WATER QUALITY ASSESSMENT FOR IRRIGATION CANALS
Case Study in the Bingol, Turkey

by

Hasan ER [a,b] * ***and Fevzi SEVIK*** [c*]

[a] Department of Biosystem Engineering, Faculty of Agriculture, Bingol University, Bingol, Turkiye
[b] Bee and Natural Products R&D and P&D Application and Research Center, Bingol University, Bingol, Turkiye
[c] Vocational School of Health Services, Bingol University, Bingol, Turkiye

Original scientific paper
https://doi.org/10.2298/TSCI2304299E

The aim of this study was to determine the quality of the water used as irrigation water by the agricultural farmers in the city center of Bingol, to determine the physico-chemical properties of the water used in the region, to study the seasonal changes and to calculate of the irrigation water quality evaluation. Taking into account the seasonal fluctuations of the irrigation water sampling points (O, K, A), pH values 7.63-7.94, EC values 0.14-0.16 dS/m, Na values 0.27-0.32 me/L, K values 0.08 me/L, Ca values 0.75-0.81 me/L, Mg values 0.33-0.38 me/L, SO_4 *values 0.12-0.13 me/L, bicarbonate 3.16-3.36 me/L, and chlorine values between 0.51-0.55 me/L. Parameters such as SAR, KI, Na%, and PI were calculated to determine the suitability of the existing irrigation water quality in the study area. When the SAR values were examined, it was determined that they were between 0.36-0.42, RSC values were between 1.5-2.5, and IWQI values were between 77.33-78.42. As a result of the quality evaluations made at the irrigation water line located in the center of Bingol province, it was determined that there was no difference in the quality parameters when the seasonal changes in the long-term sampling for five years were taken into consideration.*

Key words**:** *irrigational water quality, irrigation water quality index, water quality criteria, seasonal variation*

Introduction

The rapid increase in population, industrialization and human factors is accompanied by water resource scarcity and consequent shortage of agricultural production. Water shortages have become particularly acute in countries with rapid population growth, [1]. Water is a vital resource for long-term economic, social and human development, [2, 3].

Water resources are one of the most fundamental elements of agricultural production. Access to sufficient water resources of usable quality is the most important factor for sustainable agricultural production and is considered a major consumer of freshwater resources, [4, 5]. To ensure global food security, agricultural food production needs to increase by an estimated 60% by 2050, and irrigation will be increasingly needed to help meet this demand, [6]. As a result of the rapid increase in world population, the amount of product obtained per unit area must be increased to meet the increasing nutrient requirements. Increasing

* Corresponding authors, e-mail: fsevik@bingol.edu.tr, hasaner@bingol.edu.tr

the amount of product is only possible through effective management of water resources. Water resources management is thought to offer solutions that can respond to the reduction of available resources due to the impact of climate change and ensure the sustainability of water uses, especially in agriculture, [7]. In this direction, research on effective water management is rapidly increasing around the world, [8]. To reduce the extra pressure on water resources in arid and semi-arid regions and to ensure sustainable management of irrigation water, water resources management has targeted water quality improvement resulting from the understanding of the harmful effects of various pollutants on irrigation water, [9].

Water quality is one of the most important environmental determinants affecting a country ecosystem, agricultural production and socioeconomic development, [10]. Water quality indicates the condition of the body of water or water source. Water quality can be defined as qualitative or quantitative. Water quality includes all of the physical, chemical, and biological factors that affect the most effective use of water. For this reason, when determining water quality, it is necessary to determine the physical, chemical and biological parameters that affect water quality, [11, 12]. Also, crop productivity depends on the quality of the soil and the quality of the water available for irrigation. Anonna *et al.* [9]. Furthermore, crop productivity is related to the quality of the soil and the quality of water available for irrigation. Irrigation water quality is generally based on total dissolved solids, cations, anions, pH, electrical conductivity, alkalinity, Na%, SAR, and RSC parameters [13, 14]. The problem of salinity leads to the loss of fertile soils every year around the world. It leads to irrigation of their lands with low quality water and reduced crop productivity, [15]. In general, physical, chemical, and biological water quality parameters are required for a comprehensive assessment of surface and groundwater. One of the main limitations of water quality surveys is the number of potentially traceable parameters, and the time and cost involved in collecting, analyzing, and interpreting this data. To overcome such problems, efficient water quality indices based on water quality parameters have been developed to make a water quality classification suitable for the intended end use (*e.g.* domestic water, irrigation water), [16]. Numerous researchers have used hydrochemical indices such as SAR, Na%, KI, PI, and irrigation water coefficient, [17]. Instead of using a single parameter, a combination of chemical analysis of all ions is expected to give better results. In addition, irrigation water quality index (IWQI) uses a number of indicators to simplify water quality to a single value that is considered a better solution, [18, 19]. An IWQI allows the conversion of large data sets describing the suitability of irrigation water sources into a single numerical score, thus facilitating the assessment of water quality.

The aim of this study was to determine the quality of the water used as irrigation water by the agricultural farmers in the city center of Bingol, to determine the physico-chemical properties of the water used in the region, to study the seasonal changes and to calculate of the irrigation water quality evaluation.

