Long-term changes in mineralization and ionic composition of the Karadarya and Naryn Rivers, Uzbekistan

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Abstract. In the article the relationships between mineralization, ionic composition, and water discharge of the Karadarya and Naryn Rivers has been studied. In Karadarya River-Uchtepa and Naryn River-Uchkurgan points during the decreasing of water discharge the increasing of the water mineralization is observed. In the Karadarya River-Uchtepa and Naryn River-mouth points high value of mineralization is mainly because sulfate (SO_4^{2-}) and magnesium (Mg^{2+}) concentration.

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Key words: mineralization; main ions; water discharge; observation points; low-water year; high-water year; Karadarya River; Naryn River; Uzbekistan.

Introduction

The Naryn and Karadarya rivers are main tributaries of the Syr Darya River and flow through one of the most densely populated areas of Uzbekistan – the Fergana Valley [1]. The feeding type of these rivers is snow-glacial. In the Karadarya River, high-water period under natural conditions was observed in March-June, with maximum discharge in May and minimum discharge in October-February. In the Naryn River, the high-water period is from April to August with a maximum in June, the low water period is observed from October to February [2,3]. The water of these rivers is used for irrigation, as well as for water supply of cities and towns along the rivers. Water quality of rivers is essential in water availability for domestic, industrial and agricultural needs of Andijan and Namangan provinces. Mineralization of the river water is an important indicator in assessing of the river water quality for the water supply. Changes in river water mineralization depend entirely on the chemical composition of the water source, as well as on the water content of the year [4,5,6]. The study of the relationship between mineralization and water discharge is of high importance for for investigating the processes of formation of the chemical composition of natural waters and its spatial-temporal changes.

The aim of the work is to identify and investigate the relationship between mineralization, ionic composition and water discharge of the Karadarya and Naryn rivers.

Object of study is the Naryn and Karadarya rivers. These rivers originate in the territory of Kyrgyzstan and flow into Uzbekistan. Within the territory of Uzbekistan, these rivers are forming the Syrdarya River.

Materials and methods. Long-term water quality observation data were used and traditional methods of hydrochemical calculations and estimations, generalization, and mathematical statistics were applied.

Results and discussion. Regular observations of water chemistry in the Karadarya River have been started since 1976 at the observation points Karabagish (5 km downstream of the Andijan Reservoir dam) and Uchtepa (2 km downstream of Uchtepa village). These observation points are coincided with hydrological gauging stations. In 1985 observation points Andijan city (1 km above the wastewater discharges of treatment facilities of the Andijan city water pipeline and 2.7 km below the mouth of the Asaka discharge) were opened. In 1995, the Karabagish observation point was closed. Currently, observations of the chemical composition of the Karadarya River water are carried out at 3 observation points (Uchtepa village, above and below the Andijan city) [7,8].

Regular observations of the Naryn River water chemistry were started in 1977 at the upstream observation point Uchkurgan (3 km upstream of Uchkurgan town). In 1984, observation points were opened below Uchkurgan (1 km below Uchkurgan town) and in 1985 at the river mouth (0.2 km above the river mouth). The observation points above and below Uchkurgan are coincided with the hydrological gauging station, but in 1993 observations at these points were stopped and only at the river mouth point observations are still being carried out. Due to technical reasons, the one and only observation point at the mouth of the river was closed in 1992-1995, but in 1996 it was reopened and currently observations of the chemical composition of the Naryn River water are carried out at this point. There is no gauging station at this observation point, water discharge is not measured and calculated [7,8].

Water mineralization in the Karadarya and Naryn rivers depends on water discharge. The general course of mineralization change is mainly in inverse dependence on the water discharge. At equal water discharges, mineralization is higher at the rise of floods than at the fall and during low-water periods. Table 1 shows the long-term averages of mineralization and water composition of the Karadarya and Naryn rivers.

