HYDROCHEMICAL INDICATORS AND SUITABILITY FOR IRRIGATION OF SIRDARYA RIVER WATER

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Abstract. Rivers often become primary receivers of pollution and this affects the ecological state of water biogeocenoses, soil and plants. Uneven water use in the upper and lower reaches of the Syrdarya River and accumulation of contaminants in the upper reaches leads to changes in the ecological balance in the middle reaches. Hydrochemical indicators of water samples from the Syrdarya River in the middle flow and suitability of water for irrigation were studied. Samples were taken during the warm period of the year from 8 stations during 2018 and 2019. The water was found to be slightly mineralised with a normal value of electrical conductivity. 18.75% of water samples had an alkaline reaction; in 97.9% of samples, the bicarbonathion content exceeded the standard values. By chloride content 95.84% of samples are suitable for surface irrigation. The concentration of nitration was within the limits of normative values. To be used for irrigation purposes, it is necessary to dilute river water with fresh water, normalise pH and regularly monitor hydrochemical indicators.

Keywords: water samples, hydrochemical indicators, Syrdarya river, suitability for irrigation.

Environmental pollution is one of the longstanding problems of human society, which continues to grow rapidly as a result of the growing technological load. Water bodies often become primary receptors of pollution, and this affects the ecological status of water biogeocenoses, affecting both external and internal parameters, including water quality[1]. Rivers are the main source of water for domestic, irrigation or industrial purposes, so hydrochemical characteristics are of great importance for sustainable management of water resources and environmental protection. Ions in water are considered as natural "indicators", so the analysis of the main ion composition in water can be used to identify and control the main processes affecting the chemical composition of water [2]. Meanwhile, anthropogenic factors have a significant influence on water mineralisation, as many salts and agrochemical compounds will influence water quality due to return water from collector-drainage runoff [3].

Syrdarya is the longest river in Central Asia. The upper and middle streams of the river are located on the territory of Uzbekistan. Despite the double burden of water shortages caused by uneven use of water in the upper and lower reaches of the river and accumulation of pollutants in the upper reaches, river water is still necessary for the everyday life of the population as well as for ecological balance along the river. As a result, the river middle course becomes a vulnerable area in terms of ecology and environment of the whole basin [4]. Also, the development of irrigation has led to a shift in the content of ions in Syrdarya River water from calcium carbonate to sodium-magnesium and sulfate-chloride (5). A total of 20 million tons of different salts per year falls into the Syrdarya River with dried backflow, which increases the mineralisation of the river from 300 to 600 mg/l in the upper reaches to 3000 mg/l in the lower reaches of the Fergana Valley. The predominant salts are MgSO4, Ca(HCO3)2, NaCl and CaSO4[6].

Research objective. To study the hydrochemical parameters of the Syrdarya River in the middle flow and determine the suitability of water for irrigation.

Research materials and methods. This research has examined hydrochemical indicators of Syrdarya river water in the warm season of 2018-2019. Samples were taken from the following stations: 1) Syrdarya River, 1 km after the inflow of the Chirchik River; 2) 100 m before the inflow of the Chirchik River; 3) 1 km before the inflow of the Chirchik River; 4) near Hakikat settlement; 5) near the Water Users Association (WUA) Sohil; 6) before the inflow of the Ahangaran River; 7) after the inflow of the Ahangaran River. The eighth station of the Chirchik River was located at a distance of 1 km before the inflow of the Syrdarya River. Samples were taken from 3 trips (in May, July and October months) each year. Suitability of water for irrigation, due to lack of uniform approved requirements, was determined based on chemical analysis by irrigation coefficients, which are calculated by different methods. In the FAO recommendations "Water Quality for Agro-crops". [7] presents recommended parameters of hydrochemical parameters of irrigation water (Table 1).

Table 1: Recommendations for Irrigation Water Quality*

Indicators	Use restriction level		
	no restrictions	minor limitation to medium	severe restriction
EC_w**, dS/m	<0,7	0,7-3,0	>3,0
Chlorides (Cl-)*** in irrigation, me/l: - surface - rain	 <4 <3	 4-10 >3	 >10
Nitrogen (NO3-N)****,mg/l	<5	5-30	>30
Bicarbonate (HCO3-),me/l	<1,5	1,5-8,5	>8,5
pH	normal range - 6,5-8,4		

Note.
**- From the University of California Consultants Committee, 1974.*

*** - ECw means the electrical conductivity, a measure of water salinity expressed in decimals per meter at 25°C, unit of measure V""/m or millimhos/sm. Both are equivalent.*
**** - In surface irrigation, most woody crops and woody plants are sensitive to chlorides, so the specified values must be used. In rain irrigation and low humidity (<30%), chlorides can be absorbed through the leaves of sensitive crops.*
***** - NO3-N means nitrate nitrogen, represented as elemental nitrogen (NH4-N and organic nitrogen should be included in wastewater studies).*

Water containing large amounts of salts is known to harm plant and animal organisms, resulting in soil salinisation. Most researchers use the indicator of salinity of irrigation water when assessing water quality. The founder of such assessment is A.N. Kostyakov [8], who characterises the irrigation properties of water following its mineralisation (Table 2).