Materials and methods

Description of the study area

The average altitude of the study area is 1030 m above sea level, and the study area is located at latitude 38°53'01, 91"-38°53'01, 52" and longitude 40°32'57, 82"-40°32'56, 73". According to the long-term data (1961-2021), the average annual temperature in Bingol province is 12.2 °C and the total amount of precipitation is 944.6 mm, [20]. Precipitation occurs in winter in the form of heavy snowfall and in spring and autumn usually in the form of rain. The lowest temperature is observed in January-February, and the highest temperature is observed in July-August. Agricultural activities are carried out from May to September, when temperature changes are minimal. Downtown DSI (General Directorate of State Hydraulic Works in Türkiye) water channels are used for irrigation water, fig. 1.

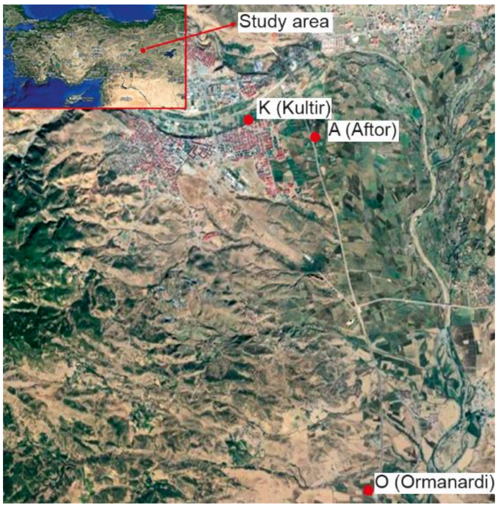

Figure 1. Study area and sampling points; O – Ormanardi, K – Kultur, and A – Aftor

Sampling and field analyses

In order to determine the quality of the irrigation water, samples were taken at three different points (O, N, A) of the DSI irrigation canals in the city center of Bingol. Samples were collected once a month during the months of May-September, when irrigation was at its most intense over a 5-year period between 2018 and 2022. Three samples were taken at each point and the total number of irrigation water samples was 225. Water samples were collected in sterile 1 L pet bottles and transported to the laboratory in ice boxes and stored at +4 °C until analysis.

Analytical methods

Physico-chemical properties of irrigation water samples, sodium adsorption ration (SAR), residual sodium carbonate (RSC), sodium percentage (Na%), Kelleys index (KI), magnesium ratio (MR), permeability index (PI), and irrigational water quality index (IWQI) values were determined. Electrical conductivity (EC) and pH values of irrigation water quality parameters were determined with pH and EC meters (Metter ToledoSeven Compact, USA). The main cations calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+}), and potassium (K^{+}) were measured with a flame photometer (BWB XP). The CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-} ions were determined using the titration method [21].

To determine the suitability of the irrigation water quality in the research area for agricultural use, the irrigation water rating SAR [22, 23], RSC [24], %Na, KI [25], MR and PI [26] were calculated using the following eqs. (1)-(6) respectively, tab. 1.

The weighted arithmetic index method for calculating IWQI has been used, [27]. Many scientists have relied on this mathematical method. The steps required to arrive at a single IWQI score are defined as identifying the parameters, classifying them, assigning a relative weight to each, and then combining all the results [28, 29].

The IWQI was calculated using eqs. (7)-(9). In the first stage, each parameter studied was assigned a weight value, W_i, between 1 and 5 according to its relative importance in influencing water quality, and the relative weight, R_{Wi}, was calculated:

$$R_{Wi} = \frac{W_i}{\sum W_i} \tag{7}$$

where W_i was the weight of each parameter. In the next step, the quality mark, q_i, was calculated by dividing the measured parameters, C_i, by the values, S_i, and multiplying them by 100:

$$q_i = \frac{C_i}{S_i}100 \tag{8}$$

Finally, the mathematical formula of IWQI is given:

$$IWQI = \sum_{i=1}^{n} q_i \, x \, w_i \tag{9}$$

Table 1. Irrigation water quality assessment parameters

$\text{SAR} = \dfrac{\text{Na}^+}{\sqrt{\dfrac{\text{Ca}^+ + \text{Mg}^+}{2}}}$	(1)
$\text{RSC} = (\text{CO}_3^{2-} + \text{HCO}_3^{2-}) - (\text{Ca}^{2+} + \text{Mg}^{2+})$	(2)
$\text{Na\%} = \dfrac{\text{Na}^+}{\text{Ca}^+ + \text{Mg}^+ + \text{Na}^+ + \text{K}^+}100$	(3)
$\text{KI} = \dfrac{\text{Na}^+}{\text{Ca}^+ + \text{Mg}^+}$	(4)
$\text{MR} = \dfrac{\text{Mg}^+}{\text{Ca}^+ + \text{Mg}^+}100$	(5)
$\text{PI} = \dfrac{\text{Na}^+ + \sqrt{\text{HCO}_3^-}}{\text{Ca}^+ + \text{Mg}^+ + \text{Na}^+}100$	(6)

Statistical analysis

The data obtained within the scope of the study were subjected to one-way analysis of variance (ANOVA). Tukey test was used to confirm the significant differences in water quality parameters between months on an annual basis, $p < 0.05$.

