2024, 21(4): 1147-1161
https://doi.org/10.21123/bsj.2023.8320
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
Baghdad Science Journal

Water Quality Assessment of Smaquli Dam- Erbil for Drinking, Irrigation and Fish Farming

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Received 03/01/2023, Revised 10/03/2023, Accepted 12/03/2023, Published Online First 20/09/2023, Published 01/04/2024

Abstract

This study was devoted to characterizing the water quality of Smaquli Dam, based on the calculation method of using the Water Quality Index (WQI) for drinking, irrigation and fish farming purposes. Water samples were collected from eight sites monthly from September 2021 to June 2022. The water quality index (WQI) was determined for drinking purposes based on the most important fifteen physical and chemical parameters, including; pH, electrical conductivity, turbidity, dissolved oxygen, biochemical oxygen demand, total alkalinity, total hardness, calcium and magnesium ions, sodium, potassium, chloride, nitrite, nitrate and sulphate. The relative weight of each parameter varied from 1 to 5 based on the most critical important parameter essential for aquatic life, domestic use and household. The results indicated that the water of the Smaquli Dam, with its inlet and outlet, is suitable for drinking after traditional treatment (DWQI) of all sites ranging from (68.11 to 83.93). However, for the irrigation water quality index (IWQI), studied samples were analyzed for EC, sodium adsorption ratio (SAR), sodium (Na^{+1}), chloride (Cl^{-1}) and bicarbonate (HCO_3^{-1}) contents. The results of (IWQI) ranged from (68.84 to 70.20), which means that the water samples fall within the class of low (LR) and moderate restriction category (MR) for irrigation purposes. Finally, six parameters including: pH, turbidity, TDS, DO, Total Hardness and Nitrate were determined to evaluate Smaquli dam water quality for fish farming based on standard limits for each parameter. The results for all parameters of all locations were within the permissible standard limit for fish farming except total hardness parameter.

Keywords: Drinking, Fish Farming, Irrigation, Sodium Adsorption Ratio, Water Quality Index.

Introduction

Water is one of the ecosystem's most essential and plentiful substances. It is one of the most crucial ecological factors for our planet's survival and growth. Water is essential for the reproduction and developing all living organisms on planet [1]. Approximately 71 percent of the Earth's surface is covered by water which is a vital natural resource. It is crucial in maintaining metabolic activity and homeostasis in living cells. Because of their immense biological diversity, freshwater habitats are one of the most important natural resources in the world [2]. This ecosystem's high economic value makes it suitable for aquaculture as a source of food for food security, leisure, and nature tourism, as well as genetic resources. However, it has become highly contaminated with various toxic pollutants due to increased human population, industrialization, agricultural fertilizer usage, and man-made operation [3]. The availability of high-quality water is critical for disease prevention and improved quality of life. Impurities are released into the aquatic environment in various ways, involving several human activities, such as mining, manufacturing, and the usage of metal-based materials, as well as the weathering of rocks and the leaching of soils [4].

Water quality features are decided by chemical, biological and physical aspects[5, 6] ; though it provides an indicator for the safe of the water for consumption by humans[7, 8]. River water quality management is a significant environmental concern [9]. Various indicators of water quality have been developed worldwide that may be easily evaluate the entire water quality across a given area quickly and effectively for industrial study aims [10]. Water quality index has been chosen in this study because it indicates the water quality in terms of index number which provides a single number that is understandable, usable by the public and offers a useful representation of overall water quality based on several water quality parameters [11]. The quality of water in irrigation systems is primarily defined as the amount of dissolved salts and their ionic composition, which vary based on the water source and the moment of water sampling [12]. Due to the building of salt content in the soil, which affects water quality, soil fertility, and soil porosity, the use of water of poor quality could significantly reduce agricultural output, especially in semiarid and arid regions [13, 14]. Consequently, the current study uses the WQI tool to assess the water quality of the Smaquli Dam for drinking, irrigation purposes and fish farming from September to June (2021-2022).

Materials and Methods

Study Area

This study was conducted in the Smaquli Dam located in Koya district. It is, approximately 55 km situated east of Erbil city, the capital of the Iraqi Kurdistan Region and about 12km from Koya district. The location of the Dam is between the inlet (latitudes 36° 11' 34.2888" N, longitudes 44° 30' 49.8528" E), and outlet (latitudes 36° 10' 18.34" N, longitudes 44° 35' 18.56"E). The coordinates of all other sites are represented in (Table 1). The Dam is situated between the mountains of Awagrd in the North and North East; Bawaji Mountain in the South and South East, and Bina-Bawi Mountain in the South and South West (Figs. 1 - 4). The elevation of the Dam is 730 m above sea level. It is generated by an earth-fill embankment dam on the two sub-catchments, Sarwchawa and Krosh with areas. It was finished in 2016 with the main objective of supplying water for irrigation of 2200 Dunams of agricultural land and providing ground water[15] for the villages around it but recently employed for leisure activities as well. The water sources are based on two streams: seasonal streams (rain water) and permanent streams (springs in two locations). The Dam is 21 m high with the storage capacity of 8.600000 eight million and six hundred thousand cubic meters of water. The total area of the Dam is about 1200 km^2. The climate of study area is regarded as semi-arid and is equivalent to the climatic conditions in the Mediterranean (hot and dry summer and rainy, cold winter) [2].

