Surface water quality in the upper reaches of the Naryn River basin: composition and seasonal changes

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Abstract. Data on the quality of surface waters of the Naryn River according to chemical indicators from 3 monitoring posts for the period from 2014 to 2020 were analyzed. The results showed that the contents of Ca^{2+}, Mg^{2+} and Na^{+} are high in spring. These studies serve to provide a detailed assessment of the surface water hydrochemistry reported in this article and will provide the basis for scientific water quality assessment monitoring for water users. They also are important in management and water resources and plays a significant role in informing the population about rational use as the basis for sustainable development. Since the economic development of the country requires reasonable management of river basins. It is important that local communities collaborate with scientists and change local needs in determining priorities to improve water quality and reasonable water resources.

1 Introduction

Water plays an important role in the ecosystem and societies life. For many rivers in Central Asia, most of the water volume is collected from the mountains. Human activities are highly dependent on the river system. However, the consequences of land use in the catchment, such as livestock grazing in the watershed area, deforestation, erosion of slopes of the soil surface, gully erosion, and mining lead to the degradation of catchments [1 , 2 , 3]. The watershed areas are mainly used for agricultural activities. Excess sediment in the river affects water quality and land users' activities, and also affects sedimentation. The most common types of degradation in the Naryn River catchment area also include frequent droughts and dry winds, deflation of light soils, landslides and mudflows, atmospheric transport of sand, salt, dust and greenhouse gases, overgrazing, especially near rural and foothill areas.

This or that ecological state of watershed areas depends on the basic processes of functioning of river systems. The natural components of a river basin are greatly influenced by the environment. The temperature trend due to climate warming increases glacier

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melting and runoff [4, 5]. Heavy precipitation and sediment transport also contribute to the removal of huge amounts of solid runoff and their migration. During dry periods, they affect the state of river waters, disrupt the hydrological regime and worsen water quality by reducing the availability of natural waters. The latter is reflected in the state of the morphological structure of rivers and river valleys. It is known that increased surface runoff and removal of bottom sediments worsens water quality.

There is a lack of information in the local and international literature on the characteristics of the composition of hydrochemistry in the upper reaches of the Naryn River; existing works are devoted to assessing the state of the upper reaches of the Syrdarya River [6]. Our research has attempted to make a contribution to the study of this issue. The purpose of this work is to study seasonal changes in water quality and local fluctuations in the components of the flow of the Naryn River of Kyrgyzstan in the annual hydrograph.

2 Materials and methods

2.1 Study area

The object of the study is the Naryn River, located in the region of the same name in Kyrgyzstan. It is important in the water consumption of the irrigation and energy sectors not only for Kyrgyzstan, but also for Uzbekistan and Kazakhstan. Its source begins in the Tien Shan mountains of the eastern part of Kyrgyzstan, with the formation of the confluence of the Big and Little Naryn. The Naryn River then flows into the Fergana Valley, where it merges with the Kara Darya and forms the Syrdarya. The area of the Naryn River basin is about 58 thousand km^2 (Fig. 1). Most of the watershed area is located mainly in Kyrgyzstan.

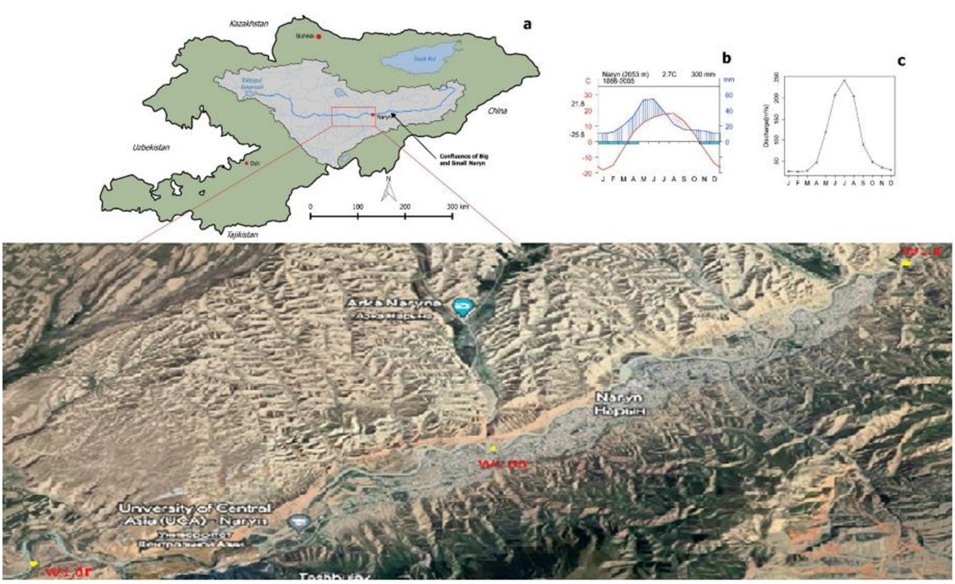

Fig. 1. The watershed area of the Naryn River with indication of water sampling sites, b - climate diagram of the city of Naryn, c - hydrograph of the Naryn River