Results and discussion

As part of the study, the physico-chemical and qualitative assessment parameters of the irrigation water samples, which were taken at three different locations over a 5-year long period, were analyzed. Within the scope of OG [30], treated wastewater is evaluated within the scope of Class B (irrigation of crops such as orchards and vineyards with keel irrigation). The long-term monitored irrigation water in this study meets the criteria in the national legislation. Parameter values for irrigation water quality and irrigation water trace elements values were given, respectively, tabs. 2 and 3.

Table 2. Parameter values for irrigation water quality, [31]

Potential irrigation problem		Unit	Degree of restriction on use		
			None	Slight to moderate	Severe
Salinity	EC	[dSm^{-1}]	<0.7	0.7-3.0	>3.0
	TDS[c]	[mgL^{-1}]	<450	450-2000	>2000
Permeability (effects infiltration rate of water into soil)	SAR = 0-3	and *EC*=	>0.7	0.7-0.2	<0.2
	SAR = 3-6		>1.2	1.2-0.3	<0.3
	SAR = 6-12		>1.9	1.9-0.5	<0.5
	SAR = 12-20		>2.9	2.9-1.3	<1.3
	SAR = 20-40		>5.0	5.0-2.9	<2.9
Specific ion toxicity (affects sensitive crops)[b]	Sodyum[a]	*SAR*	<3	3-9	>9
	Chloride[a]	[meL^{-1}][d]	<4	4-10	>10
	Boron	[mgL^{-1}]	<0.7	0.7-3	>3
	pH	[–]	Normal range 6.5-8.4		

[a] Represents surface irrigation, [b] trace elements, see tab. 3, [c] Total Dissolved Solids represent with TDS, and [d] milliequivalent/liter is me/L.

Table 3. Irrigation water trace elements values, Ayers and Westcot [31]

Parameter	Unit	[a] FAO (standard)
Ca^{+2}	[meL^{-1}][b]	0-20
Mg^{+2}	[meL^{-1}]	0-5
Na^{+}	[meL^{-1}]	0-40
CO_3^{-}	[meL^{-1}]	0-1
HCO_3^{-}	[meL^{-1}]	0-10
SO_4^{-}	[meL^{-1}]	0-20
K^{+}	[mgL^{-1}]	0-2

[a] Food and Agriculture Organization of the United Nations represent with FAO and [b] milliequivalent/liter is me/l

Physico-chemical characteristics of the irrigation water

Water samples taken from three different points determined within the scope of the study were monitored for 5 years. Taking into account the seasonal changes in the O, K, and A points, it was determined that pH values in the range of 7.63-7.94, EC values in the range of 0.14-0.16 dS/m, Na values in the range of 0.27-0.32 me/L, K values in the range of 0.08 me/L, Ca in the range of 0.75-0.81 me/L, Mg values in the range of 0.33-0.38 me/L, SO_4 in the range of 0.12-0.13 me/L, bicarbonate in the range of 3.16-3.36 me/L, and chlorine values in the range

Table 4. Quality parameter values of irrigation water sampling points over the years

Years	Sample point	pH	EC [dSm^{-1}]	Na	K	Ca	Mg	SO_4	HCO_3	Chlorine
2018	O	7.67± 0.05 A*	0.15± 0.01 A	0.30± 0.05 A	0.08± 0.01 A	0.76± 0.04 A	0.35± 0.04 A	0.12± 0.01 A	3.17± 0.05 A	0.52± 0.02 A
	K	7.70± 0.07 A	0.15± 0.02 A	0.29± 0.05 A	0.08± 0.01 A	0.75± 0.05 A	0.35± 0.05 A	0.13± 0.02 A	3.18± 0.08 A	0.51± 0.01 A
	A	7.80± 0.21 A	0.15± 0.02 A	0.30± 0.07 A	0.08± 0.01 A	0.75± 0.05 A	0.36± 0.02 A	0.12± 0.02 A	3.20± 0.06 A	0.53± 0.02 A
2019	O	7.76± 0.23 A	0.16± 0.02 A	0.28± 0.04 A	0.08± 0.01 A	0.76± 0.04 A	0.33± 0.03 A	0.12± 0.02 A	3.20± 0.05 A	0.52± 0.03 A
	K	7.74± 0.42 A	0.15± 0.01 A	0.29± 0.06 A	0.08± 0.01 A	0.76± 0.04 A	0.33± 0.04 A	0.13± 0.02 A	3.22± 0.05 A	0.54± 0.02 A
	A	7.74± 0.29 A	0.16± 0.01 A	0.32± 0.08 A	0.08± 0.01 A	0.75± 0.04 A	0.33± 0.02 A	0.13± 0.02 A	3.19± 0.09 A	0.54± 0.03 A
2020	O	7.63± 0.22 A	0.15± 0.01 A	0.27± 0.04 A	0.08± 0.01 A	0.77± 0.06 A	0.34± 0.02 A	0.12± 0.02 A	3.33± 0.15 A	0.52± 0.02 A
	K	7.77± 0.30 A	0.15± 0.01 A	0.30± 0.05 A	0.08± 0.01 A	0.78± 0.04 A	0.36± 0.06 A	0.12± 0.02 A	3.21± 0.11 A	0.55± 0.05 A
	A	7.65± 0.12 A	0.16± 0.01 A	0.29± 0.04 A	0.08± 0.01 A	0.75± 0.03 A	0.38± 0.03 A	0.12± 0.02 A	3.24± 0.06 A	0.54± 0.03 A
2021	O	7.72± 0.14 A	0.16± 0.01 A	0.28± 0.03 A	0.08± 0.01 A	0.8± 0.09 A	0.35± 0.04 A	0.12± 0.01 A	3.36± 0.22 A	0.52± 0.04 A
	K	7.94± 0.44 A	0.15± 0.01 A	0.32± 0.06 A	0.08± 0.01 A	0.76± 0.03 A	0.35± 0.04 A	0.13± 0.01 A	3.31± 0.15 A	0.53± 0.03 A
	A	7.72± 0.19 A	0.15± 0.01 A	0.32± 0.07 A	0.08± 0.01 A	0.77± 0.02 A	0.36± 0.04 A	0.12± 0.02 A	3.22± 0.09 A	0.54± 0.03 A
2022	O	7.79± 0.35 A	0.14± 0.01 A	0.28± 0.05 A	0.08± 0.01 A	0.81± 0.07 A	0.36± 0.04 A	0.13± 0.02 A	3.16± 0.04 A	0.53± 0.03 A
	K	7.86± 0.28 A	0.14± 0.01 A	0.29± 0.03 A	0.08± 0.01 A	0.79± 0.07 A	0.37± 0.04 A	0.13± 0.02 A	3.20± 0.03 A	0.53± 0.03 A
	A	7.82± 0.29 A	0.15± 0.01 A	0.30± 0.04 A	0.08± 0.01 A	0.79± 0.04 A	0.33± 0.03 A	0.12± 0.02 A	3.16± 0.04 A	0.54± 0.03 A

