HYDROCHEMISTRY OF MOUNTAIN PAMIR: TRIBUTARIES OF THE TRANSBOUNDARY PYANJ RIVER AND THEIR WATERS APPLICABILITY FOR IRRIGATION

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The results of chemical analyses of the waters of the transboundary Pyanj river tributaries – Gunt, Shakhdara, Bartang, Yazgulem and Vanch rivers are presented. The absence of stationary sources of pollution in the river basins and the dominance of rock weathering in the formation of hydrochemistry of the studied tributaries of the transboundary Pyanj River were established.

KEYWORDS:

Pyanj river, transboundary, weathering, hydrochemistry, correlation, tributary.

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1. Introduction

The Pyanj River by a length of 921 km, a catchment area of about 115 thousand km2 and average annual runoff of more than 1000 m^3/s is one of the main tributaries of the Amu Darya [1; 2].

It should be noted that the concentration of salts and the sodium adsorption ratio (SAR) are considered the main indicators determining the degree of applicability of waters for irrigation of agricultural lands. The weakening of the growth of agricultural crops and a decrease in soil permeability occurs at an increase of SAR [3].

In the context of global climate change and an increasing rate of water scarcity, it is important to reuse wastewater both in irrigation to expand available water resources and to prevent inflow to surface waters. Recycled wastewater, for example, produced by municipalities and farms in California is increasingly being reused for irrigation, and California's wastewater reuse is expected to reach 3.0 Bln.m3 by 2030 [4].

However, the high salinity and sodium (Na+) concentration causes a serious problem for their sustainable reuse in crop production [5–7]. The harmful effects of high concentrations of potassium (K^+) and magnesium (Mg^{2+}) of wastewater on the hydraulic properties of the soil are indicated in [7].

The sodium adsorbtion ratio (SAR) is expressed as follows [8]:

$$SAR = Na^+/ [(Ca^{2+} + Mg^{2+})/2)] 1/2. \quad (1)$$

In socio-economic significance, agriculture remains the most important sector of the economy in most states of the Central Asia region. The livelihoods of the main population directly depends on the productivity and efficiency of agriculture, since most of the population of the region (from 43% in Kazakhstan to 75% in Tajikistan) lives in rural areas. The total area of arable land in the Republic of Tajikistan is 720.2 Th. ha that 502.8 Th. ha are irrigated (7.1% of the total area of irrigated land in the Central Asian region). Water in the Republic of Tajikistan for irrigation is used limitedly. For example, the total withdrawal of water from the Pyanj River is about 300,000 m^3/year [9].

In the Pamirs, only 240 km^2 (less than 1%) of the total area occupied by mountains (25,700 km^2) is arable land [10], accordingly, the amount of water used for irrigation is negligible.

The statistics of recent years on the indicators of river water quality confirm the presence of negative trends in the mineralization increase both in time and in the length of riverbeds. The chemical composition is a determining indicator of the suitability of water for irrigation of agricultural crops.

This work is devoted to the study of the chemical composition of the main tributaries of the transboundary river Pyanj and assessment of their use for irrigation of agricultural land.

Table 1

Hydrological characteristics of some Pamir Rivers [11]

River	Catchment area (km^2)	River length (km)	Average annual flow (m^3/s)	Average drop (m/km)	Source height (m)	Estuary height (m a.s.l)
Shakhdara	4180	178	38	17,4	4640	2060
Gunt	9620	296	68	8,7	4680	2060
Yazgulem	1940	80	39	21	3300	1930
Bartang	24700	528	129	3,6	2553	1975

2. Objects and Methodology

Water samples were taken from the Shakhdara (3748903N 71.58356E), Gunt (38.87092N 69.99751E), Bartang (37.93236N 71.59297E), Yazgulem (38.15266N 71.33961E) and Vanch (38.30353N 71.33006E) rivers – the main tributaries of the transboundary Pyanj river, to conduct chemical analyses and determine the applicability of water for irrigation. The main characteristics and location are presented on the Table 1 and Fig.1 accordingly.