Geographical location of the catchment area extends approximately between 40° and 41° north latitude and 75° and 76° west longitude. The elevation of the watershed area ranges from 388 to 5118 m above sea level with an average elevation of 2738 [4]. Climatic conditions are characterized by large temperature fluctuations, with an average annual temperature of more than 4.261°C. The average temperature of the cold period reaches −7.83°C in January, and the warm average temperature of 17.9°C is observed in July. The average annual air temperature with an absolute minimum is 32.3°C in winter and a maximum of +36°C in summer. The average annual precipitation varies at 306 mm [7]. The highest proportion of precipitation occurs in spring and early summer and there is also the least amount of precipitation in the summer. The melting of snow and glaciers introduces significant fluctuations in the hydrological regime, mainly during the summer.

The soils in the watershed are classified as chestnut soils. The textures of these soils include sand, loam and sandy loam fractions. The pH of the soil environment ranged from 8.0 to 8.46. The Naryn River has fluvial sediments and sandstones. The acreage's watershed is divided into different land uses such as: headland, forestry, grassland, agricultural land and populated urbanized areas.

2.2 Methods

The research method chosen was the monitoring program of the Naryn River of the "Kumtor Gold Company", which was implemented from 2014 to 2020. Data collection was carried out weekly by Naryn State University staff. In total, water samples were taken from three sections W1.8, W1.8b, W1.8r in the Naryn River bed each year for 67 weeks (Fig. 1) and sampling locations were determined using GPS. Water samples were sent within 24 hours to the accredited laboratory "ALS International laboratory", located in the city of Kara-Balta, Kyrgyz Republic. They were refrigerated at 4°C upon delivery. Water analyzes tested for main water quality W1, complete water W2, complete hydro W3, W4 PRO hydro, water salinity W5 and total hardness W6. Total water hardness, total alkalinity, free cyanide, CO_3 and HCO_3 titrimetric method. A method was used to determine water quality by the concentration of suspended particles. Statistical analysis of the data was performed using SAS software version 9.4 differences between element concentration methods were tested least significant at a significance level of $p < 0.05$ [8].

The watershed area is determined by the QGIS program in the analysis of the SRTM-1 digital elevation model (DEM). DEM analysis includes catchment delineation to highlight stream length and elevation distribution within the river drainage basin. The r.stream modules in the GRASS GIS were also used [9]. The geographical location of the catchment considered in this study extends from the upper Tien Shan Mountains to the Toktogul Reservoir.

3 Results and discussion

Consideration of the content of sediment in the river for each season of the year included the concentration of cations, anions, chloride anions and heavy metals. Analysis of the seasonal pattern of precipitation flux varies from one time period to another. The concentration of cations in runoff sediments increases in spring and decreases in summer, then increases again in autumn. The concentrations of cations in three areas were determined and their results are shown in Fig. 2. As the results show, the highest concentrations of cations have Ca^{2+}, Mg^{2+} and Na^{+} in section W18b. Since natural water contains a complex mixture of cations and anions. Among the indicators of primary cations Ca^{2+}, K^{+}, Mg^{2+}, Na^{+} at site W1.8, the maximum value of Ca^{2+} reaches 65.98 mg/l in spring, and the minimum content of 56.26 mg/l is observed in summer (Fig. 3).