* The difference between the values denoted by the same letter is not statistically significant.

of 0.51-0.55 me/L, tab. 4. Carbonate CO_3, analysis was also performed in irrigation water samples and CO_3 value was determined as 0 me/L in all samples as a result of the analysis. When the irrigation water points are analyzed on the basis of parameters, it is understood that the physicochemical parameters are similar within themselves, considering the long-term and seasonal changes. Points O, K, and A were monitored for a long period of time and no external interference was detected along the irrigation water line.

Suitability of water quality for irrigation use

Parameters such as SAR, KI, %Na and PI were calculated to determine the suitability of the surface water quality of the study area for irrigation. Classification of irrigation water suitability based on SAR, %Na, RSC, KI, MR, and PI were given in tab. 5. The SAR, RSC, %Na, KI, MR, and PI values of the irrigation water quality parameters were given in tab. 6.

Table 5. Classification of irrigation water suitability based on SAR, Na%, RSC, KI, MR, and PI [14, 32]

Index	Excellent	Good	Permeable	Doubtful	Suitable	Unsuitable
SAR	<10	10-18	–	18-26	–	>26
Na%	<20	20-40	40-60	60-80	–	>80
RSC	–	<1.25	–	1.25-2.50	–	>2.5
KI	–	–	–	–	<1	>1
MR	–	–	–	–	<50	>50
PI	–	–	–	–	>75%	<25%

Sodium adsorption ratio

The SAR parameter represents the tendency for Na ions to adsorb more than the tolerance limit in soil, [33]. High sodium concentrations affect soil permeability and have a direct impact on the total salinity of water. Indicates that such concentrations may be toxic to sensitive crops, [34]. According to the analysis of irrigation water samples, SAR values were between 0.36-0.42. For all years, SAR values have been less than 20, indicating that the water is *Good* for irrigation. In a study on the irrigation water quality of the Bangladesh Mahananda River, it was stated that SAR values ranged between 0.18-0.678 and were classified as *Good* irrigation water, [12]. Giri *et al.* [14], conducted a similar study on hydrochemical and quality assessment of irrigation water in Leh, Ladakh, Trans-Himalayan high-altitude regions of India and found that all water samples are suitable for irrigation based on the current SAR results.

The United States Salinity Lab. (USSL) salinity diagram is prepared to assess the suitability of irrigation water samples using EC and SAR parameters. It is seen that all of the irrigation waters analyzed between 2018-2022 are in the C1-S1 class and it is understood that they are suitable for irrigation, fig. 2.

Residual sodium carbonate

Permanent sodium carbonate in irrigation waters deteriorates the physical properties of soils and causes the formation of sodic soils. These soils can be called black alkaline soils, [10]. The RSC is a parameter that evaluates the relationship between the amount of carbonate and bicarbonate and total calcium and magnesium, [35]. In the study, RSC values of all irrigation water samples were found to be between 1.5 and 2.5. It can be used as an irrigation water as it does not exceed the RSC limit of 2.5. If the RSC is greater than 2.5, this indicates that it is not suitable for irrigation purposes, [36, 37]. In researches to assess the irrigation water quality from underground and rivers in different regions, it was found that the irrigation water samples taken can be used safely, [10, 38].