Figure 1. Map of Iraq.

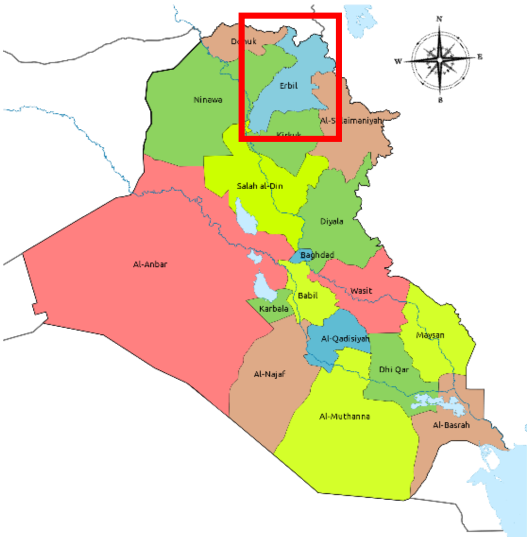

Figure 2. Map of Iraq indicating Erbil Governorate.

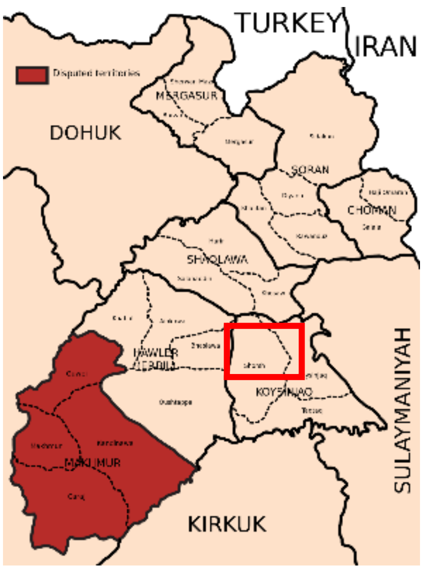

Figure 3. Map of Erbil Governorate indicating study area.

2024, 21(4): 1147-1161
https://doi.org/10.21123/bsj.2023.8320
P-ISSN: 2078-8665 - E-ISSN: 2411-7986