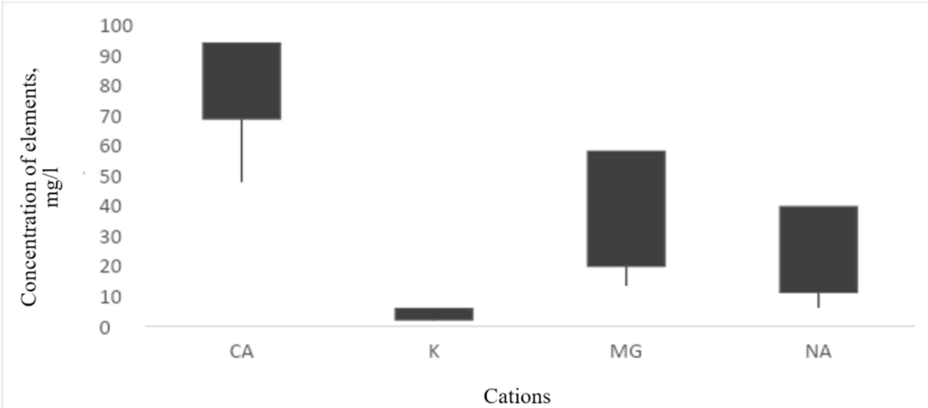

Fig. 2. Maximum concentration of cations in the Naryn River

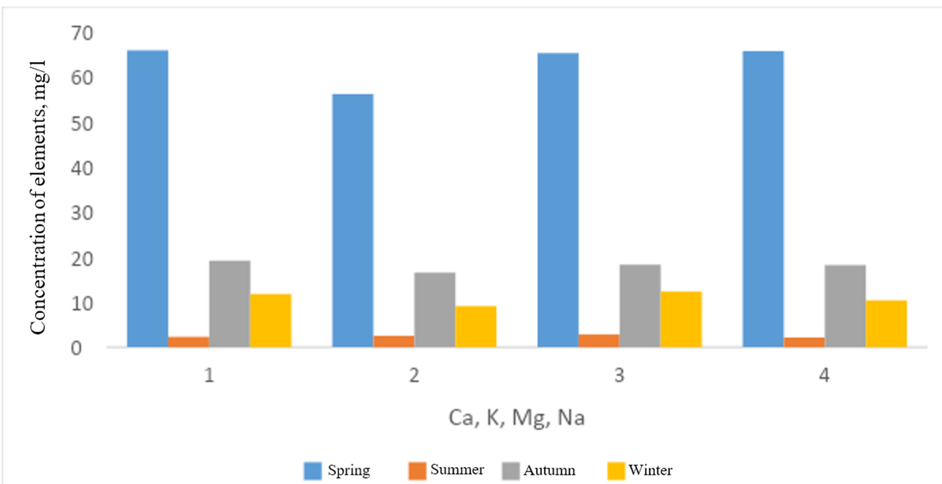

Fig. 3. Comparative analysis of cation concentrations by season

An analysis of cation concentrations by season in the Naryn River is shown in Fig. 4 by season at site W1.8. The highest concentrations of the elements under consideration occur during two seasons - spring and autumn. The reason for the high concentration in spring is explained by the beginning of the growing season and the beginning of leaching of minerals from the parent rocks. Also, the maximum amount of precipitation occurs in the spring-summer period and is accompanied by the melting of glaciers. In addition, more than 95% of the annual flow occurs from May to September. Changes in element concentrations throughout the year are considered by season. As Figure 4a shows, the highest concentrations are observed in the summer. The maximum precipitation in the spring-summer period reaches more than 95% of the annual runoff and occurs from May to September. During this period of the elements under consideration, Mg^{2+} also has a maximum value of 154.21 mg/l.

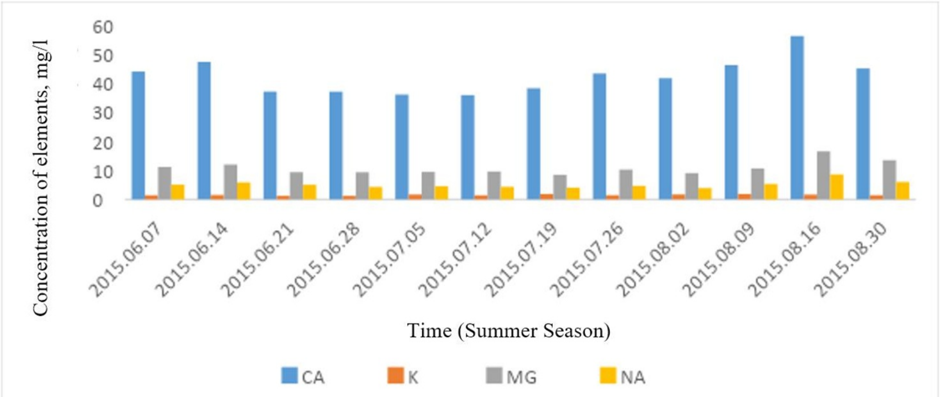

Fig. 4a. Seasonal changes in the concentration of elements determined at site W1.8 (summer season)

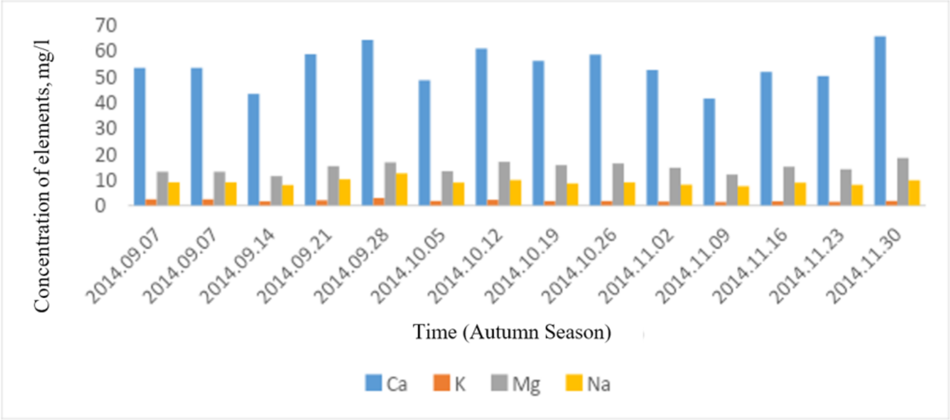

Fig. 4b. Seasonal changes in the concentration of elements determined at site W1.8 (autumn season)