Table 6. The SAR, RSC, Na%, KI, MR, and PI values of irrigation water points by year

Years	Sampling points	SAR	RSC	Na%	KI	MR	PI
2018	O	0.39	2.06	19.8	0.26	31.5	148.4
	K	0.39	2.08	19.6	0.26	31.5	150.0
	A	0.39	2.09	19.7	0.26	32.1	149.3
2019	O	0.38	2.11	19.3	0.26	30.1	151.8
	K	0.39	2.13	19.6	0.26	30.1	152.2
	A	0.42	2.11	21.1	0.29	30.6	151.2
2020	O	0.36	2.22	18.4	0.24	30.4	152.9
	K	0.39	2.08	19.5	0.26	31.5	146.7
	A	0.38	2.11	19.3	0.26	33.7	147.6
2021	O	0.37	2.21	18.5	0.24	30.3	149.4
	K	0.42	2.21	21.0	0.29	31.1	151.5
	A	0.42	2.09	20.5	0.28	31.8	146.2
2022	O	0.36	1.99	18.1	0.24	30.4	142.8
	K	0.38	2.03	19.0	0.25	31.9	143.4
	A	0.39	2.03	19.8	0.26	29.5	146.7

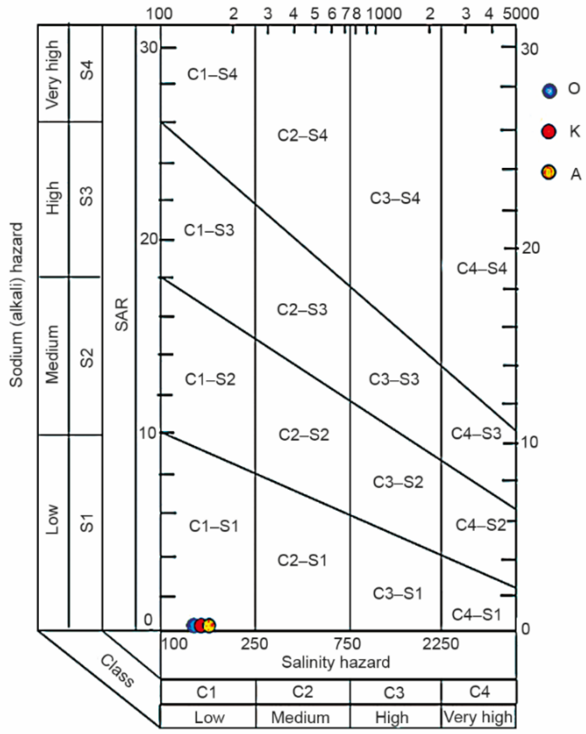

Figure 2. The USSL diagram for classification of irrigation water

Sodium percentage

The Na% is one of the most important basic factors related to the quality of irrigation water. The fraction of all cations made up of sodium is referred to as the Na%. Sodium concentration is expressed as a percentage, [17]. The Na% value in the water to be used in irrigation is required to be below 60%. Abdel-Fattah *et al.* [39] reported that Na% values ranged between 19.96% and 37.32% in a study carried out to evaluate the irrigation water quality in Bahr Mouise Canal, East Nile Delta. In a similar study, 60 irrigation water samples collected in Indian localities were reported to have Na% values between 7.49-40.27, [13]. In addition, Kumar *et al.* [40] indicate that irrigation water with a Na% value of less than 50% is of good quality and suitable for irrigation. As part of the research, the Wilcox diagram was created as a result of irrigation water analysis. All of the irrigation water samples analyzed as a result of the diagram were in the *Excellent* class and were determined as suitable for irrigation, fig. 3.

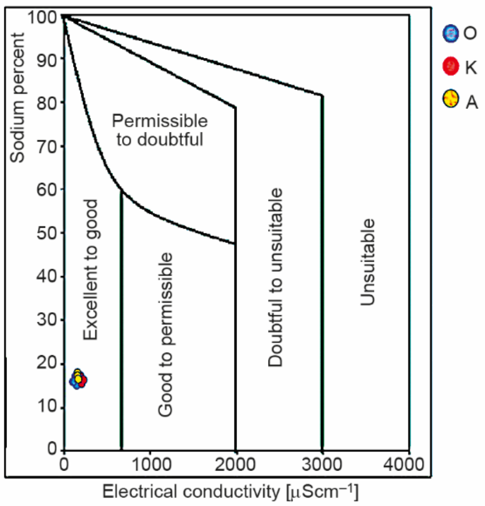

Figure 3. Wilcox diagram sodium percentage graph [41]

Kelley index

Waters with KI values less than 1 are suitable for irrigation, while waters with KI values greater than 1 are not suitable for irrigation, [25]. As a result of the research, when all the years and locations were examined, it was determined that the KI values varied from 0.24 to 0.29 and that there was no damage in the irrigation water samples in terms of the KI parameter. In the studies conducted by Dash and Kalamdhad [11] and Amer and Mohamed [42] on the evaluation of irrigation water quality, KI < 1 was determined and it was stated that it was suitable for irrigation water.