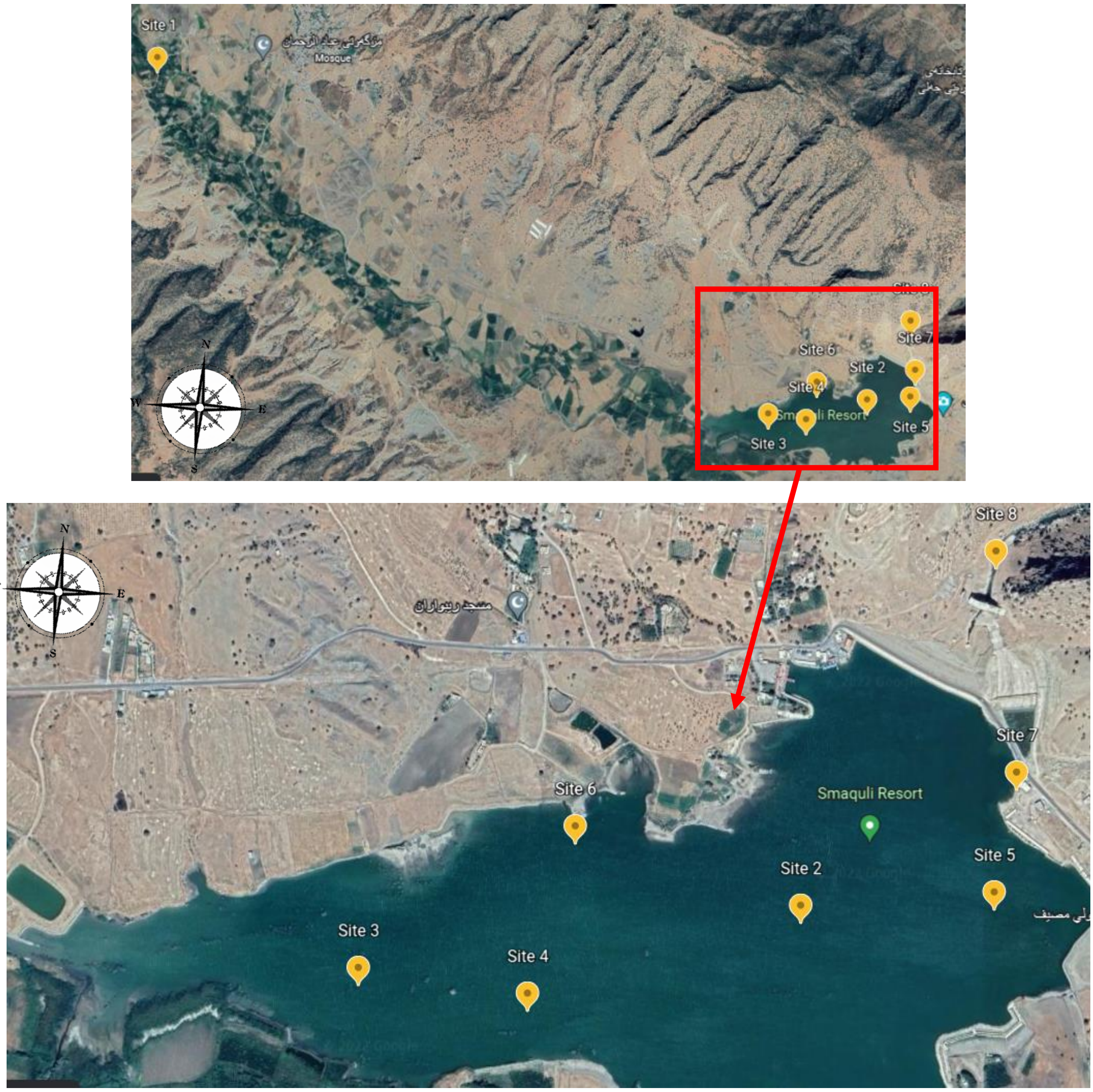

Figure 4. Map of Smaquli Dam studied sites from (Google Earth 2022).

Table 1. GPS* data for each sampling site.

Site	Latitude	Longitude	Elevation (m)
1	N 36° 11' 34.2888"	E 44° 30' 49.8528"	760
2	N 36° 9' 55.9656"	E 44° 35' 2.8212"	710
3	N 36° 9' 51.7536"	E 44° 34' 30.3456"	710
4	N 36° 9' 50.3064"	E 44° 34' 40.9332"	710
5	N 36° 10' 0.4908"	E 44° 34' 44.8356"	710
6	N 36° 9' 55.584"	E 44° 35' 18.4956"	710
7	N 36° 10' 4.692"	E 44° 35' 19.7592"	710
8	N 36° 10' 18.34"	E 44° 35' 18.56"	719

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Sample Collection and Analysis

From September 2021 to June 2022, water samples were collected monthly from eight sites and placed in a clean polyethylene bottle. Standard methods were used [16] to analyze sixteen physico-chemical parameters: pH, electrical conductivity and TDS were measured in the field by using portable measuring tools (pH-EC-TDS meter, HI 98129, Hanna instrument). The device was calibrated before each sampling with buffer solutions of 4, 7 and 10 provided by manufactured company at 20 C°[16]. Turbidity by utilizing Turbidity meter (micro-950, Singapore), total hardness, calcium and magnesium (EDTA titrimetric method). Chloride (argentometric method), SO_4^{-2} using Buffer solution and spectrophotometric methods, alkalinity (titrimetric method), Na^+ and K^+ (flame photometric method). Azide modification of the conventional Winkler procedure was used to measure dissolved oxygen, biochemical oxygen demand (BOD_5)[17]; NO_2 using diazotized sulfanilamide techniques, NO_3 using UV spectrophotometric method [16, 18].

Applied Water Quality Indices

Fifteen parameters were chosen to calculate the drinking WQI. The calculation and development of drinking WQI involved the following steps:

1- In the first step, each of the fifteen parameters has been given weight (AWi) varying from 1 to 5 based on its relative significance to the overall quality of water that can be used for drinking (Table 2). The parameter nitrate has been given a maximum weight of 5 due to its critical role in determining the water quality. Sodium and potassium, which are given a minimum weight of 1, might not be detrimental on their own [11].

2- In the second step, the relative weight (RW) was determined using Eq. 1. Where Rw = is the relative weight, AW = the assigned weight of each parameter, n = the total number of parameters.

$$\boldsymbol{Rw = \frac{Aw_i}{\sum_{i=1}^{n} AW_i}} \quad \text{..................} \ \mathbf{1}$$

3- In the third phase, quality rating scale (Qi) for all the parameters was assigned except pH and DO.

$$\boldsymbol{Q = \frac{c_i}{si} * 100} \quad \text{..................} \ \mathbf{2}$$

However, the quality rating for pH or DO (Q pH, DO) was determined:

$$\textbf{Q pH, DO} = \boldsymbol{\frac{C_i - v_i}{s_i - v_i} * 100} \quad \text{..................} \ \mathbf{3}$$

Where:

Qi =the quality rating

Ci = value of the water quality parameter obtained from the laboratory analysis

Si = standard value of the water quality parameter obtained from recommended [19]

Vi = the ideal value considered as 7 for pH and 14.6 for DO (Table 2).

Finally, the sub-indices (SIi) for each parameter were determined to calculate the WQI using Eqs. 4 and 5:

$$\boldsymbol{SI = RW * Qi} \quad \text{..................} \ \mathbf{4}$$

$$\boldsymbol{WQI = \sum_{i=1}^{n} SIi} \quad \text{..................} \ \mathbf{5}$$

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Table 2. Steps of Calculation WQI for Drinking Purposes.

