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WATER WITHDRAWAL AND CLIMATE CHANGE CAUSING WATER QUALITY PROBLEMS ALONG THE ZARAFSHAN RIVER (TAJIKISTAN, UZBEKISTAN)

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The Zarafshan River is a typical transboundary (Tajikistan/Uzbekistan) river in Central Asia with a large mountainous part of the upper river catchment, covered by snow and ice. These mountains are part of Central Asia's „water towers" [1]. The highly dissected mountain relief with its steep slopes, the relatively negligible water retention by thin soils, and weak evaporation due to low temperatures in high mountains, cause a rapid runoff onto the adjacent semi-arid and desert plains, creating a good water supply where little is precipitated [2]. That is why river valleys of the lowland part were and are the main centers of the agricultural and social development in Central Asia. The research presented here provides a detailed overview of the Zarafshan River, the lifeline for more than six million people. The findings are based on field measurements, existing data from the national hydrometeorological services and an extensive literature analysis. They cover the status quo of hydrological characteristics of the Zarafshan as well as water quality parameters. The discharge of the Zarafshan is characterized by a high natural discharge dynamic in the mountainous upper parts and by sizeable anthropogenic water extractions in the lower parts of the catchment, where on average 60.6% of the available water is diverted for irrigation purposes in the Samarkand and Navoi provinces. The water quality is heavily affected by the unsustainable land use and inadequate/missing water purification techniques. The reduced discharge and the return flow of untreated agricultural drainage water lead to a critical pollution of the river in the lower parts of the catchment. Additional sources of pollutants where identified in the Navoi special economic area and the mining industry in the Tajik part of the catchment. The impact of the global climate change and the socioeconomic growth on the water availability and the water demand will aggravate the detected problems and might lead to severe local and transboundary upstream-downstream water conflicts within the next decades.

Key words: Discharge reduction, water extraction, irrigation, mineralization, Zarafshan River

ИЗМЕНЕНИЕ ВОДЫ И ИЗМЕНЕНИЕ КЛИМАТА, ВЫЗЫВАЮЩЕЕ ПРОБЛЕМЫ КАЧЕСТВА ВОДЫ НА РЕКЕ ЗЕРАВШАН (ТАДЖИКИСТАН, УЗБЕКИСТАН)

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Река Зеравшан является типичной трансграничной (Таджикистан / Узбекистан) рекой в Центральной Азии с большой горной частью верхнего водосбора, покрытого снегом и льдом. Эти горы являются частью «водонапорных башен» Центральной Азии [1]. Высоко расчлененный горный рельеф с крутыми склонами, относительно незначительное удержание воды тонкими почвами и слабое испарение из-за низких температур в высоких горах вызывают быстрый сток на соседние полузасушливые и пустынные равнины, создавая хороший запас воды, где мало осаждается [2]. Именно поэтому речные долины равнинной части были и остаются главными центрами сельскохозяйственного и социального развития в Центральной Азии. Представленное здесь исследование дает подробный обзор реки Зеравшан, которая является спасательным кругом для более чем шести миллионов человек. Результаты основаны на полевых измерениях, существующих данных национальных гидрометеорологических служб и обширном анализе литературы. Они охватывают статус-кво гидрологических характеристик Зеравшана, а также параметры качества воды. Слив Зеравшана характеризуется высокой естественной динамикой расхода в горных верхних частях и значительными антропогенными водозаборами в нижних частях водосбора, где в среднем 60,6% имеющейся воды отводится для целей орошения в Самарканде и Навоийская губерния. На качество воды сильно влияют неустойчивое землепользование и неадекватные / недостающие методы очистки воды. Уменьшение сброса и обратный поток неочищенных сельскохозяйственных дренажных вод приводят к критическому загрязнению реки в нижних частях водосбора. Дополнительные источники загрязняющих веществ были выявлены в Навоийской особой экономической зоне и в горнодобывающей промышленности в таджикской части водосбора. Влияние глобального изменения климата и социально-экономического роста на доступность воды и спрос на воду усугубит выявленные проблемы и может привести к серьезным локальным и трансграничным конфликтам между водами вверх и вниз по течению в течение следующих десятилетий.