Table 1. Mineralization and water type of the Karadarya and Naryn rivers for 1976-2022

Observation point	Mineralization, mg/dm^3	Water type	Observation years
Karadarya River			
Karadarya River - Karabagish village	322.4-429.2	Ca-HCO_3 type	1976-1994
Karadarya River – Andijan city, above the WWTP	415.0-552.1 381.9-926.3	Ca-HCO_3 type	1985-1995 1996-2022
Karadarya River – Andijan city, below the Asaka discharge	429.2-565.4 408.4-943.6	Ca-HCO_3 type	1985-1995 1996-2022
Karadarya River - Uchtepa village	468.8-742.1 467.5-832.1	Ca-HCO_3 type	1976-1995 1996-2022
Naryn River			
Naryn River - above Uchkurgan town	255.4-356.3	Ca-HCO_3 type	1977-1993
Naryn River - below Uchkurgan town	233.8-303.5	Ca-HCO_3 type	1986-1993
Naryn River – river mouth	322.4-574.0 349.5-951.5	Ca-HCO_3 type	1985-1992 1996-2022

Karadarya River water in the Karabagish point refers to waters of average mineralization, and in the Uchtepa and Andijan points of refers to waters of medium and increased mineralization. Naryn River water at points above and below Uchkurgan refers to water of medium mineralization, and at the river mouth point refers to water of medium and increased mineralization.

The intra-annual distribution of water mineralization in the Karadarya and Naryn rivers is closely related to water availability. Features of the intra-annual hydrological and hydrochemical regimes of the rivers were studied at the points where water discharge is measured – Uchtepa (Karadarya River) and Uchkurgan (Naryn River) (Fig. 2 and 3).

Analysis of the relationship between mineralization and water discharge during years of different water content on two rivers showed that in decreasing of water discharge, mineralization increases. It was revealed that for years of different water availability mineralization values of Karadarya River in Uchtepa in low-water year (1986) ranged from 457 mg/dm^3 (June) to 687 mg/dm^3 (September), in high-water year (1988) from 369 mg/dm^3 (July) to 636 mg/dm^3 (November). Mineralization values of Naryn River water in Uchkurgan point in low-water year (1978) ranged from 254.6 mg/dm^3 (September) to 545.5 mg/dm^3 (January), in high-water year (1989) from 239 mg/dm^3 (July) to 303 mg/dm^3 (May).

For these observation points regression equations representing the relationship between mineralization and water discharge depend on water content of year were obtained and their accuracy was evaluated (Table 2).

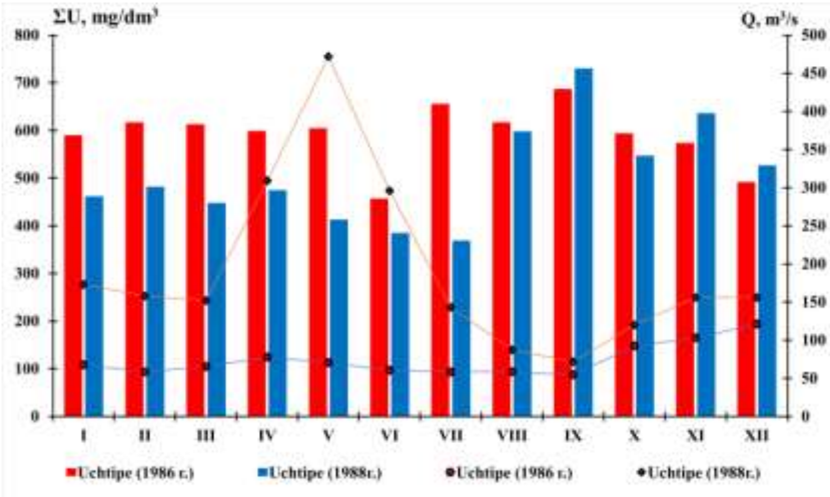

Figure 2. Changes in monthly average mineralization and water discharge in Karadarya River, Uchtepa (low-water-1986, high-water-1988)

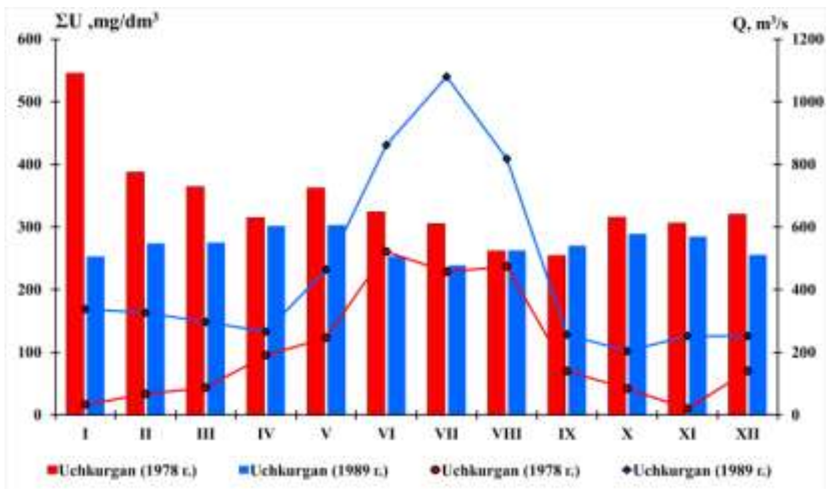

Figure 3. Changes in monthly average mineralization and water discharge in Naryn River, Uchkurgan (low-water-1978, high-water-1989)