Table 2: Assessment of water quality by total mineralisation

Water class	Mineralisation, g/l	Quality Assessment
I	less 0,4	good
II	0,4-1,0(fresh)	limited use, considering local natural and irrigation conditions
III	1,0-3,0 (demineralized)	high risk to plants
IV	more 3,0	secondary salinisation

In terms of the water content of chlorides and sodium sulfates, Stebler [9] proposed to calculate the alkaline characteristic, expressed in the form of irrigation coefficients, which is a layer of water in inches, which contains as much alkali as necessary for the soil to become harmful to a depth of 1.2 m for most crops. A formula is used for calculation: K = 288/5Cl (if Na+ ions are less than Cl- ions) and by the formula: K = 288/Na++4Cl (if there are more Na+ ions than Cl- ions). These coefficients determine the water quality as good (Ka>18.0), satisfactory (Ka- 18.0 to 6.0), unsatisfactory (Ka- 5.9 to 1.2) and bad (Ka<1.2), i.e., water is not suitable for irrigation [10].

In our study, the electrical conductivity of water was measured with a portable device of YSI-85 type. We used methods of variation statistics with the calculation of mean value (M), standard error (±m) and relative values (frequency, %). The statistical significance of differences between the obtained values was assessed using the Student's criterion (t). The differences at $p \leq 0.05$ were statistically significant. The statistical processing of the obtained results was performed using the standard Excel-2013 software package for Windows.

Results and discussion. The obtained results of the hydrochemical study of Syrdarya river water samples are grouped in Table 3. The average water temperature in May was 29.5 ºC, in July - 24.5 ºC, in October - 13.9 ºC.

Table 3 shows the average water temperature in May, which was 29.5°C in July and 24.5°C in October.

Table 3: Average hydrochemical parameters of Syrdarya river water samples at the surveyed stations, M±m(n=48)

Indicators	The 2018 year

	May	July	October
pH	8,2±0,59	8,5±0,41	7,8±0,65
ECw, mS/sm	17,0±0,30	23,0±14,90	12,5±5,08
Mineralization, mg/l	1216,7±217,18	2132,4±1623,83	1131,9±218,54
Chlorides, mg/l	75,5±20,48	107,0±41,81	74,0±16,63
Nitrates, mg/l	3,0±0,37	3,5±1,87	3,0±1,05
Bicarbonates, mg/l	217,5±47,80	242,6±47,87	194,0±31,46
	2019 год		
pH	7,9±0,61	8,0±0,45	7,4±0,16
EC_w, mS/sm	13,0±0,30	2,3±0,14	6,2±6,69
Mineralization, mg/l	1347,7±135,82	1141,9±169,08	1222,6±237,40
Chlorides, mg/l	93±12,10	78,1±10,67	84,1±17,14
Nitrates, mg/l	2,9±0,80	2,4±0,29	2,3±0,53
Bicarbonates, mg/l	188±22,11	206,0±76,17	216,0±22,2