Ключевые слова: уменьшение стока; водозабор; орошение; минерализация; река Зеравшан.

Introduction and Research Overview

River catchments of Central Asia show a big variation of peculiarities. A great number of rivers are part of the vast undrained interior Eurasian basin, the biggest inland watershed of the Earth. Therefore a high share of water courses flow into terminal lakes, with considerable lake level fluctuations, changing extensions and translocations. Besides the Amu-Darya and Syr-Darya, the Zarafshan River was, until 1957, was the third largest river of the Aral Sea basin and the mightiest tributary to the Amu-Darya. Since 1957 the discharge of the Zarafshan River has not reached the Amu-Darya due to an extensive anthropogenic water withdrawal. For irrigation purposes (Table 1).

The Tajik headwater of the Zarafshan is characterized by high relief energy, low density of vegetation cover, soil erosion processes, a high sediment load, pollution by mining activities, pastureland use, as well as plans for the construction of dams for hydropower generation. In Uzbekistan the Zarafshan River provides both the ancient river oases of Samarkand and Bukhara and the industrial center of Navoi with the water required. 96% of all surface water resources in the Zarafshan River catchment are consumed in the Uzbek part and while the annual water deficit is already 1.6 km^3, the strong socio-economic growth will further increase the water demand in the near future [3]. Both water quantity and water quality data had been observed during the Soviet period along the Zarafshan River. However, after the breakdown of the Soviet Union no joint transboundary measurements were carried out along the Tajik and the Uzbek part of the Zarafshan River, and the separate national measurements in the two states parts were carried out only sporadically. The maintenance of the scientific infrastructure has been neglected and the essential interregional data exchange is nonexistent.

Irrigated areas and water withdrawal for irrigation in the Aral Sea catchment [7]

Year	Irrigated area (mln. ha)	Water use (km^3)	Salt content of water (g/l)	Water use (m^3/ha)	Collector water (km^3)
1915	3.246*	<15.0	0.3-0.5	2,600	-
1931	3.071	20.0	0.3-0.5	5,300	-
1940	4.337	26.1	0.3-0.6	6,000	-
1950	4.545	32.1	0.3-0.6	7,100	1-2
1960	4.982	40.4	0.3-0.7	8,200	5-6
1970	5.129	50.3	0.5-1.0	9,800	10-12
1980	6.127	65.8	0.7-1.0	10,700	29-30
1990	6.930	86.0	1.0-2.5	12,400	32-34

Within the WAZA-CARE project along the Zarafshan River, from the headwater in Tajikistan to the downstream section in Uzbekistan, water deficit and water quality problems have been studied. These investigations were the first analyses of the transboundary sections of the Zarafshon River both in Tajikistan and in Uzbekistan after the breakdown of the Soviet Union [4]. Field data was collected at 48 sampling sites (24 in Tajikistan, 25 in Uzbekistan) along the Zarafshan River, its tributaries and the vast irrigation and drainage network (Figure 1). Based on these measurements (pH, conductivity, temperature, selected elements and macrozoobenthos) and existing data from 11 hydrological, 8 meteorological and 7 water quality monitoring stations, analyses of the quantity and quality of the Zarafshan water resources were carried out, working together with experts from Tajikistan and Uzbekistan who had not collaborated on that matter since the 1990s [3, 5, 6].