Magnesium ratio

Waters with MR values lower than 50% are suitable for irrigation, while waters with MR values higher than 50% are not suitable for irrigation. The MR values of the irrigation water samples collected as part of the study ranged from 29.5-33.7 and as the values were below 50% it was determined to be suitable for irrigation. In the researches conducted in the Bangladesh Mahananda and Kosovo Blinaja rivers, it was found that the MR values of the water used for agricultural irrigation were suitable, [12, 43].

Permeability index

The PI is an indicator to study the suitability water for irrigation purpose [44]. According to Doneen [45], PI can be categorized in three classes: Class I (>75%, suitable), Class II (25-75%, good), and Class III (<25%, unsuitable). Water under Class I and Class II is recommended for irrigation. In this study, it was found that PI values ranged between 142.8-152.9, tab. 6. Kundu *et al.* [10] determined the PI values to range from 108.6-121.7 and the samples were reported to fall into Class I and Class II categories, confirming their suitability for irrigation. In a similar study, Dash and Kalamdhad [11] found in their irrigation water quality assessment study that values ranged from 50-75% and over 75%.

Irrigation water quality index

The EC, Na^+, Cl^-, HCO_3^-, and SAR parameters were used to calculate the IWQI. These are the parameters that define the best water quality. The IWQI is classified in five different categories. The IWQI value $0 \leq 40$ should be avoided its use for irrigation under normal conditions. The IWQI value $40 \leq 55$ may be used in soils with high permeability without compact layers. The IWQI value $55 \leq 70$ may be used in soils with moderate to high permeability values, being suggested moderate leaching of salts. The IWQI value $70 \leq 85$ recommended for use in irrigated soils with light texture or moderate permeability, being recommended salt leaching, and IWQI value $85 \leq 100$ may be used for the majority of soils with low probability of causing salinity and sodicity problems, being recommended leaching within irrigation practices, except for in soils with extremely low permeability, [46]. The limit values of the parameters used in the calculation are given in tab. 7 and the calculated IWQI weight values are given in tab. 8.

Table 7. Parameter limiting values for quality measurement, q_i, calculation, [46]

q_i	EC [dSm^{-1}]	SAR	Na [meqL^{-1}]	Cl [meqL^{-1}]	HCO_3 [meqL^{-1}]
85-100	$0.2 \leq EC < 0.75$	$2 \leq SAR < 3$	$2 \leq Na < 3$	$1 \leq Cl < 4$	$1 \leq HCO_3 < 1.5$
60-85	$0.75 \leq EC < 1.50$	$3 \leq SAR < 6$	$3 \leq Na < 6$	$4 \leq Cl < 7$	$1.5 \leq HCO_3 < 4.5$
35-60	$1.50 \leq EC < 3.00$	$6 \leq SAR < 12$	$6 \leq Na < 12$	$7 \leq Cl < 10$	$4.5 \leq HCO_3 < 8.5$
0-35	$EC < 0.20$ or $EC \geq 3.0$	$SAR < 2$ or $EC \geq 12$	$Na < 2$ or $Na \geq 12$	$Cl < 1$ or $Cl \geq 10$	$HCO_3 < 1$ or $HCO_3 \geq 8.5$

As a result of the calculations on the irrigation water samples taken from the region, the IWQI values between 77.3 and 78.4 were calculated. In this direction, considering the IWQI limit values, it was determined that it is suitable for use as irrigation water. The IWQI values of Abdel-Fattah *et al.* [39] for irrigation water quality in the Bahr Mouise canal changed between 85 and 100, and they stated that it was suitable for irrigation water. Similarly, in the research conducted to examine the quality of groundwater for irrigation purposes in the Sistan and Balochistan regions of Iran, it was found that most of the wells were rated excellent and good according to the *IWQI*, [47].

Table 8. Weights for the IWQI parameters, [46]

Parameters	W_I
Electrical condutivity	0.211
Sodium	0.204
Bicarbonate	0.202
Chloride	0.194
Sodium adsorption ration	0.189
Total	1.00

Conclusion

In this study, long-term quality parameters of agricultural irrigation water channels in the center of Bingol province were followed and irrigation water quality evaluation was carried out. Considering the seasonal changes of irrigation water samples in the 5-year long term it was determined that pH values of 7.63-7.94, EC values of 0.14-0.16 dS/m, Na values of 0.27-0.32, K values of 0.08, Ca values of 0.75-0.81, Mg values of 0.33-0.38, SO_4 values of 0.12-0.13, bicarbonate values in the range of 3.16-3.36 and chlorine values in the range of 0.51-0.55. In terms of irrigation water quality assessment, it was determined that SAR values were between 0.36-0.42, RSC values between 1.5-2.5 and IWQI values between 77.33-78.42. It has been determined that the Na% values are excellent to good, the USSL salinity diagram is in the C1-S1 Class, and the irrigation water class Class-I according to PI, and considering the KI, MR, and IWQI limit values, it can be used as irrigation water. Long-term irrigation water resources should be monitored taking into account environmental interventions. Analysis of canal bottom sludge should also be performed in irrigation water quality assessment.

