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Evaluation of the Suitability of the Euphrates River water for Drinking and Irrigation purposes in Haditha City, Western Iraq

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ABSTRACT

The supply of freshwater is essential to life, socio-economic development, and political stability in the Middle East. Recently, Iraq's rivers have experienced extreme shortage water scarcity as a result of climate change, as evidenced by the rarity of rainfall and high temperatures. To assess the Euphrates river water for drinking and irrigation uses in Haditha city, Ten water samples were collected in the study region and analyzed for major ions. It was established that water samples in the study region are considered freshwater, low enrichment of salts, and slightly alkaline water**.** Piper diagram indicates the overall samples belong to class1 (Mg^{2+}, Ca^{2+}, SO_4^{2-}, Cl^-) and category I (Ca^{2+} - Mg^{2+} and SO_4^{2-} - Cl^-), calcium chloride type (permanent hardness). The Water Quality Index shows that water samples are suitable for drinking purposes. All water sample is suitable for irrigation in the study region.

1. Introduction

The quality of surface waters is a very sensitive issue. Surface water is widely used in industrial, domestic, and agricultural uses around the world, it's an important source of drinking water in both urban and rural regions because it is a natural resource [1]. Anthropogenic influences (agricultural activities, industrial, urban, and increasing water resource consumption) in addition to natural processes (weathering of crustal materials, erosion, changes in precipitation inputs) degrade surface waters and make them unfit for drinking, agricultural, recreational, industrial, or other uses [2]. Water quality is also linked to a number of geological and climatic factors, forming its own ecosystem governed by the laws of its environmental constituents. The Euphrates River water quality reflects a continuous decline. It has been observed in recent years that the quality of the Euphrates River's water has begun to deteriorate at an increasing rate; the Euphrates River's water quality deterioration is caused by agricultural retained irrigation, drainage performs, land management, geological formations, in addition to the effect of climate change. One of the most important strategies to maintain long-term water sustainability is to regularly examine it and verify that it is free of harmful impurities (inorganic and organic) [3]. The construction of dams by Turkey and Syria reduced the flow regime. TDS of Euphrates River water in Turkey does not exceed 300 mg/l, but it eventually rises to 600 mg/l near the Iraqi-Syrian border, reaching 2100 mg/l at Nasiriya city [4].

Rivers is the most important natural resource for human development, but they are contaminated by careless industrial waste, sewage discharge and a variety of human activities, which have a negative impact on their microbiological and physicochemical quality. An extensive water quality monitoring program is increasingly needed to protect public health and valuable freshwater resources. The current study was conducted with the aim of evaluating the suitability of the Euphrates River water for drinking and irrigation purposes in Haditha city**.**

2. Location of the study region

The study region is located at the northeast border of the Iraqi Western Desert. The study region is restricted to longitudes (42º 17' 7.66"- 42º 92' 44.92"

E) and latitudes (34º 14' 2.67" – 33º 59' 48.92" N) with an area of about 323 km^2 (**Fig. 1**).

3. Geological setting and Climate

Anah, Euphrates, and Fatha Formations represent the main sedimentary formation in the study area in add Quaternary deposits (Fig. 2). The oldest is the Anah Formation (Upper Oligocene) which consists of coralline, massive, dolomitic limestone, and very hard limestone, which are locally strongly karstified leading to cavities of different sizes. The Euphrates Formation exposes along both banks of the Euphrates River. Euphrates Formation (Lower Miocene), The Formation is formed by two members, the bottom unit: It is mainly composed of gravels conglomerate followed by layers of limestone and dolomite and the upper unit: It consists of a sequence of limestone, dolomite, brescia with horizontal layers and lenses of the green shell [6]. Fatha Formation (Middle Miocene) lies unconformably with Euphrates Formation. It consists of gypsum and anhydrite interbedded with limestone, marl, and relatively fine-grained clastic [7]. These formations are covered by various types of Quaternary sediments (Pleistocene-Holocene) that form a discontinuous cover that includes river terraces, gravel, conglomerates and sand [8]. The geomorphology of the Haditha city includes many features such as isolated hills, sinkholes, flood plains and islands along the Euphrates River. Karsts formed by gypsum and limestone solutions occur in both Fatha and Euphrates Formations [9].