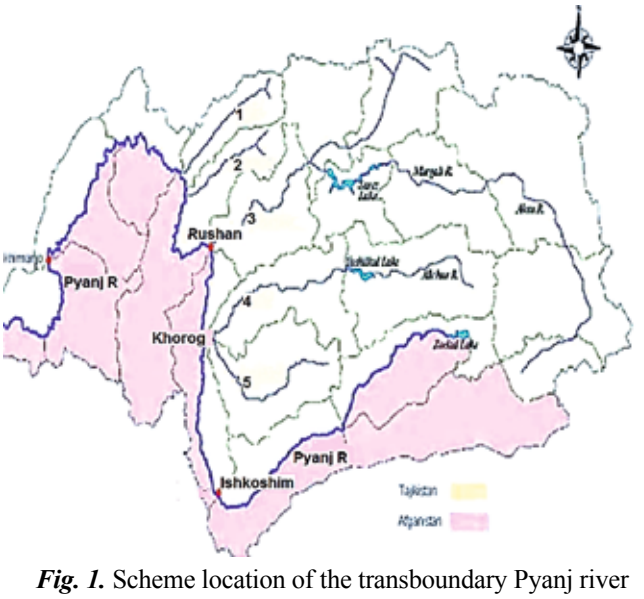

Fig. 1. Scheme location of the transboundary Pyanj river tributaries: *1* – Vanch, *2* – Yazgulem, *3* – Bartang, *4* – Gunt and *5* – Shakhdara

The physical and chemical analyses of water samples were carried out using the "TaLab" spectrophotometer in accordance with the relevant state standards. At chemical analyses and interpreting the results, we were guided by the normative document [12].Were also guided by the next state standards: Na^+ (State standard 26449.1-85, p.17.1), K^+ (State standard 26449.1-85, p. 18.1), Ca^{2+} (State standard 26449.1-85, p. 11.1), Mg^{2+} (State standard 26449.1-85, p.12).

The Shakhdara river is the largest tributary of the Gunt river with a basin area of 4130 km^2. The Shakhdara receives about forty tributaries with a length of more than ten kilometers. The river Bodomdara is largest of them. In the annual flow of Shakhdara, snow water makes up 39%, glacial water – 20% and underground water–41%. For the period May – September passes 75% of the annual runoff [11].

The Yazgulem River is formed at the confluence of the Mazardara and Rakzou rivers the first of which is considered the main source of water supply. Mazardara flows from the moraine-laden tongue of the Yazgulem glacier (second name – Mazardara) by an area about 25.7 km^2. The second component of Yazgulem – Rakzou flows from the Rakzou glacier with an area of 47.8 km^2. The contribution of glacial flow, melting snow cover and groundwater to the annual river runoff is 35%, 29% and 36%, respectively. The share of glaciers in providing the Yazgulem river is 52% of the annual runoff [11].

A significant contribution to the formation of the Pyanj River runoff is made by its tributary the Gunt River (about 250 km long, basin area 14840 km^2) [13].

The Vanj river is formed at the reunification of the two rivers Kasholyakh and Abdukagor in the Pamirs and is characterized by a length of 921 km and basin area of 114000 km^2 [14]. At the low water period, the underground waters of the basin make a significant contribution to the formation of river flow.

3. Results and Discussion

The results of chemical analyses of alkaline and alkaline earth elements in the waters of the tributaries-the rivers Bartang, Gunt, Shakhdara, Vanch and Yazgulem are presented on the Fig.2 demonstrate high values of Ca and Mg concentration in all tributaries of the Pyanj River.

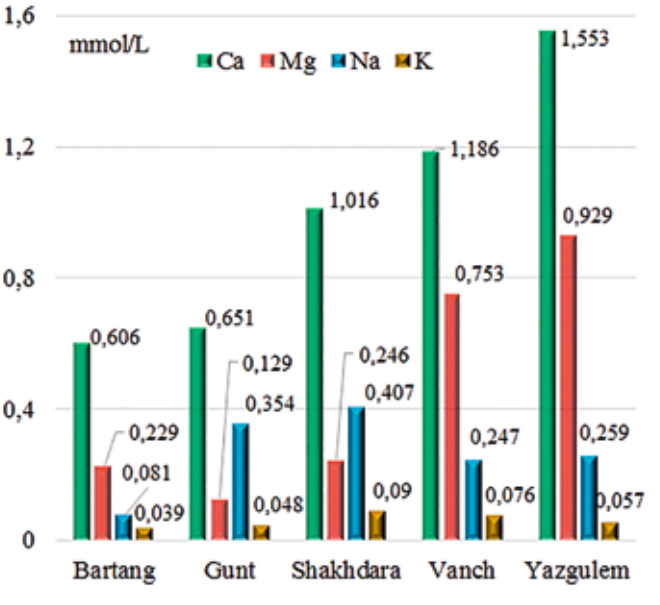

Fig. 2. Distribution of Na^+, K^+, Ca^{2+} and Mg^{2+} cations in the main tributaries of the Pyanj river