References

[1] Lu, Z., *et al.*, Decentralized Water Collection Systems for Households and Communities: Household Preferences in Atlanta and Boston, *Water Research, 167* (2019), Dec., 115134
[2] Shamshad, I., *et al*., Unrevealing the Biosorption Capacity of Freshwater Algae Biomasses for Toxic Heavy Metals in Aqueous Solutions, *Desalin. Water Treat., 184* (2020), Apr., pp. 189-198
[3] Din, I. U., *et al.*, Groundwater Quality Assessment for Drinking and Irrigation Purposes in the Hangu District, Pakistan, *Journal of Food Composition and Analysis, 115* (2023), Jan., 104919
[4] Khedr, M., Challenges and Issues in Water, Climate Change, and Food Security in Egypt, *Conventional Sources and Agriculture in Egypt,* (2019), pp. 229-243
[5] Abuzaid, A. S., Jahin, H. S., Implications of Irrigation Water Quality on Shallow Groundwater in the Nile Delta of Egypt: A Human Health Risk Prospective, *Environmental Technology & Innovation, 22,* (2021), May, 101383
[6] Malakar, A., *et a.*, Irrigation Water Quality, A Contemporary Perspective, *Water, 11* (2019), 7, 1482
[7] Gao, Y., *et al.*, Hydrogeochemical Characterization and Quality Assessment of Groundwater Based on Integrated-Weight Water Quality Index in a Concentrated Urban Area, *J. Clean. Prod., 260* (2020), July, 121006
[8] Saliba, R.,*et al.*, Stakeholders' Attitude Towards the Reuse of Treated Wastewater for Irrigation in Mediterranean Agriculture, *Agricultural Water Management, 204* (2018), May, pp. 60-68
[9] Fan, X., *et al.*,Assessment of River Water Quality in Pearl River Delta Using Multivariate Statistical Techniques, *Procedia Environmental Sciences, 2* (2010), pp. 1220-1234
[10] Kundu, R., Ara, M. H., Irrigation Water Quality Assessment of Chitra River, Southwest Bangladesh, *Journal of Geoscience and Environment Protection, 7* (2019), 4, pp. 175-191
[11] Dash, S., Kalamdhad, A. S., Hydrochemical Dynamics of Water Quality for Irrigation Use and Introducing a New Water Quality Index Incorporating Multivariate Statistics, *Environmental Earth Sciences, 80* (2021), 3, pp. 1-21
[12] Anonna, T. A., *et al.*, Water Quality Assessment for Drinking and Irrigation Purposes in Mahananda River Basin of Bangladesh, *Earth Systems and Environment, 6* (2022), 1, pp. 87-98
[13] Chowdhury, P., *et al.*, Hydrochemical Assessment of Groundwater Suitability for Irrigation in the North-Eastern Blocks of Purulia District, India Using GIS and AHP Techniques, *Physics and Chemistry of the Earth, Parts A/B/C, 126* (2022), June, 103108
[14] Giri, A., *et al.*, Hydrochemical and Quality Assessment of Irrigation Water at the Trans-Himalayan High-Altitude Regions of Leh, Ladakh, India, *Applied Water Science, 12* (2022), 8, pp. 1-20
[15] Etteieb, S., *et al.*, Hydrochemical Assessment of Water Quality for Irrigation: A Case Study of the Medjerda River in Tunisia, *Applied Water Science, 7* (2017), 1,pp. 469-480
[16] Misaghi, F., *et al.*,Introducing Awater Quality Index for Assessing Water for irrigation Purposes: A Casestudy of the Ghezel Ozan River, *Science of the Total Environment, 589* (2017), July, pp. 107-116
[17] Bhunia, G. S., An assessment of Irrigation Water Quality of Kasai River Basin Using Geo-Analytical Approach, *Arabian Journal of Geosciences, 15* (2022), 17, pp. 1-16

