow expanding irrigated land by thousands of hectares and using them for growing orchards and vineyards. In turn, this will allow not only satisfying the domestic market demand, but also boosting exports.

4.2. Practices in developed countries

Let's consider the experiences of injecting (recharging) industrial wastewater into deep aquifers in other countries, and the possibility of applying this technology in Uzbekistan.

As mentioned above, the volume of wastewater discharged into the target river averages 1.4 km^3/year. Industrial wastewater injection into deep aquifers is a common wastewater management practice. For instance, in Western Kazakhstan in order to ensure public health and safety as well as environment protection a vast experience of pumping industrial wastewater into terrigenous suprasalt deposits has been accumulated. The first positive results of injecting industrial wastewater into subsalt carbonates were obtained. Special attention was paid to the technique of vibration clay treatment and filtration of well filters in the oil and gas industry, which can be applied during the development of productive formations in production wells and injection of industrial wastewater into deep aquifers (Ayupov, Musakayeva, 2016). In order to avoid further pollution, it is necessary to explore the experiences of developed countries.

For example, Germany has several hundred underground landfills used for disposing sewage from potassium, chemical, oil and gas industries. Wastewater is pumped to the depth of 1,100 m or more into carbonate and terrigenous rock mass. Injection speed is 120-4,800 m^3/day per well at wellhead pressure of 1.0-2.0 MPa. Annually, the potassium enterprises in German Hessen inject 400 mln m^3 of wastewater via 10 wells to the depth of 325-525 m (Ilchenko, 2000).

In the UK, for 60 years commercial wastewater has been injected into the Cretaceous deposits near Whitchurch via 19 wells.

In France, the first injection well was drilled in 1970 at the Grandpuy plant 60 km away from Paris. During 1950-1980, 1,100 m^3/day of wastewater were pumped into the Jurassic caldera at the wellhead pressure of 1.0 MPa (Ilchenko, 2000).

In Canada, there are several hundred injection wells for pumping industrial wastewater into underground aquifers. Ontario alone has 16 such wells. Over 30,000 m^3 of wastewater from refineries is disposed of every day in Alberta (Ilchenko, 2000).

Likewise, in Japan multiple types of industrial and household wastewater are pumped underground. For instance, for many years a former copper mine has been used for injecting acidic drainage water into 150 wells 35-60 m deep drilled from the mine in the andesite formation with seat sandstone. Every day, 13,000 m^3 of wastewater get injected underground via this mine (Ilchenko, 2000).

5. Conclusions

In Uzbekistan, along with the Amudarya and Syrdarya the Zarafshan River is one of the main water sources. In ancient times, it was a tributary of the Amudarya. Thanks to modern technologies, it may be possible to restore the runoff and connect the river channels, which will require 0.5 km^3 of water from the theoretically saved 2 km^3. Likewise, the introduction of drip irrigation may allow irrigating new farmland, orchards and vineyards with the saved water, which will positively affect not only the economic, but also the social living conditions of Uzbekistan’s population.

The Decree of the President of Uzbekistan “On 2018-2019 State Program for the Development of Irrigation and Improvement of Reclamation Status of Irrigated Land” of November 27, 2017 stipulates for covering 22,060 hectares of land in the country in the next 2 years, including 9,560 ha in 2018, and another 12,500 ha in 2019 (Decree of the President of the Republic of Uzbekistan, 2017). As of today, only 12,500 ha of farmland use drip irrigation. The introduction of this technology in the agricultural land of the Zarafshan River Basin may lead to several-fold expansion of such land.

To date, untreated wastewater, specifically industrial wastewater, is discharged into the river. Inaccessibility of information about the corresponding enterprises complicates their monitoring. It is necessary to obligate water users to provide actual data to environmental authorities to allow them to prevent pollution of the Zarafshan River with heavy metals and other pollutants in a timely manner.

6. Recommendations

Given that cotton is the main crop grown on the irrigated land of the Zarafshan River Basin, and that it requires a lot of water, it is recommended to replace cotton with a less moisture-intensive crop (for example, saffron), which can be used as a spice and food dye obtained from the dried stigma of saffron flower seeds. It has an orange color, and has long been considered one of the most expensive spices, requiring little water (Hill, 2004). It is also recommended to study the experience of countries that have been long engaged in saffron cultivation and export, and implement the corresponding practices in a pilot plot in Uzbekistan. If successful, saffron cultivation should be expanded nationwide. This will help not only saving water, but also making more profit compared to cotton production. In addition, knowing the average amount of water that can be saved by introducing drip irrigation, it is recommended to use it for planting orchards and vineyards. The calculations performed within the framework of the study show that proper management of such saved water may allow developing and growing additional hundreds of thousands of hectares of new gardens. An underground wastewater injection system should also be introduced. It is likewise recommended to establish collaborations and information exchange among hydrologists and hydrogeologists, so that they can join their efforts in protecting the water resources and preventing the further pollution of the Zarafshan River.

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