The enrichment of river waters with magnesium and calcium cations is primarily due to the processes of rock washout. The observed effect may indicate the mineralogical composition of rocks along riverbeds. The absence of industrial and mining enterprises in the river basins suggests that the rocks of the riverbeds, especially the Yazgulem, Vanch and Shakhdarya rivers, are rich in calcite, aragonite and dolomite rich in calcium and magnesium. River water rich in cations of alkaline earth elements leads to a significant increase, as can be seen from Fig. 3 and 4, in the degree of mineralization and hardness of waters.

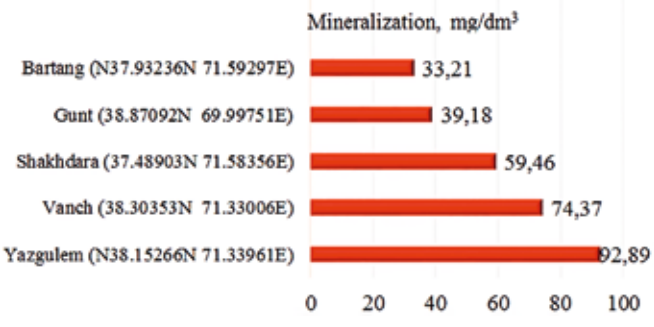

Fig. 3. Mineralization of the Bartang, Gunt, Shakhdara, Vanch and Yazgulem rivers

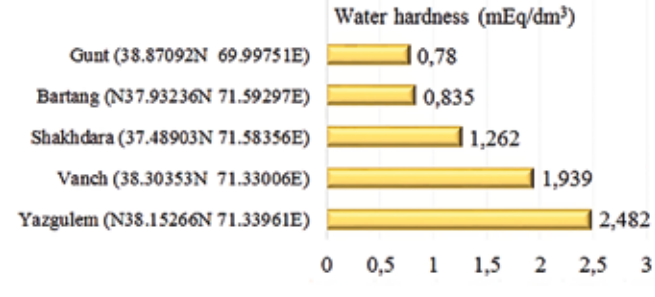

Fig. 4. Water hardness of the Bartang, Gunt, Shakhdara, Vanch and Yazgulem rivers

The tributaries of the transboundary Pyanj River – Bartang, Vanj, Gunt, Shakhdara and Yazgulem SAR values were calculated by use of equation (1) the results of which are presented on the Fig. 5 including also the mean of percentage Na+.

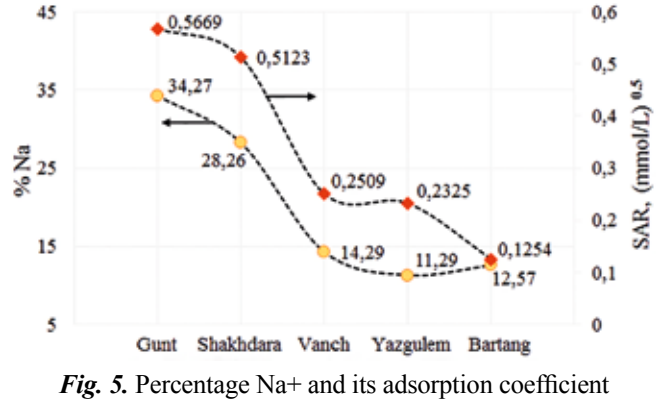

Fig. 5. Percentage Na+ and its adsorption coefficient for the transboundary Panj river tributarie

The highest content of sodium cations is observed in the Gunt river and the lowest value in the Bartang river (Fig.5). Obviously, the high concentration of cation in river water contributes to its greater adsorption capacity that is shown by SAR curve on the Fig. 5.