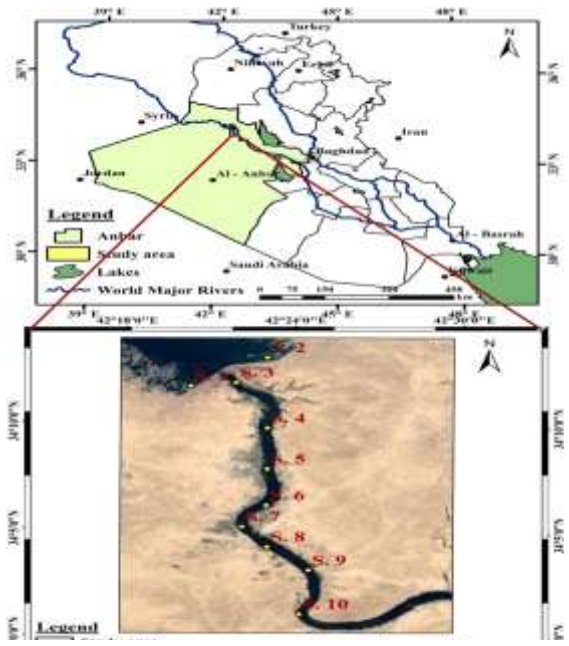


Fig. 1: Location map and locations of the selected samples of the study area

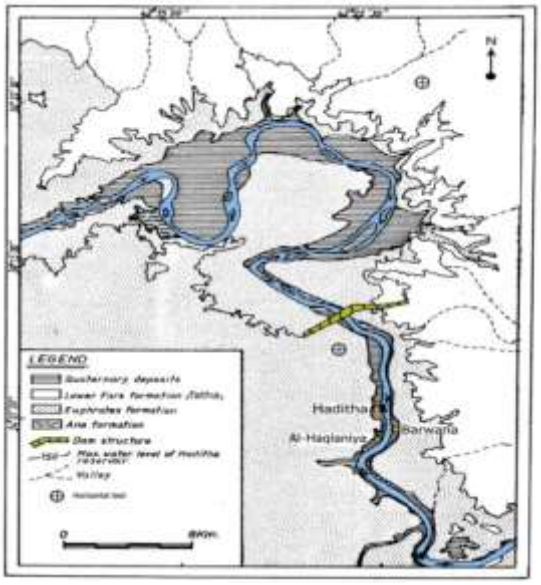


Fig. 2: Geological map of the study region [11].

Climatically, the metrological data were recorded in Haditha station during 1988 – 2019 [10]. The total yearly rainfall was 130 mm, and evaporation of 2825 mm, with a monthly average temperature of 22.1 °C, relative humidity was 46.4 %, wind speed of 3.1 m/s, and sunshine length of 8.9 h/day. The climate in the research region is classified as arid. The aims of the research proposed to evaluate the water in the Haditha area using water quality (WQI) and irrigation use evaluation.

4. Methods and Materials

Ten water samples were collected from Euphrates river in Haditha city in November 2019 (**Fig.1**). Electrical conductivity (EC), Hydrogen Number (pH), Water Temperature (T) and Total Dissolved Solids (TDS) were taken in the field, where samples were collected from the middle of the river by one liter bottles for each sample. The remaining water sample characteristics were measured in the laboratory immediately after transportation to the laboratory of Anbar Water Directorate. Each of these water samples was analyzed for 11 parameters, which are Ca^{2+}, K^{+}, Na^{+}, Mg^{2+}, SO_4^{2-}, Cl^{-}, HCO_3^{-} and NO_3^{-} (**Table 1**) using a standard procedure of [12].

Table 1: Physico-chemical analysis of water samples in study area.