As a result of the analysis, the relationships between mineralization and water discharge were determined, and the dependences ΣU=f(Q) were obtained for high-water and low-water years.

Table 2. Regression equations representing the relationship between water mineralization and water discharge of the Karadarya and Naryn rivers in different water content years

Observation point	Period	Mineralization, mg/dm^3	Water discharge, m^3/s	Equations	r ± σ_r
Karadarya River, Uchtepa village	Low -water (1986)	591.8	85.8	y=-0.8193x+662.07	0.25 ± 0.18
	High-water (1988)	489.3	219.7	y=-0.3116x+557.79	0.58 ± 0.13
Naryn River, above Uchkurgan town	Low-water (1978)	338.8	205.2	y=-0.1742x+374.54	0.41 ± 0.16
	High-water (1989)	271.8	451.3	y=-0.0403x+290	0.59 ± 0.13

* Note: r ± σ_r is the correlation coefficient and its error.

The ion content determines the chemical type of water and its most important properties. The main ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}) form the main part of the mineral composition of river water. One of the most important issues in studying the features of formation of the ionic composition of natural waters is the relationship between mineralization and its individual components. To calculate the ionic composition of the water Karadarya and Naryn rivers with different mineralization, regression equations representing the dependence of mineralization and main ions were obtained. Table 3 shows examples of the regression equation in river downstream. By analysis of correlation equations between water mineralization and the amount of major ions for all these observation points, it was revealed that at the points of Uchtepa (Karadarya River) and Naryn River mouth, high values of mineralization is associated with concentration of SO_4^{2-} and Mg^{2+} ions.

Table 3. Regression equations of relationships between water mineralization and ionic composition in the Karadarya and Naryn rivers

Karadarya River, Uchtepa village (1996-2022)		Naryn River, mouth (1996-2022)	
Regression equation	$r \pm \sigma_r$	Regression equation	$r \pm \sigma_r$
HCO_3^- =0.205ΣU+82.921	0.52±0.10	HCO_3^- = 0.0085ΣU+162.09	0.06±0.13
SO_4^{2-} = 0.5162ΣU-110.85	0.76±0.05	SO_4^{2-} = 0.2965ΣU-7.3597	0.58±0.09
Cl^- =0.001ΣU+30.407	0.01±0.13	Cl^- = 0.0023ΣU+25.465	0.03±0.13
Ca^{2+} =0.0671ΣU+23.826	0.49±0.10	Ca^{2+} = 0.0172ΣU+40.179	0.20±0.13
Mg^{2+} =0.0807ΣU-8.2773	0.54±0.09	Mg^{2+} =0.046ΣU+4.8928	0.43±0.11
Na^+ =0.0701ΣU+5.1232	0.33±0.12	Na^+ = 0.0367ΣU+21.8	0.33±0.12
K^+ =0.002ΣU+0.6278	0.18±0.13	K^+ = 0.0012ΣU+1.2332	0.20±0.13

* Note: $r \pm \sigma_r$ is the correlation coefficient and its error.

Conclusion.

1. Karadarya River water at the Karabagish point refers to water of medium mineralization, at the Uchtepa and Andijan points refers to waters of medium and increased mineralization.
2. Naryn River water at the points above and below Uchkurgan refers to water of medium mineralization, and at the point of the river mouth refers to water of medium and high mineralization.
3. The analysis shows a weak relationship between mineralization and water discharge in rivers. In high-water years, there is a relatively good relationship between mineralization and water discharge with a positive correlation coefficient (r = 0.58 and 0.59). A weak relationship in low-water years may be associated with a large discharge of collector-drainage water into rivers.
4. At the points Karadarya River (Uchtepa) and Naryn River (mouth) high dependence of mineralization is associated with SO_4^{2-} and Mg^{2+} ions.

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