Parameters	Unit	WQS	Wi	RW
Turbidity	NTU	5	3	0.08
DO	mg/L	5	4	0.10
BOD_5	mg/L	5	3	0.08
pH		6.5-8.5	4	0.10
EC	µS/cm	1000	3	0.08
T. Alkalinity	$mgCaCO_3/L$	200	1	0.03
T. Hardness	$mgCaCO_3/L$	200	2	0.05
Calcium	mg/L	100	2	0.05
Magnesium	mg/L	30	2	0.05
Sodium	mg/L	200	1	0.03
Potassium	mg/L	10	1	0.03
Chloride	mg/L	250	2	0.05
Nitrite	mg/L	3	2	0.05
Nitrate	mg/L	50	5	0.13
Sulfate	mg/L	250	4	0.10
			∑AWi = 39	∑RW = 1.000

Table 3. Water Quality Index (WQI) range and type of water can be classified according to [20].

Range	< 50	50.1 – 100	100.1 – 200	200.1 – 300	> 300
Type of water	Excellent water	Good water	Poor water	Very poor water	Water unsuitable for drinking purposes

The Model of Irrigation Water Quality Index (IWQI)

The model of (IWQI) proposed by [21] was implemented on the observed data in accordance with the steps below:

Step 1: Recognized parameters were regarded as more pertinent for irrigation application; EC, Na^{+1}, HCO_3^{-1}, Cl^{-1}, SAR°.

Step 2: The values of quality measurement (Quality rating) (Qi) for each parameter were determined using Eq. 6, based on the tolerance limitations indicated in (Table 4), and the observed water quality results. The tolerance limitations indicated in (Table 4) were according to irrigation water quality parameters suggested by University of California Committee of Consultants- (UCCC) and by the standards defined by Ayers [22].

$$\boldsymbol{Qi = Qi\,max - \left[\frac{(Xij - Xinf) * qi\,amp}{X\,amp}\right]} \text{ .... } \mathbf{6}$$

Where:

Qimax = the maximum value of quality rating scale (qi) for the class of Table 4;

Xij = the observed value for the parameter,

Xinf = the lower limit of the quality parameter,

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Qiamp = the category amplitude of qi,

Xamp is the class amplitude to which the parameter belongs.

In order to evaluate the sample of the final class of each parameter, the upper limit was taken into consideration to be the maximum value discovered during the physico-chemical examination of the samples of the water.

Step 3: The weight of each parameter has been given according to its relative significance in the overall irrigation water quality, as indicated in Table 5.

Step 4: The water quality index was calculated as follows:

$$\boldsymbol{IWQI = \sum_{i=1}^{n} Qi\, wi} \text{ .... } \mathbf{7}$$

Step 5: The sodium adsorption ratio (SAR) that depends on the ion's concentration of calcium, magnesium, and sodium is estimated as below:

$$\mathbf{SAR} = \frac{\boldsymbol{Na}}{\sqrt{\frac{\boldsymbol{Ca^{+2}+Mg^{+2}}}{\mathbf{2}}}} \text{ .... } \mathbf{8}$$

Where:

SAR: Sodium Adsorption Ratio $(\mathrm{meq.l^{-1}})^{\frac{1}{2}}$

Na^{+}, Ca^{+2}, and Mg^{+2}: Concentration of Ions by milliequivalents per liter ($meq.l^{-1}$) units.

IWQI is a dimensionless parameter ranging from 0 to 100; Qi is the i^{th} parameter's quality rating, and WI is the i^{th} parameter's normalized weight. Division into classes depending on the required water quality index was based on current water quality indices, and classes illustrated the possible risk of salinity issues, reducing the osmotic potential of soil, as well as toxicity to plants, as observed in the classifications presented by [21]. Limitations to water consumption classes were classified as given in Table 6.

Table 4. Parameter limiting values for (Qi) Calculation Ayers [22].

Qi	**EC ($ds.m^{-1}$)**	**SAR°** $(\mathbf{meq.l^{-1}})^{\frac{1}{2}}$	**Na^{+1} ($meq.l^{-1}$)**	**Cl^{-1} ($meq.l^{-1}$)**	**HCO_3^{-1} ($meq.l^{-1}$)**
85-100	200≤EC<750	SAR°< 3	2≤Na< 3	Cl< 4	1≤ HCO_3< 1.5
60-85	750≤EC<1500	3≤SAR° < 6	3≤Na< 6	4≤Cl< 7	1.5≤ HCO_3< 4.5
35-60	1500≤EC<3000	6≤ SAR° <12	6≤Na< 9	7≤Cl< 10	4.5≤ HCO_3< 8.5
0-35	EC< 200 or EC≥3000	SAR° ≥ 12	Na< 2 or Na ≥9	Cl ≥ 10	HCO_3 < 1 or HCO_3 ≥ 8.5

Table 5. Weights for the (IWQI) parameters [21].