Samples	T (°C)	TDS (ppm)	EC (µS/cm)	pH	Ca^{2+} (ppm)	Mg^{2+} (ppm)	Na^{+} (ppm)	K^{+} (ppm)	Cl^{-} (ppm)	SO_4^{2-} (ppm)	HCO_3^{-} (ppm)	NO_3^{-} (ppm)
S 1	18	411	583.4	7.7	53.35	33.45	30.9	2.8	80	144	60	3
S 2	18	350	569.6	7.7	51.63	15.81	32.5	2.9	58.8	121.3	50.4	3.1
S 3	18	422	552.6	7.6	58.81	28.1	33.4	2.9	80.9	133.3	72.7	4
S 4	19	442	572.7	7.7	60	33.15	33.3	2.8	120.08	154.3	25	3.5
S 5	18	448	583.5	7.4	56.7	33.5	34.6	3	87.8	143.6	67	5
S 6	18	441	561.9	7.7	53.66	36.9	34.9	3	83.8	154.3	65	4.2
S 7	19	788.2	1126	7.4	85.8	55.86	85.1	9.9	256.66	225.5	34	3.4
S 8	18	546	661.5	7.2	60.4	48.7	45.6	4.1	170.5	172.8	33	6
S 9	18	451	550	6.7	55.47	34.5	36.3	2.4	106	138.2	60.9	6.2
S 10	18	472	626.8	6.9	54.28	43.84	38.6	3.6	107.47	162.9	55.8	5.6
min.	18	350	550	6.7	51.63	15.81	30.9	2.4	58.8	121.3	25	3
max.	19	788.2	1126	7.7	85.8	55.86	85.1	9.9	256.66	225.5	72.7	6.2
ave.	18.2	477.1	638.8	7.4	59.01	36.38	40.5	3.7	115.2	155	52.38	4.4

5. Results and Discussion:

The Physicochemical characterization for water samples of the Euphrates river is given in (**Table 1**). Water in the study region was described as colorless, and odorless. The temperature range 18 - 19 °C with a mean of 18.2 °C. The ranges of pH value from 6.7 - 7.7 with a mean of 7.4 these values are within the permissible ranges (6.5–8.5) indicating slightly alkaline water samples [13] and [14]. The ranges of EC value from 550 to 1126 µS/ cm with a mean of 638.8 µS/ cm. The water samples in the study area are classified as low enrichment of salts according to [15]. The ranges of TDS value from 350 to 788.2 mg/l with a mean of 477.12 mg/l. According to [16] the water samples are considered to be Fresh water.. We note through (Table 1) that sample No. (7) shows a very high value compared to the rest of the samples, due to the sulfur springs of Hajlan, Where the sample was taken after the confluence of the sulfur springs of Hajlan with the Euphrates River and we note through these concentrations the effect of the sulfur springs on the river.

5.1 Hydrochemical Facies

The trilinear diagram [17] was used to classify the water samples depending on their main anion and cation. The hydro-chemical facies of water samples in the study region is revealed in (**Fig.3**), Illustrated by Piper diagram it's all samples belong to class 1 (Ca^{2+}, Mg^{2+}, Cl^{-} and SO_4^{2-}), permanent hardness (calcium chloride type) for the water in the study area (**Table 2**).

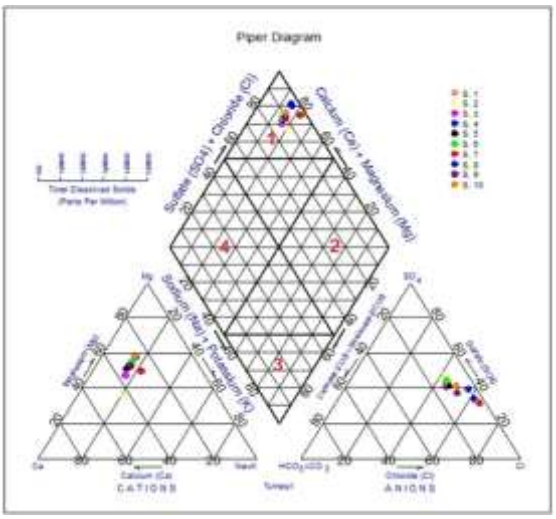


Fig. 3: Type of groundwater according [17]

Table 2: Surface water sample classification using the Piper diagram.