[18] Alavaisha, E., *et al.*, Assessment of Water Quality Across Irrigation Schemes: A Case Study of Wetland Agriculture Impacts in Kilombero Valley, Tanzania, *Water, 11* (2019), 4, 671
[19] Yildiz, S., Karakus, C. B., Estimation of Irrigation Water Quality Index with Development of an Optimum Model: A Case Study, *Environment, Development and Sustainability, 22* (2020), 5, pp. 4771-4786
[20] ***, TurkStat, Turkish Statistical Institute Data Basis, http://www.tuik.gov.tr, 2023
[21] ***, APHA, *Standard Methods for the Examination of Water and Wastewater*, 20th ed., Washington, DC, USA: American Public Health Association, 1998
[22] Richards, L. A., *Diagnosis and Improvement of Saline and Alkali Soils*, Washington: United States Department of Agriculture, (Agriculture Handbook No. 60), *78* (1954), 2, 160
[23] Ehya, F., Mosleh, A., Hydrochemistry and Quality Assessment of Groundwater in Basht Plain, Kohgiluyeh-va-Boyer Ahmad Province, SW Iran, Environ, *Earth Sci., 77* (2018), 164
[24] Subramani, T., *et al.*, Groundwater Quality and Its Suitability for Drinking and Agricultural Use in Chithar River Basin, Tamil Nadu, India, *Environmental Geology, 47* (2005), Apr., pp. 1099-1110
[25] Kelley, W. P., Use of Saline Irrigation Water, *Soil Science, 95* (1963), 6, pp. 385-391
[26] Raghunath, I. I. M. *Groundwater*, 2nd ed. New Delhi: Wiley Eastern Ltd., (1987), 563
[27] Brown, R. M., *et al.*, A Water Quality Index Crashing the Psychological Barrier, In Indicators of Environmental Quality: *Proceedings*, Symposium Held During the AAAS Meeting in Philadelphia, Pennsylvania, December 26-31, 1971, (pp. 173-182), Springer, USA, 1972
[28] Sener, S., *et al.*, Evaluation of Water Quality Using Water Quality Index (WQI) Method and GIS in Aksu River (SW-Turkey), *Science of the Total Environment, 584* (2017), Apr., pp. 131-144
[29] Taloor, A. K., *et al.*, Spring Water Quality and Discharge Assessment in the Basantar Watershed of Jammu Himalaya Using Geographic Information System (GIS) and Water Quality Index (WQI), *Groundwater for Sustainable Development, 10* (2020), Apr., 100364
[30] ***, OG, Wastewater Treatment Plants Technical Procedures Communiqué (in Turkish), Republic of Turkey, Official Gazette, No: 27527, 2010
[31] Ayers, R. S., Westcot, D. W., *Water Quality for Agriculture*, Rome: Food and Agriculture Organization of the United Nations, *29* (1985), 174
[32] ***, United States Environmental Protection Agency 1986, Quality criteria for water (Gold Book). EPA, USA.https://www. epa. gov/sites/production/files/2018–10/documents/quality–criteria–water–1986.pdf
[33] Zaidi, F. K., *et al.*, Evaluation of Groundwater Chemistry and Its Impact on Drinking and Irrigation Water Quality in the Eastern Part of the Central Arabian Graben and Trough System, Saudi Arabia, *Journal of African Earth Sciences, 120* (2016), Aug., pp. 208-219
[34] Gonzalez-Acevedo, Z. I., *et al.*, Quality Assessment of Irrigation Water Related to Soil Salinization in Tierra Nueva, San Luis Potosi, Mexico, *Revista Mexicana de Ciencias Geologicas, 33* (2016), 3, pp. 271-285
[35] Khalid, S., An Assessment of Groundwater Quality for Irrigation and Drinking Purposes Around Brick Kilns in Three Districts of Balochistan Province, Pakistan, Through Water Quality Index and Multivariate statistical Approaches, *Journal of Geochemical Exploration, 197* (2019), Feb., pp. 14-26
[36] ***, United States Environmental Protection Agency, *Treatment Wetland Habitat and Wildlife Use Assessment: Executive Summary*, EPA, Washington, USA, 1999
[37] Mandal, S. K., *et al.*, Assessment of River Water Quality for Agricultural Irrigation, *International Journal of Environmental Science and Technology, 16* (2019), Feb., pp. 451-462
[38] Makhlof, H. A. H., *et al.*, The Demarcation of Groundwater Quality for Irrigation Purposes in Sirte, Libya, *Water Resources and Irrigation Management-WRIM, 10* (2021), 1-3, pp. 15-24
[39] Abdel-Fattah, M. K.,*et al.*, Multivariate Analysis for Assessing Irrigation Water Quality: A Case Study of the Bahr Mouise Canal, Eastern Nile Delta, *Water, 12* (2020), 9, 2537
[40] Kumar, P. M., *et al.*, Assessment of the Groundwater Quality for Irrigation Purposes in Rasipuram Taluk, Tamilnadu, India, *Asian J. Res. Soc. Sci. Humanit., 6* (2016), 10, pp. 547-553.
[41] Wilcox, L., Classification and Use of Irrigation Waters (No. 969), US Department of Agriculture (1955)
[42] Amer, A. S., Mohamed, W. S., Assessment of Ismailia Canal for Irrigation Purposes by Water Quality Indices, *Environmental Monitoring and Assessment, 194* (2022), 12, pp. 1-19
[43] Cadraku, H. S., Groundwater Quality Assessment for Irrigation: Case Study in the Blinaja River Basin, Kosovo, *Civil Engineering Journal, 7* (2021), 9, pp. 1515-1528
[44] Rawat, K. S., *et al.*, Assessment of Groundwater Quality for Irrigation Use: a Peninsular Case Study, *Applied Water Science, 8* (2018), Nov, pp. 1-24

[45] Doneen, L. D., Notes on Water Quality in Agriculture, Davis: Department of Water Science and Engineering, *University of California*, 1964
[46] Meireles, A. C. M., *et al.*, A New Proposal of the Classification of Irrigation Water, *Revista Ciencia Agronomica, 41* (2010), pp. 349-357
[47] Abbasnia, A., *et al.*, Evaluation of Groundwater Quality Using Water Quality Index and Its Suitability for Assessing Water for Drinking and Irrigation Purposes: Case Study of Sistan and Baluchistan Province (Iran), *Human and Ecological Risk Assessment: An International Journal, 25* (2019), 4, pp. 988-1005

Paper submitted: January 20, 2023
Paper revised: February 25, 2023
Paper accepted: May 5, 2023