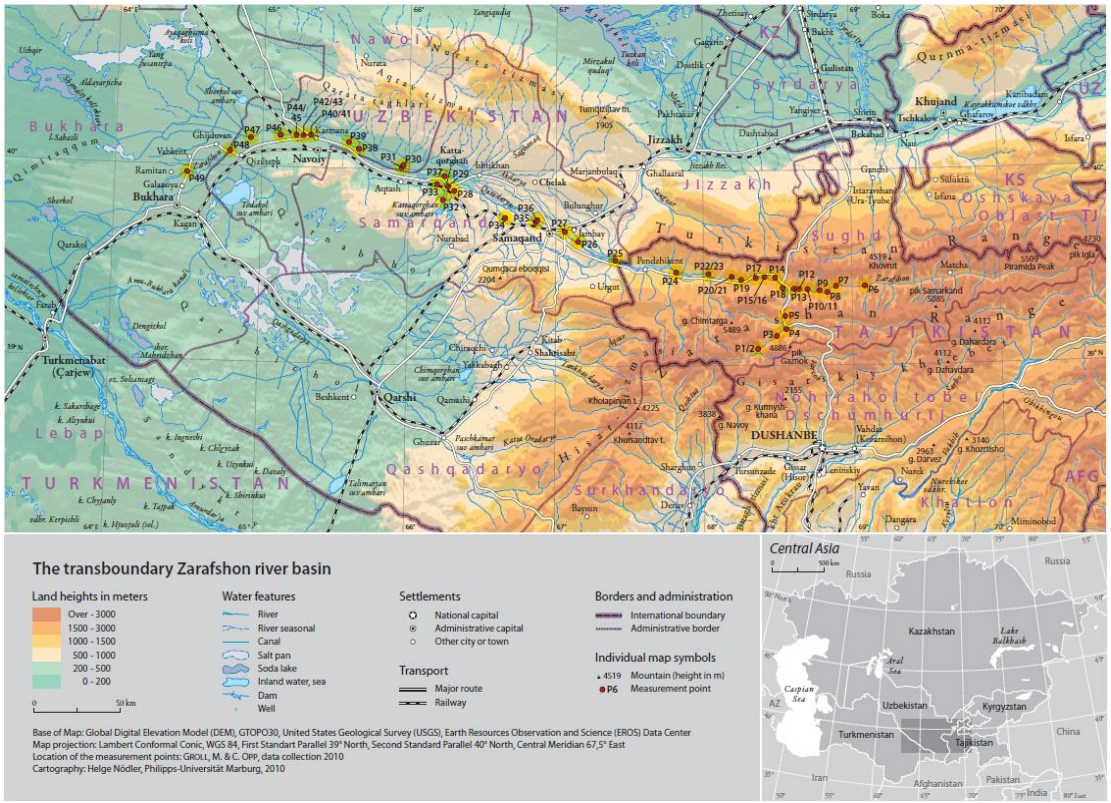

Fig. 1. Zarafshan River basin with measuring points

Results

Both meteorological and hydrological changes can be observed along the Zarafshan River from the upper to the lower sections of the catchment with on average increasing temperatures and decreasing precipitation amounts. However, the most significant change of the discharge can be observed at Ravathodja, the first hydropost on Uzbek territory, located just downstream of the borderline, after the water withdrawals of three big canals (Figure 2). The maximum long-term average discharge of the Zarafshan River is 157.9 m³/s at the Tajik-Uzbek border (hydropost Ravathodja). Immediately downstream of this point 61.8% of the water are withdrawn throughout the year and channeled into an irrigation network of 3,140 km length (+ 17,400 km of interfarm canals). The mineralization, as a parameter for the overall water quality increased exponentially (R^2=0.926) between the Tajik-Uzbek border (243.1 mg/l) and the official end of the river (1,799.0 mg/l) (Figure 3). Both the transboundary field measurements and the long-term monitoring conducted by the UZHYDROMET showed, that the national threshold for the mineralization is exceeded downstream of Navoi, where the agricultural and the industrial waste water have a combined effect. The analysis of different water body categories identified the drainage water collectors as the main source of this pollution as the average mineralization in the sampled collectors was 2,235 mg/l. A similar increase along the Zarafshon was detected for Nitrate (4-10 mg/l at the border and up to 75 mg/l downstream of Navoi), Copper (0.002 mg/l at the border, 2.35 mg/l downstream of Navoi), Chromate VI (0.5 mg/l at the border, 1.5 mg/l downstream of Navoi) and Phenols (0 mg/l at the border, 0.01 mg/l downstream of Navoi). Phosphate also showed increased concentrations in the Uzbek part of the catchment (up to 100 mg/l), but the highest levels of phosphate were detected in the upper Tajik catchment were erosion from the steep and hardly vegetated slopes led to concentrations of up to 250 mg/l.