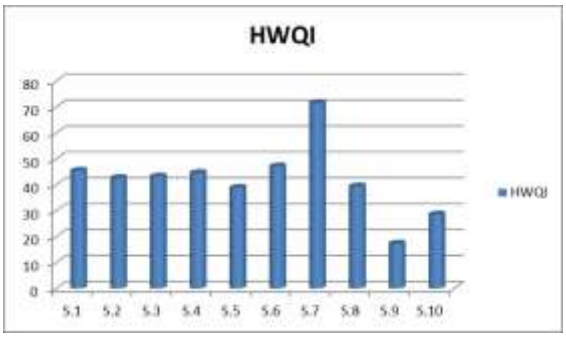
Class	Hydrochemical facies	Category	Water type
1	Ca^{2+}-Mg^{2+}-Cl^{-}-SO_4^{2-}	I	SO_4^{2-}-Cl^{-} and Ca^{2+}-Mg^{2+} (noncarbonated hardness exceeds 50 %) calcium chloride type (Permanent hardness).
2	Na^{+}-K^{+}-Cl^{-}-SO_4^{2-}	II	SO_4^{2-}-Cl^{-} and Na^{+}-K^{+} (non-carbonate alkali exceeds 50 %) sodium chloride type(Saline).
3	Na^{+}-K^{+}-HCO_3^{-}	III	HCO_3^{-}-CO_3^{2-} and Na^{+}-K^{+} (carbonate alkali exceeds 50 %) sodium bicarbonate type (Alkali carbonate).
4	Ca^{2+}-Mg^{2+}-HCO_3^{-}	IV	HCO_3^{-}-CO_3^{2-} and Ca^{2+}-Mg^{2+} (carbonate hardness exceeds 50 %) magnesium bicarbonate type (Temporary hardness).
		V	Mixing zone (no one anion- cation exceed 50 %)

5.2 Drinking Water Quality Index (WQI)

Surface water chemistry has been used to estimate water quality for drinking and irrigation purposes [18]. WQI is calculated by reducing a large amount of data to a single number**.** The three steps are taken into account when calculating WQI [19].

The nine parameters which were pH, TDS, Potassium, Magnesium, Sulphate, Calcium, Chloride, Sodium, and Nitrate were used for evaluation of surface water suitability for human consumption of WQI (**Fig.4**). The World Health Organization drinking water standards [13] are used to calculate the

water quality index (HWQI) model. **(Table 3)** shows the standard and weighted arithmetic for each parameter.



Fig, 4: Water Quality Index (WQI) for water samples in the study region

Table 3: The standard and weighted arithmetic for each parameter according to [13]

Parameters	WHO Standard	1/Si	K	Relative Weight (Wi)
PH	6.5 - 8.5	0.1176	3.5137	0.413
TDS (ppm)	1000	0.001		0.003
Ca^{2+} (ppm)	75	0.013		0.046
Mg^{2+} (ppm)	50	0.02		0.07
Na^{+} (ppm)	200	0.005		0.017
K^{+} (ppm)	10	0.1		0.35
Cl^{-} (ppm)	250	0.004		0.014
So_4^{2-} (ppm)	250	0.004		0.014
No_3^{-} (ppm)	50	0.02		0.07
Total		0.2846		1

The WQI for all surface water samples is excellent drinking water, except S 7 is good for human drinking according to [20] (**Fig.5**).