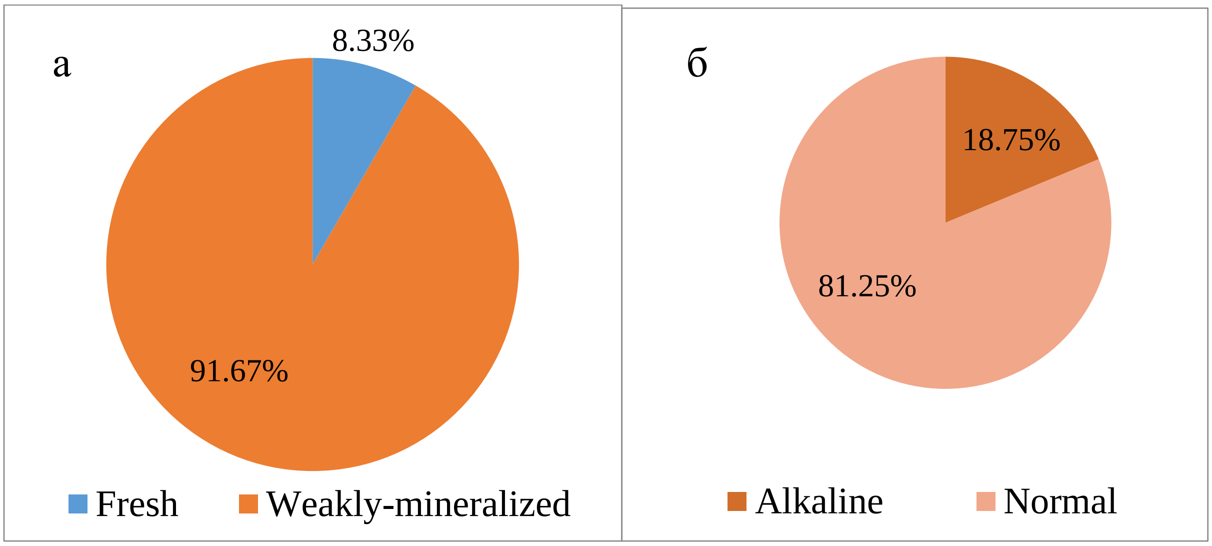
Mineralisation and electrical conductivity. Its chemical composition sulfates the water of the Syrdarya River and calcium prevails from cations. According to A.N. Kostyakov, all the samples were weakly mineralised so that they may pose an increased danger to plants. It should be noted that the total mineralisation of water samples from the Chirchik River is significantly lower than that of the Syr Darya ($p<0.05$). In the samples obtained in spring 2018, summer and autumn 2019, the dry residue was below 1 g/l (Figure 1a).

Electrical conductivity (EC) is a numerical expression of the ability of an aqueous solution to conduct electric current. The electrical conductivity of natural water depends mainly on the degree of mineralisation, ions dissolved in water, their charge and temperature. As water is a good solvent, it dissolves mineral salts in the form of ions, which keep the electric current due to ion conductivity. The high electrodensity of water indicates a high concentration of ions. The electrical conductivity of water also affects plant growth. The EC measurement at 25°C is considered to be a reference [11]. The main effect of high electrical conductivity of water on crop yields is the inability of plants to compete with ions in the soil solution for water (physiological dehydration). The higher the EC, the less water is available to plants, even if the soil is wet. Since plants can only absorb "clean" water, the good water for plants in the soil solution decreases sharply as the EC increases [12]. In our study, the electrical conductivity of water is below normative values, i.e., water can be used to irrigate crops.

Bicarbonates and pH. Bicarbonate ion (hydrogenated carbonate ion) is an anion with a negative charge. Rock venting is a source of bicarbonates in water and their concentration depends on the pH of water. It is the main alkaline component of water bodies, so it affects the water hardness and alkalinity. Many bicarbonate salts are soluble in water at standard temperature and pressure, especially sodium bicarbonate and magnesium bicarbonate; both these substances contribute to the total amount of dissolved salts, which is a standard parameter of water quality assessment [11].

The normal pH range for irrigation water is 6.5 to 8.4. Low pH values can cause accelerated corrosion of the irrigation system. High values are often associated with high concentrations of bicarbonates (HCO_3^-) and carbonates (CO_3^{2-}). At pH values above 8.5, carbonates join with calcium and magnesium ions to form insoluble minerals, leaving sodium as the dominant ion in water. Excess bicarbonate ions can form calcite or scale and reduce water flow through openings and sprayers in drip and rainfed irrigation systems [12].

We have found that pH values of water in 2018 in 12.5% of cases authentically exceeded standard values ($p<0.01$). In 2019, the hydrogen index exceeded the standard values in 6.25% of cases (Picture 1b).



Pic. 1: Suitability of water for irrigation by mineralisation index (a) and pH (b), %

The bicarbonate content was between 25.1 and 281.0 mg/l, corresponding to 0.4-4.6 me/l. Thus, in terms of alkalinity, water can be used for irrigation with little restriction, i.e. acids must be injected to normalise the pH. This is especially true when using drip and rainwater irrigation systems.

Chlorides. The most important component of ion runoff, an indicator of mineralisation and genesis of natural waters are chloride ions, which belong to the group of very mobile water migrants. Water with chloride ions content of more than 350 mg/l has a brackish flavor, and at chloride concentration of 500-1000 mg/l it adversely affects stomach secretion[13]. In small concentrations chloride ions are necessary for plant growth, but high chloride content in water can have toxic effect on sensitive crops. Monitoring of chloride ions concentration is especially important in rain irrigation. At sprinkling, possible leaf burns from high chloride concentrations can be reduced by nighttime irrigation or by irrigation on cool, cloudy days [12].

The results of the study showed that the chloride content in almost all samples was within the normative values (less than 4me/l). Only water samples obtained in July 2018 near the settlement of Hakikat and WUA Sohail were 1.3 times higher than the standard values (Figure 2a). In our study, the chloride content of 9.6% of water samples was in the range from 3 to 4me/l (Figure 2b). Thus, water from the Syrdarya River can be used for surface and rainfall irrigation, but constant monitoring of indicators is necessary. Results of water quality assessment of water samples by irrigation factor for Stebler showed that 6.25% of samples characterised water quality as unsatisfactory, and 93.75% of samples - as poor.