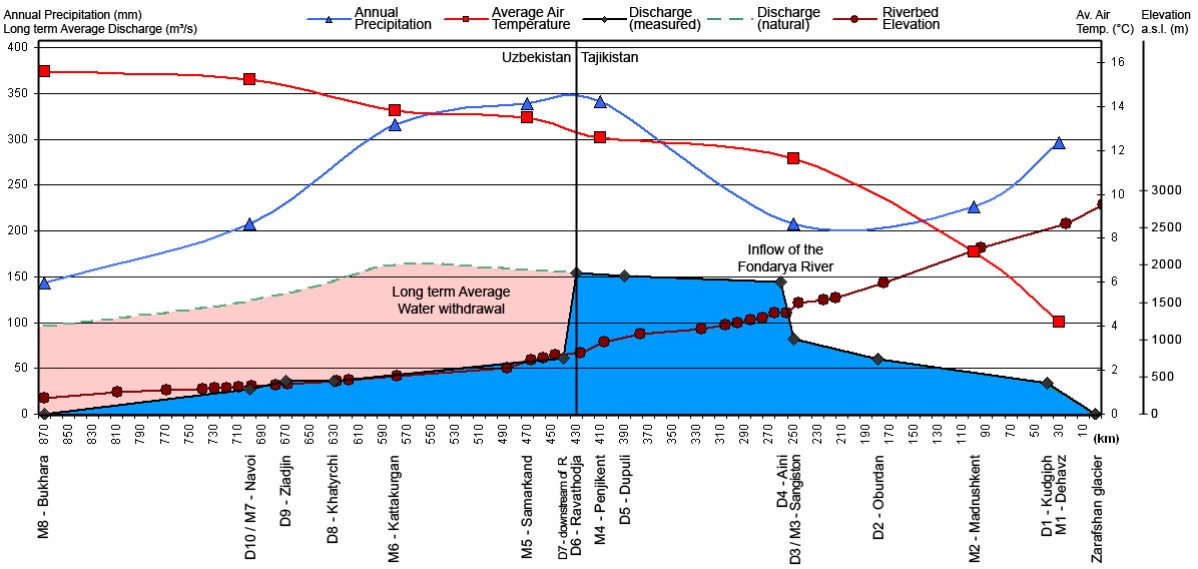

Fig. 2. Meteorological and hydrological characterization of the Zarafshan River

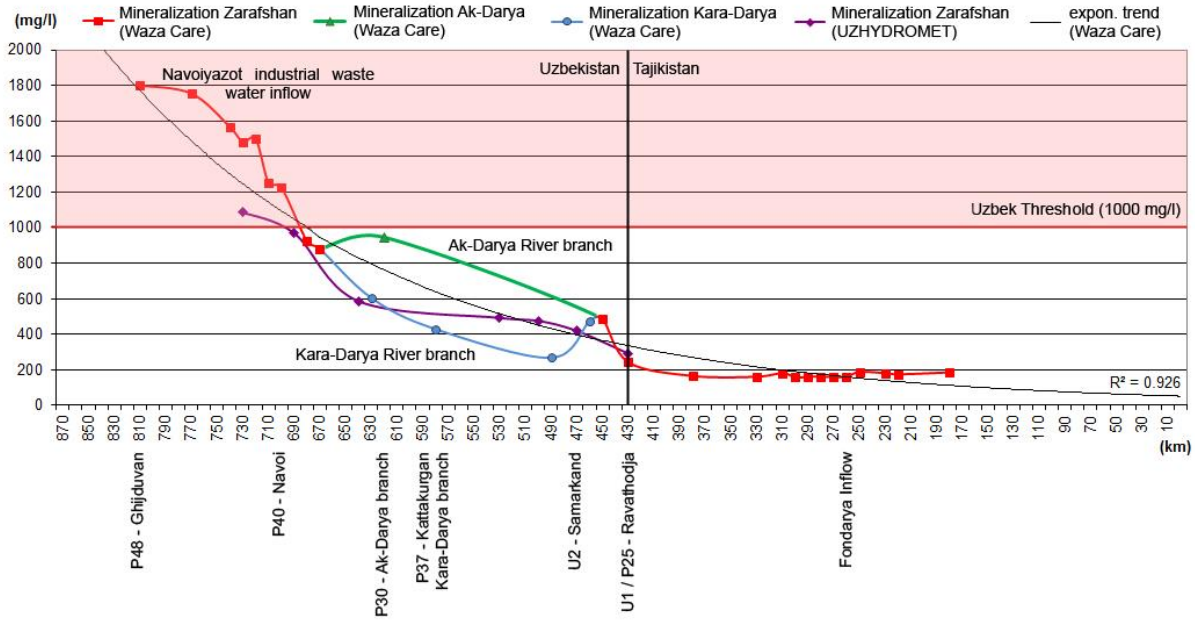

Fig. 3. Mineralization along the Zarafshan River [3, 7]

The water quality of the Zarafshan River is critical and at the same time it is the sole source for drinking water for the rural population. The health implications of this situation are not yet documented but would be well worth investigating, as the future development will only lead to a worsening of the current problems. As an effect of the global warming the Central Asian glaciers are receding at an accelerating speed (0.026-0.5% per year during the first half of the 20th century, 0.14-1.0% during the second half of the 20th century) [1, 3]. By 2050 the Zarafshan glacier could be reduced to just 50% of its current size while the large number of smaller glaciers (<1km²) in the catchment will be completely gone. As the Zarafshan River is mainly fed by glacier melt water this will directly affect the runoff, which could be up to 30% lower than today. The water demand on the other hand will equally increase over the next decades as the higher air temperatures lead to higher evapotranspiration rates, longer vegetative periods and increased municipal and industrial water consumption. The latter two will also increase due to the strong population and economic growth (currently +1.7% and +8% per year) in the region, which might result in an overall water demand which is up to 30% higher than at