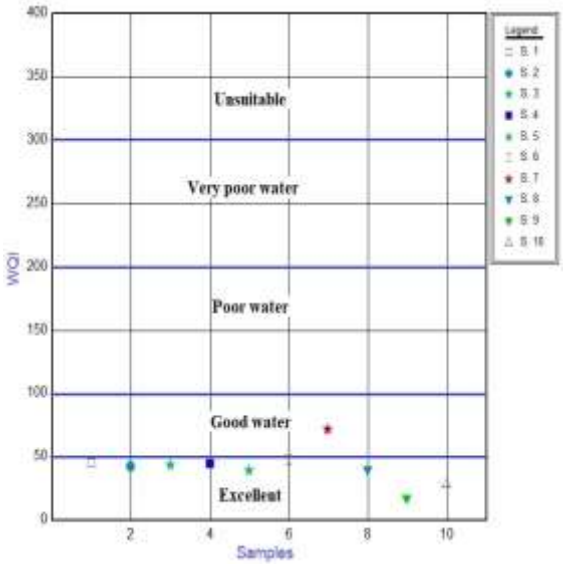


Fig. 5: Water quality classification for the study area samples based on [20]

5.3 Suitability for irrigation

The importance of assessing irrigation water stems from the impact of water quality on crops, soil, and plants. Irrigation water suitability is determined by the effects of salt concentration on plants [18]. Many problems have arisen during using of water for irrigation, particularly different parameters such as salinity, permeability, infiltration trace element toxicity, specific ion toxicity, and hazards due to other factors sensitive crops, so, water with a high salt ratio will have an effect on crop growth. In addition, the TDS, pH, sodium, and trace elements all have an impact on the suitability of irrigation water [21]. The suitability of the Euphrates river in Haditha city for irrigation is evaluated by estimating the percent sodium (Na%), sodium adsorption ratio (SAR), Kelly's index (KI), permeability index (PI) and residual sodium carbonate (RSC). Ten samples of Euphrates river in the study region are suitable for irrigation in general based on EC (ranged between 550 - 1126 µS/cm), TDS (ranged between 350 - 788.2 mg/l), Na% (ranged between 20.7 - 30.8), SAR (ranged between 0.81 - 1.75), KI (ranged between 0.24 - 0.41), RSC (ranged between -8.31 - -3.05) and PI (ranged between 25.9 - 42.3) (**Fig.6**). Thus, the ten samples belong to good to a permissible class of EC, freshwater class of TDS, good of Na%, no problem of SAR, suitable for irrigation of KI, safe for irrigation of RSC and suitable for irrigation of PI (**Fig. 6**).

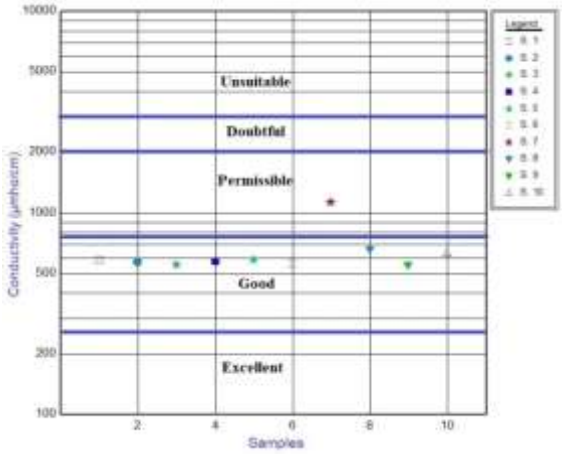


Fig. 6 a: Irrigation water suitability depending on EC [22]

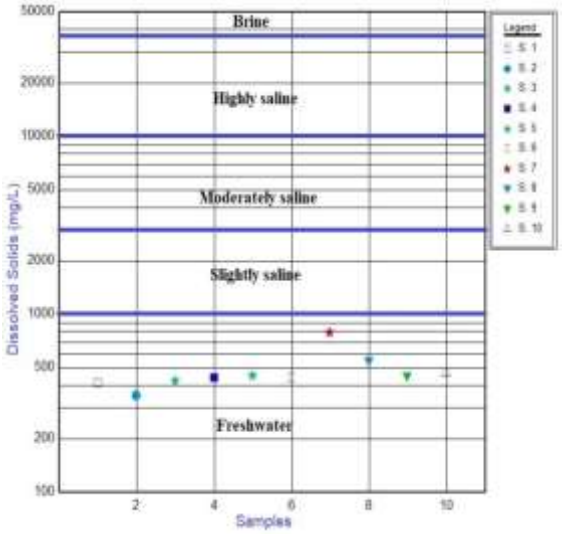


Fig. 6 b : Irrigation water suitability depending on TDS [23]