Parameters	EC	Na^{+1}	HCO_3^{-1}	Cl^{-1}	SAR°	**Total**
Wi	0.211	0.204	0.202	0.194	0.189	**1.000**

Table 6. Irrigation Water Quality Index (IWQI) Characteristics [21].

IWQI	85-100	70-85	55-70	40-55	0-40
Water use restriction	No restriction (NR)	Low restriction (LR)	Moderate restriction (MR)	High restriction (HR)	Sever restriction (SR)

Table 7. Means for physico-chemical parameters for the study sites.

Sites / parameters	1	2	3	4	5	6	7	8
Turbidity (NTU)	10.04	3.30	5.10	4.29	3.16	3.33	3.63	3.30
DO ($mg.l^{-1}$)	8.50	8.42	8.25	8.61	8.38	8.40	8.33	9.28
BOD_5 ($mg.l^{-1}$)	3.27	2.33	2.10	2.46	2.49	2.43	2.53	2.73
pH	8.12	8.27	8.28	8.27	8.29	8.28	8.28	8.13
EC ($\mu S.cm^{-1}$)	732.80	608.50	613.50	613.30	601.90	605.70	599.10	615.00
TDS ($mg.l^{-1}$)	367.80	304.30	307.10	306.70	301.30	303.10	300.60	305.95
Total Alkalinity (mg $CaCO_3$. l^{-1})	264.20	197.60	202.00	207.80	199.40	201.20	197.60	207.30
Total Hardness (mg $CaCO_3$. l^{-1})	264.00	198.20	209.80	202.80	194.20	198.20	202.20	203.70
Ca^{+2} ($mg.l^{-1}$)	61.16	43.93	46.17	46.49	47.29	46.57	48.66	47.53
Mg^{+2}($mg.l^{-1}$)	27.07	21.53	22.99	21.09	18.52	19.93	19.63	20.68
Na^{+} ($mg.l^{-1}$)	29.26	35.74	35.21	36.57	36.83	37.84	36.15	40.16
K^{+} ($mg.l^{-1}$)	5.14	5.42	4.92	5.14	5.20	5.33	5.15	5.44
Cl^{-1} ($mg.l-^{1}$)	24.29	22.59	23.19	22.09	23.69	23.19	25.09	23.74
NO_2 (μg NO_2-$N.l^{-1}$)	0.64	0.65	0.65	0.76	0.70	0.73	0.72	0.87
NO_3 (mg. NO_3-$N.l^{-1}$)	14.26	12.83	13.28	13.26	12.82	12.94	12.77	12.62
SO_4 (mg $SO_4.l^{-1}$)	84.69	111.57	107.40	110.30	107.84	107.09	106.44	103.88
SAR ($meq.l^{-1}$)	0.78	1.10	1.06	1.11	1.14	1.17	1.10	1.22

Results and Discussion

The water quality index in the historical and the contemporary study is established from the significance of different physico-chemical parameters for surface water [23, 24]. The alkalinity and acidity of the water condition are indicated by the hydrogen ion concentration [25]. In the Kurdistan region, waters can be identified by the pH change to the alkaline side of neutrality, related to the area of the geological formation [26, 27], which primarily constituted of $CaCO_3$ 2, [28] who studied limnological investigation in Erbil province; in Sulaimani [29] and Duhok [30]. The mean pH values of the water sample in this study ranged from 8.12 to 8.29 (Table 7). This is parallel with recommendations of [25, 31, 32]. (Table 12) the pH range between 6.5 and 8.5 for drinking purposes, (Table 12). The mean electrical conductivity value in this study area varied from 599.10 to 732.80 $\mu s.cm^{-1}$, and these changes are influenced by the soil's ionic salt content, the climate, and the soil's geological origin [2]. According to the [25], the highest permitted conductivity level is 1000 $\mu s.cm^{-1}$, and according to the [31] (Table 12), the highest permitted level is between 600-1200 $\mu s.cm^{-1}$. Hence, all the studied sites were within the appropriate drinking range. Turbidity is one of the parameters for the acceptability of drinking water quality [33]. The selected sites had turbidity ranges of 3.16 to 10.04 NTU. The high turbidity levels during the rainy season are attributable to soil erosion in the neighboring fields and may be caused by the sewage effluents of a nearby village [34]. The WHO and IRQ standards have established 5 NTU as the acceptable threshold of turbidity. If the value exceeds the specified limit, it will be unsuitable for drinking.