present [3, 6, 8]. A third factor influencing the water availability is the possible implementation of one or more hydropower projects in the Tajik upper catchment. Currently 16 small and medium sized power plants (between 45 and 250 MW each) with a total capacity of 2,300 MW are planned in the Zarafshan catchment. These 16 projects represent 43% of all hydropower projects planned in Tajikistan, which shows the great importance of this region for the Tajik government [3]. If or when one or more of these projects will be implemented is uncertain as it depends on the investment of foreign capital, but as hydropower is the most important resource in Tajikistan and as the country still heavily depends on importing energy, these plans have a high priority. One or more dams and reservoirs in the upper Zarafshan would alter both the discharge and sediment regimes and influence the downstream water use. One of the planned hydropower projects also involves the diversion of Zarafshan water through the Turkestan Mountain Range into the neighboring Syr Darya catchment (near Istaravshon) which could dramatically decrease the quantity of the available water resources in the downstream catchment.

The combination of reduced water availability and increased water demand could increase the annual water deficit from currently 1.6 km³ to up to 5.8 km³ [6]. As the deficit would be higher than the available water resources, the reuse of drainage and waste water will be intensified and additional water resources (ground water, water diverted from another catchment) might be utilized to cover the demand. These solutions will cause problems of their own so that a strong emphasize has to be placed on water saving and purification techniques in order to overcome the upcoming challenges.

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