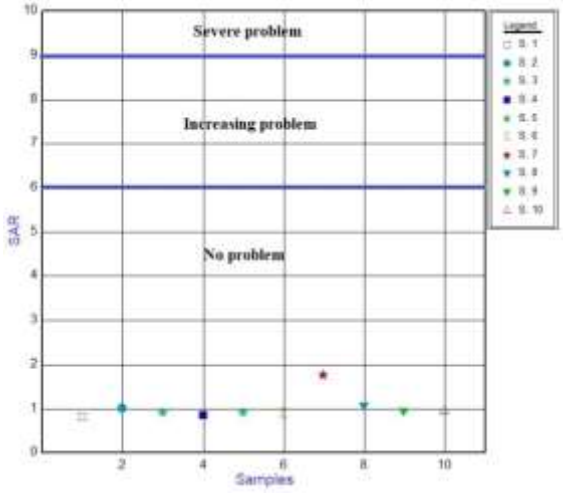


Fig. 6 c :Irrigation water suitability depending on SAR [24]

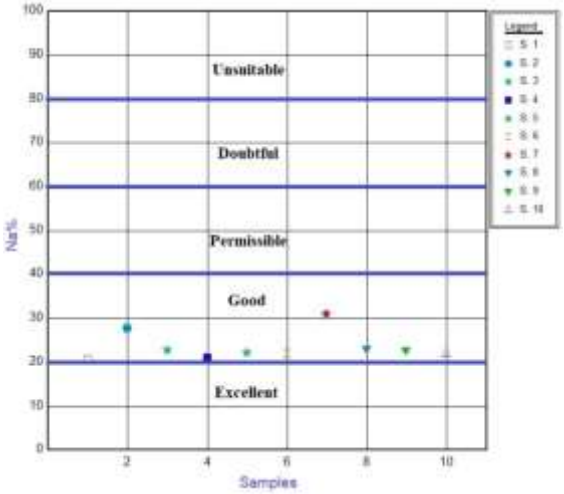


Fig. 6 d : Irrigation water suitability depending on Na% [25]

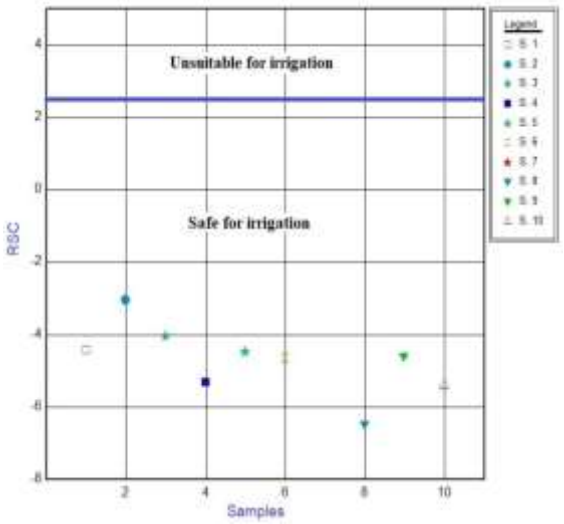


Fig. 6 e : Irrigation water suitability depending on RSC [26]