The mean value of total alkalinity during the study period was 197.60 to 264.20 mg $CaCO_3.l^{-1}$ (Table 7). The highest value was recorded in site 1, while the lowest was in sites 2 and 7. This might be connected to the soils ionic makeup and buffering ability [19]. Water's concentration of polyvalent cations, namely calcium and magnesium, which are known to precipitate soap, causes water to be hard [35]. According to the study's findings, the mean value of total hardness ranged from 194.20 to 264.00 mg $CaCO_3.l^{-1}$. The rise in hardness may refer to the reduction in water volume in the evaporation rate at high temperatures, high-loading organic substances, detergent, chlorides, and other pollutants [36] or may be due to a shortage of rainfall during the study period 2021-2022 [2]. In the study area, calcium concentration is higher than magnesium, which may be explained by the area's geological formation, which is primarily composed of limestone, and the solubility of calcite rock, which is abundant in the study area [37]. Both nitrite and nitrate are harmful ions for people when they are in high drinking water concentrations. Nitrite and nitrate concentrations in the current data were below the WHO and IRQ- permitted limits of 3 $mg.l^{-1}$ and 50 $mg.l^{-1}$. Chloride levels in the research varied from 22.09 to 25.09 $mg.l^{-1}$. As a result, the water at all sites of the research was deemed freshwater because it contained little chloride and was within the WHO-recommended limit of 250 mg per liter for drinking water. The maximum was recorded in site 7, while the minimum was in site 4. An increase in the concentration of this ion in the water bodies under study may result from higher chloride concentrations in water samples observed during the warmer season [38]. While the low chloride concentration can be attributed to the dilution process caused by rainfall. One of the main anions found in natural waters is sulfate. The mean value ranged from 84.69 to 111.57 $mg.l^{-1}$. The greatest sulfate concentration in the current study was caused by weathering and surface water runoff from the catchment area [39]. One of the most crucial elements in aquatic systems is dissolved oxygen for aerobic organisms. Since a high oxygen concentration often indicates good water quality [40]. A number of variables, including atmospheric aeration, temperature, runoff, rainfall, and the photosynthetic activity of algae and green plants, affect the concentration of DO in natural water.

In the present study, DO ranged from 8.25 to 9.28 $mg.l^{-1}$ was recorded in sites 3 and 8. The biochemical oxygen demand measures how much oxygen is required by aerobic microorganisms for the biological breakdown of organic materials in water [41]; for the aquatic life and aesthetic appeal of water bodies to be preserved, there must be enough oxygen present [39]. In the current study, the mean value of BOD_5 ranged from 2.10 to 3.27 $mg.l^{-1}$. Typically, BOD_5 levels increased during the warmer months, which may be related to an increase in the metabolic rate of organisms and organic matter breakdown [36, 42]. Potassium (K^+) and sodium (Na^+) are also frequently used to determine water quality. The primary sources of sodium in the aquifer system are weathering of silicate minerals and the dissolution of salt minerals [43]. The concentrations of Na^+ and K^+ at the study locations ranged from 29.26 to 40.16 $mg.l^{-1}$ and 4.92 to 5.44 $mg.l^{-1}$, respectively. The Na^+ and K^+ concentrations at the study locations were below the permitted limits during the analyzed times.

Water Quality Index (WQI) for Drinking Purposes

The WQI was used to aggregate numerous metrics and their aspects into a single score of [44], giving a snapshot of the chronicled water quality at the eight sites in the Smaquli Dam. This study determined the overall WQI, with values ranging from 68.11 at site 8 to 83.93 at site 1 (Table 8). WQI status of the sites under investigation indicated that the water quality was “Good" and all results were between 50–100. Finally, according to [20] (Table 3), the classification of the examined waters across all sites demonstrated

2024, 21(4): 1147-1161
https://doi.org/10.21123/bsj.2023.8320
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
Baghdad Science Journal

that the water quality of the Smaquli Dam is suitable for drinking purposes for humans. The outcomes are supported by [28].

Table 8. Water Quality Index (WQI) for drinking purposes in the studied sites.

Sites	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
WQI	83.93	70.83	74.21	72.88	70.76	71.14	71.78	68.11
Water quality	Good	Good	Good	Good	Good	Good	Good	Good

Water Quality Index for Irrigation Purposes (IWQI)

The IWQI was considered as one of the greatest instruments for decision-makers to evaluate irrigation water quality [45]. Based on how the irrigation water affected the irrigated soil and how dangerous it was to plants; it gave a clear rating of the irrigation water quality. Consequently, the IWQI values in the current study ranged from a lowered value of 68.84 at site 1 to a highest value of 70.20 at site 2 (Table 9). According to (Table 6), the IWQI values for the soil and waters in sites 1,4,5,6 and 8 fall under the moderate restriction category (MR) for irrigation purposes, meaning they can be used in soils with moderate to high permeability without compact layers. Only moderate salt leaching is necessary to ensure no harm to plants. While sites 2, 3, and 7 falls under the low restriction category and can be used in irrigated soils with light texture or moderate permeability, their usage should be avoided in soils with high clay content (heavy texture) since this may promote soil sodicity and necessitate salt leaching.

Table 9. Water use restrictions are based on the calculated values of IWQI for Smaquli Dam.

Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
IWQI	68.84	70.20	70.12	69.68	69.93	69.66	70.13	68.97
Water Use Restriction	Moderate restriction (MR)	Low restriction (LR)	Low restriction (LR)	Moderate restriction (MR)	Moderate restriction (MR)	Moderate restriction (MR)	Low restriction (LR)	Moderate restriction (MR)

Richard's Classification (1954)

This classification is based on electrical conductivity and sodium adsorption ratio (EC and SAR), which is divided into four classes depending on EC and SAR separately, as shown in Table 10. In the present study the mean value of EC and SAR ranged from 0.59 to 0.73 $ds.m^{-1}$ and 0.78 to 1.22 $meq.l^{-1}$, therefore, the water for the study areas for irrigation purposes according to Richards classification fall within the class C2S1.

Table 10. Water classification of irrigation according to [46].

Water class	**Electrical conductivity $ds.m^{-1}$ at 25 C°**	**Water class**	**SAR Value**
C_1 = Low-salinity	$0 < EC \leq 0.25$	S_1 = Excellent	$S_1 < 10$
C_2 = medium- salinity	$0.25 < EC \leq 0.75$	S_2 = Good	$10 < S_2 \leq 18$
C_3 = high-salinity	$0.75 < EC \leq 2.25$	S_3 = Doubtful	$18 < S_3 \leq 26$
C_4 = very high-salinity	$2.25 < EC \leq 5.00$	S_4 = Unsuitable	$S_4 > 26$

Quality of water for fish farming

The concentration of a particular parameter, such as an increase in calcium or a decrease in nitrate toxicity, will not have an individual impact on fish longevity [47]. Therefore, it is evident that an increase in a particular ion's concentration that is over the allowed range may not be dangerous to aquatic life because it depends on other factors, including age, weight, water quality, and fish species [48]. The water was categorized for fish farming by [48], depending on six criteria (pH, turbidity, TDS, Total hardness, DO and Nitrate) as represented in Table 11.

Table 11. Water quality guidelines for fish farming [48].

Parameter	pH	Turbidity (NTU)	TDS ($mg.l^{-1}$)	TH ($mg.l^{-1}$)	DO ($mg.l^{-1}$)	NO_3 ($mg.l^{-1}$)
Maximum Permissible value	**5.5-9**	**<40**	**<3000**	**20-100**	**>5**	**<50**

According to the classification of [48], the mean values of water quality parameters of all tested sites were compared to standard values given in Table 11, the results showed that:

1. All of the tested sites water pH values, as shown in (Table 7), fell within the acceptable range 5.5–9, indicating that the water in all locations was adequate for fish production.
2. The value of turbidity in each location was less than 40 NTU, this indicates that the water in each location was suitable for fish farming.
3. The value of total dissolved solids of all sites were within the standard value of less than 3000 $mg.l^{-1.}$ This implies that the water could be used for fish farming.
4. All of the locations' water was acceptable for fish production since their dissolved oxygen (DO) values were greater than 5 $mg.l^{-1.}$
5. According to total hardness concentration, citing [48], water of all locations was unfit for fish farming since their TH values were outside of the acceptable range (20-100 $mg.l^{-1}$) (Table 11).
6. The nitrate concentration of all sites was less than 50 $mg.l^{-1}$ in accordance with table, making the water in all locations suitable for fish production (Table 11).

Conclusion

The important different physicochemical parameters in eight sites were utilized to establish the water quality index for drinking and irrigation purposes as well as to guideline the water characteristics used for fish farming in Smaquli Dam. The results of studied sites varied from 68.11 to 83.93, illustrating that the water quality index is safe for drinking purposes. The IWQI values for irrigation were calculated using the [21]Meireles model. The results varied from 68.84 to 70.20. The findings illustrate that the values of IWQI for water samples fall within the class of low restriction (LR) and moderate restriction categories (MR) for irrigation purposes. The study also demonstrated that all of the studied sites had values for pH, turbidity, TDS, DO, and nitrate that were acceptable for fish farming in accordance with water guidelines, with the exception of all locations' total hardness ratings, which ranged from (194.20 to 264.00 mg CaCO3.l-1), that fell outside of the permissible range. Therefore, from the findings of this study, it can be concluded that the application and uses of water quality index for overall assessment of the water quality of Smaquli Dam is a useful tool.

2024, 21(4): 1147-1161
https://doi.org/10.21123/bsj.2023.8320
P-ISSN: 2078-8665 - E-ISSN: 2411-7986

Table 12. Water quality standards (guideline) for drinking, irrigation and fish farming