The concentration of heavy metals in the runoff showed high content in summer compared to other seasons. The importance of studying sediment content lies in assessing rates of soil erosion, variations in local migration, and dry sediment inputs into terrestrial systems. The results of this study will be influenced by the land use conditions in the watershed area. Fig. 5 shows the maximum concentration of heavy metals in the river at section W18b and it can be seen that Fe^{2+} and Mn^{2+} have a high content of the elements.

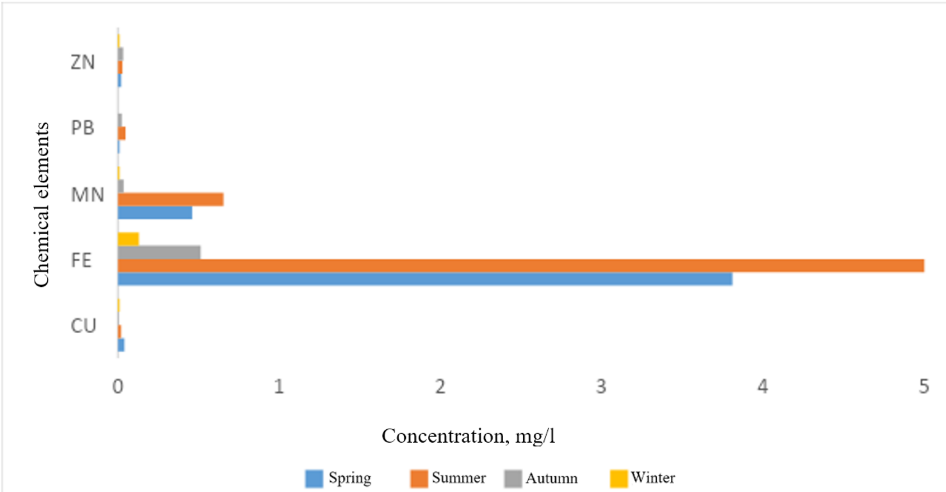

Fig. 5. Maximum concentration of heavy metals in the Naryn River

Research by Gan et al. noted that maximum flow occurs in June, when snow in the mountains melts and contributes to an increase in the volume of river flow [5]. As the water level in the river rises, sediment transport also increases to a maximum. It is known that surface waters contain sand, silt, clay, organic detritus and plankton [10]. The smallest particles in water have significant amounts of organic carbon and oxide coatings that attract metal ions. Ionization has a significant effect on the behavior of a chemical in water and can be very important in mixing areas or when pH changes. The formation of free metal ions is particularly important for the toxicity of organisms. Research by Turdiev and Lee revealed that in the Syrdarya, Nura and Ili rivers the concentrations of Fe, Cd, Cr (VI), Hg, Mn and As significantly exceeded the standards established by local and international drinking water standards. This is due to the economic activities of processing coal, iron and copper ore, as well as the production of iron, steel and ferroalloys [11].

Thus, when using dissolved oxygen as an indicator for assessing surface water quality, seasonal variations must be taken into account. Dissolved solids are impurities that occur in all natural waters due to the weathering of rocks and soils, as well as solution carbon dioxide from the atmosphere. As the content of dissolved solids increases, the density of water also increases. It is known that the dissolution of minerals from rocks can occur slowly. When solutions are in equilibrium, it is possible to calculate the distribution of elements among all possible and expedient anions, cations and complexes.

4 Conclusions

An assessment of annual changes in river water quality was determined at three monitoring sites of the Naryn River. The impact of anthropogenic activities is manifested in changes in water quality in terms of the content of heavy metals. This study is important in explaining the annual variance of key water quality indicators. The results of the study of seasonal changes in precipitation concentrations will affect the quality of irrigation water. An increase in the volume of surface runoff is accompanied by the leaching of small particles from mountain slopes. Transport of sediment from surface runoff negatively affects the state of the ecosystem in the river's catchment area. Therefore, minerals such as Ca^{2+}, K^{+}, Mg^{2+}, Na^{+} are necessary to enrich the soil and maintain organic nutrients in it. Reducing transported nutrients is important for farming and maintaining soil structures. Further research calls for the need to develop a holistic approach to sustainable ecosystem management and watershed conservation to improve water quality and enhance the well-being of local communities in watersheds.

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