Nitrates. Nitrates and phosphorus are the main nutrients for crop growth, but their excessive content in water and soil can have a negative effect.

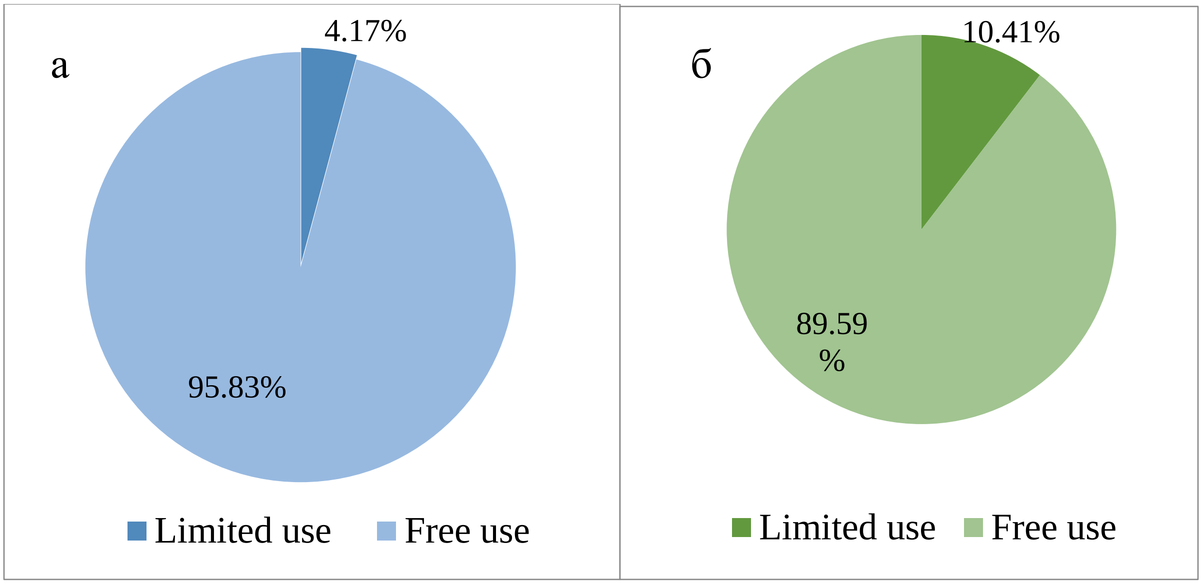


Figure 2: suitability of chloride water for irrigation - for surface irrigation (a) and rainwater irrigation (b), %

Excess nitrogen and phosphorus, especially in the case of paddy rice, can lead to a loss of yield due to excessive growth [14]. Therefore, in South Korea, Taiwan and Japan, there are restrictions on the total nitrogen content in water for irrigation of rice fields [15, 16]. Excess nutrients in water can also cause contamination of groundwater and eutrophication in coastal areas or lakes [17, 18].

The nitrate ion is often found in higher concentrations than ammonium in irrigated water. High nitrogen levels in water reduce yields of sensitive crops such as barley and sugar beet and can also cause excessive growth of some vegetables. However, this can be prevented by the rational use of mineral fertilisers and the right watering regime [12].

In our study, the nitrate ion content in water was within normal values. Therefore, the water in the Syrdarya River can be used for irrigation.

Conclusions and recommendations.

1. Mineralisation of 91.67% of the Syrdarya River water samples was within the range of 1.0 to 3.0 g/l, which limits the use of water for irrigation purposes. Mineralisation of irrigated water can be reduced by diluting it with fresh water. Water can also be used for irrigation of sustainable crops such as barley, sugar beet, cotton, but the problem of soil salinisation should be taken into account.

2. The content of bicarbonate ion in 97.9% of samples was 1.5-8.5 me/l, and pH of water in 18.75% of samples had an alkaline reaction. When using river water for irrigation of pH-sensitive crops, it is necessary to correct alkalinity by applying acid-containing substances.

3. Electric conductivity of water and concentration of nitrate ion in it was within the limits of normative values. According to chloride ion content, 95.84% of samples are suitable for surface irrigation and 89.59% for rainwater irrigation. At high chloride content in water, it is recommended to water the crop at night on cool overcast days. Plants tolerant to chlorides are barley, sugar beet, sorghum, wheat, zucchini, sanggrass, alfalfa, potatoes.

4. It is recommended to monitor regularly the hydrochemical indicators of irrigated water.

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