Variables	**Results (Mean)**	**Water quality Standards for drinking purposes**		**Kurdistan standards**	**Water quality Standards for Irrigation purposes**		**Water quality Standards for fish farming**		
		WHO	IQS		Ayers and Westcot (1994)	Canada	ANZECC (2000)	Russia	Canada
Turbidity (NTU)	3.16-10.04	5		18.66			<40		
pH	8.12-8.28	6.5-8.5 (7.5)	6.5-8.5	7.26	6.5-8.4		5.5-9		6.5-9
EC ($\mu S.cm^{-1}$)	599.10-732.80	100-500	600-1200	640.19	3000				
TDS ($mg.l^{-1}$)	300.60-367.80	500-1500	100-500	446.3	2000	500-3000	<3000		
DO ($mg.l^{-1}$)	8.25-9.28	4-6	5	7.39			>5	4-6	5-9.5
BOD_5 ($mg.l^{-1}$)	2.10-3.27	3	3	1.92				3	
Total Alkalinity ($mg.l^{-1}$)	197.60-264.20	100	100	242.09					
Total Hardness ($mg.l^{-1}$)	194.20-264.00	100-300	100-500	225.33			20-100		
Ca^{+2} ($mg.l^{-1}$)	43.93-61.16	75	50	68.50	400				
Mg^{+2} ($mg.l^{-1}$)	18.52-27.07	30	20	26.2	60.75				
Na^{+} ($mg.l^{-1}$)	29.26-40.16	200	200	15.43	920			120	
Cl^{-} ($mg.l^{-1}$)	22.09-25.09	250	250	42.84	1062			300	
NO_3 ($mg.l^{-1}$)	12.62-14.26	50	50	55.39	10		<50	40	
NO_2 ($mg.l^{-1}$)	0.64-0.87	3	3	0.34			<0.1		
SO_4 ($mg.l^{-1}$)	84.69-111.57	250	250	121.51	960	100-700		100	
HCO_3 ($mg.l^{-1}$)					610				
SAR $(meq.l)^{1/2}$					15				

Formula: $Meq.l^{-1} = mg.l^{-1} / \text{atomic weight} * \text{valence}$

$mg.l^{-1} = meq.l^{-1} * \text{atomic weight} / \text{valence}$

Authors' Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- Authors sign on ethical consideration's approval.
- Ethical Clearance: The project was approved by the local ethical committee in University of Salahaddin.

Authors' Contribution Statement

F. H. A. conceived the presented idea, developed the theory, planned the experiments, and supervised the project. G. A. M. performed site investigation and sample preparation, carried out the experiments and performed the numerical calculations for the experiment. G. A. M. wrote the manuscript with support and provision from F. H. A. Both authors contribtued to the interpretation and discussion of the results and contributed to the final manuscript.

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تقييم جودة المياه في سد سماقولي للشرب والري و تربية الاسماك

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الخلاصة

لقد أجريت هذه الدراسة لمعرفة نوعية المياه وملائمته لمختلف الاغراض كالشرب والري وتربية السمك في سد سماقولي وذلك بالاعتماد على مقياس نوعية وجودة المياه (WQI) بدلالة رقم مقياسى لاى استخدام مطلوب ، جمعت عينات المياه من ثمانية مواقع خلال فتره امتدت من شهر ايلول 2021 لغاية تموز 2022، حيث تم تحديد معيار جودة او نوعية المياه (WQI) لأغراض الشرب ، وذلك بالاعتماد على أهم خمسه عشر معيارًا فيزيائيًا وكيميائيًا بما في ذلك: الأس الهيدروجين(PH)،التوصيل الكهربائي (EC)، التعكر(Turbidity) ، الأكسجين المذاب (DO)، الأكسجين الكيميائي الحيوي المطلوب ، القاعدية الكلية (TA)، العسرة الكلية (TH)، أيونات الكالسيوم والمغنيسيوم (Ca & Mg ions)، الصوديوم (Na)، البوتاسيوم (K)، الكلوريد (Cl)، النتريت (NO_2)، النترات (NO_3) والكبريتات (SO_4). كما إعطيت الوزن النسبي لكل متغيراو معيار تراوحت من 1 إلى 5 بناءً على أهم متغيراو معيار ضروري واساسى للحياة المائية والاستخدام اليومى و المنزلي. أشارت النتائج الدراسة إلى أن مياه سد سماقولي بمدخله ومخرجه صالحة للشرب بعد اجراء المعالجة التقليدية، اذ تراوحت نتائج (DWQI) لجميع المواقع بين (68.11 إلى 83.93)، اما بالنسبة لمؤشر جودة او نوعية مياه الري (IWQI)، تم تحليل العينات المدروسة لمحتويات EC ونسبة امتصاص الصوديوم (SAR) والصوديوم (Na^{+1}) والكلوريد (Cl^{-1}) وبيكربونات(HCO_3).كما تراوحت نتائج (IWQI) من (68.84 إلى 70.20)، وهذا يدل الى أن عينات المياه تقع ضمن فئة الحصر المنخفض (LR) والمتوسط (MR) لأغراض الري. واخيرا سبع معايير استعملت شملت: الأس الهيدروجيني(PH)، التعكر (Turbidity) ، المواد الصلبة الذائبة (TDS)، الأكسجين المذاب (DO) ، القاعدية الكلية (TH) والنترات (NO_3). لتقييم نوعية وملائمة مياه سد سماقولى لتربية الاسماك بالاعتماد على محدودية المعيارى لكل وحدة من تلك المعاييرز أشارت النتائج لتلك المعايير فى جميع المواقع إلى أن المياه ملائمة ضمن محدودية المعايير لتربية الاسماك باستثناء معيارالعسرة الكلية TH..

الكلمات المفتاحية: الشرب، تربية الاسماك، الري، نسبة امتصاص الصوديوم، معيار جودة او نوعية المياه.