Perceptible content of cations naturally affects the change in its main characteristics such as exchangeable sodium ratio (ESP) and soluble sodium percentage (SSP). The ESP and SSP of the Gunt river shown on the Fig. 6 can evidence this.

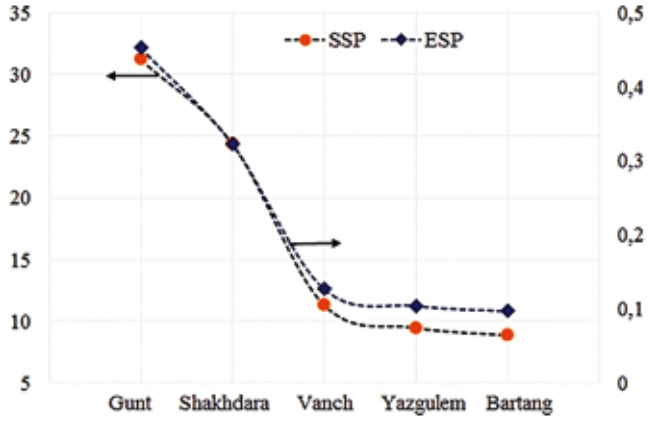

Fig. 6. SSP and ESP of the transboundary Panj river tributaries

Using thermodynamic arguments SAR can be connected to the percentage of exchangeable sodium as a key soil property affecting permeability [15]. Similarly, the potassium adsorption ratio (PAR) was determined [8] but, as noted above, there are no guidelines on PAR in the standard reference publications for assessing irrigation water quality yet [16].

The coefficient of structural stability of cations (CROSS) is used as a chemical indicator to distinguish cations that promote aggregation of soil particles from cations that promote dispersion of soil particles [17–20]:

$$CROSS = (Na + 0.56\ K) / [(Ca + 0.60\ Mg)/2]^{1/2}. \quad (2)$$

A very significant linear correlation between CROSS and salt concentration was noted in [21].

Optimization of CROSS by generalizing the equation:

$$CROSS = (Na + a\ K) / [(Ca + b\ Mg)\ /2]^{1/2} \quad (3)$$

proposed in [22], where a and b are numerical coefficients determined by a suitable method, and are generalizations of SAR and PAR, respectively. The order of negative effects of cations on soil permeability according to [19] is as follows: Na > K > Mg > Ca. At values $a < 1$ in equation (3) the negative influence of PAR on the soil structure is relatively less than of SAR and $b < 1$ reflects the lower flocculating capacity of Mg relative to Ca.

Currently, CROSS is the only proven irrigation water quality parameter that takes into account the influence of all four major cations on the meliorative conditions of the soil. The inclusion of K and Mg does not create new harmful mechanisms. The CROSS and SAR are equal for assessment the applicability of waters for irrigation It follows from the equation (3) that in all cases CROSS > SAR.

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CONTRIBUTION

Normatov P. I. collected, analyzed and systematized scientific papers on the climatic conditions of mountainous countries, participated in the discussion of the results, designed the graphic material of the article and is responsible for plagiarism; ***Normatov I. Sh***. identified the relevance of the work, set the task, prepared and presented an analysis of foreign works on the Hydrochemistry of Mountain rivers, edited the scientific component of the work; ***Ray G. Anderson*** discussion of results, editing and analysis of publications on the topic and design of a literary review; ***Shermatov N***. conducted statistical analysis of data, calculated Spearman's correlation coefficients and analyzed the relationships of chemical elements using the Pearson correlation.

CONFLICT OF INTEREST

The authors declare no conflicts of interests.

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ГИДРОХИМИЯ ГОРНОГО ПАМИРА: ПРИТОКИ ТРАНСГРАНИЧНОЙ РЕКИ ПЯНДЖ И ПРИМЕНИМОСТЬ ИХ ВОД ДЛЯ ОРОШЕНИЯ

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Приведены результаты химического анализа вод трансграничных притоков реки Пяндж – рек Гунт, Шахдара, Бартанг, Язгулем и Ванч.

Установлено отсутствие стационарных источников загрязнения в бассейнах рек и преобладание каменного выветривания в формировании гидрохимии исследованных притоков трансграничной реки Пяндж.

Ключевые слова: река Пяндж, трансграничный, выветривание, гидрохимия, корреляция, приток.

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