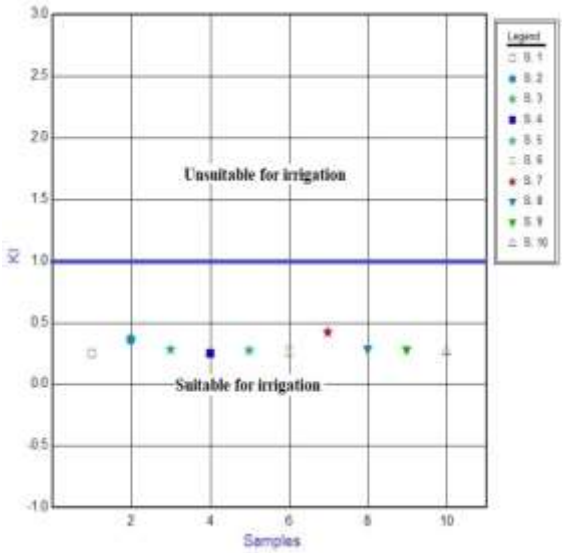


Fig. 6 f :Irrigation water suitability depending on KI [27]

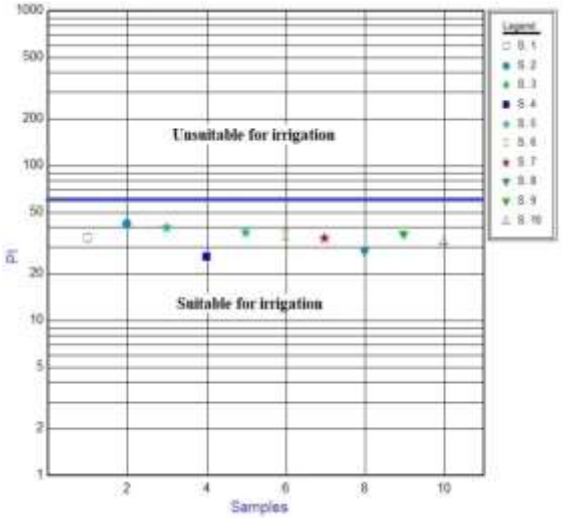


Fig. 6 g: I rrigation water suitability depending on PI [28]

Conclusions

Haditha lake and Euphrates river in Haditha city was sampled to assess the Water Quality Index and the water's suitability for irrigation uses. Based on TDS, EC, and pH classifications, the water quality in the area is Freshwater, low enrichment of salts, and slightly alkaline water respectively, within the WHO standards' permitted limit. Piper diagram illustrated all samples belonging to class1 (Mg^{2+}, Ca^{2+}, SO_4^{2-}, Cl^-) and category I (Ca^{2+} - Mg^{2+} and SO_4^{2-} - Cl^-), calcium chloride type (permanent hardness) for the waters of the study region. The calculated WQI results show that the water sample in the study region was excellent to good water for human drinking. The irrigation suitability of water has been determined based on EC, TDS, Na%, SAR, RSC, and PI. According to these classifications, all water sample is suitable for irrigation in the study region.

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تقييم مدى ملائمة مياه نهر الفرات لأغراض الشرب والري في مدينة حديثة غربي العراق

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الملخص

إن إمدادات المياه العذبة ضرورية للحياة، وللتنمية الاجتماعية والاقتصادية، والاستقرار السياسي في الشرق الأوسط. في الآونة الأخيرة، عانت أنهار العراق من نقص شديد في المياه نتيجة لتغير المناخ، بسبب ندرة هطول الأمطار وارتفاع درجات الحرارة. لتقييم مياه نهر الفرات لاستخدامات الشرب والري في مدينة حديثة، تم جمع عشر عينات من المياه في منطقة الدراسة وتحليلها للأيونات الرئيسية. ثبت أن عينات المياه في منطقة الدراسة تعتبر مياه عذبة قليلة الإثراء بالأملاح ومياه قلوية قليلاً. يشير مخطط (Piper) إلى أن العينات الإجمالية تنتمي إلى الفئة الأولى (Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-}) نوع كلوريد الكالسيوم. يوضح مؤشر جودة المياه أن عينات المياه مناسبة لأغراض الشرب. جميع عينات المياه مناسبة للري في منطقة الدراسة.