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Assessment of Groundwater Quality in Al'am District using the Canadian Water Quality Index

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Abstract: The study assesses groundwater quality characteristics in Al'am District which is a part of Salah al-Din Governorate, by use of the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI). The samples were taken from six groundwater wells for the assessment and sampling was done at six months per year. Based on CCMEWQI calculated values, the six wells from which the samples collected were in poor rank for drinking purpose. The prime causes of deterioration groundwater quality are total dissolved solids (TDS), and total hardness (TH). This study suggested further improvement and continuous monitoring for the groundwater in the study area to provide safe drinking water.
Keywords: Groundwater, The Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI).

I. INTRODUCTION

Groundwater is used for different life purposes like domestic, industrial and irrigation purposes worldwide. The demand for freshwater tremendously increased over the last decades because of the fast-growing of population and the accelerating rate of industrial enterprises. Geographically, Iraq is one of the Middle-East countries. Water in this region is inherently scarce as a result of naturally arid climatic conditions [1]. In recent years surface water in Iraq suffers from a decrease of flow rates due to the policy of the countries of the source that causes shortage water problems in Iraq for drinking and irrigation [2]. Groundwater quality is of the same value of its quantity outstanding to the relevance for multiple of water [3]. Once the groundwater is contaminated, it's difficult to recover easily [4]. The water quality indices (WQIs) characterize the water sources suitability for human consumption. These indices have been widely used to overcome this matter. Water quality index (WQI) can be outlined from the measured values of various water quality parameters into a dimensionless number (scale from 0 to 100) using different aggregation method (Ismail et al., 2018). It is one of the most effective ways to describe the quality of water. The water quality index (WQI) is an effective technique of water quality evaluation to estimate spatial and temporal changes in groundwater quality and to inform the concerned authorities about the water quality. Therefore, it becomes an important parameter for the evaluation and management of groundwater [2, 5]. The Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) was evolved to simplify and describe the survey of water quality data. The Canadian Council of Ministers of the Environment (CCME) was designed to appraise groundwater quality for the uses of drinking, recreational and livestock aided with specific guidelines [6]. CCMEWQI has been used by several scientists to determine quality of water by various provinces and Ecosystems all across the Canada [7]. Thus CCMEWQI is a tool that can use throughout the world [8].

Firstly, Horton in 1965 has developed the first water quality index, which based on 10 parameters [9]. Thereafter, different institutions and authors have suggested various water quality indices. Numerous studies on Groundwater quality assessment in the different provinces and regions in Iraq have been made, such as Al-Aboodi studied groundwater characteristics in Safwan-Zubair area and found that the groundwater in studied region is not suitable for human drinking [10]. Also, Channo collected samples from various wells located in different places in Baghdad city were used to evaluate the quality of groundwater and the possibility of using it for the human, animal, and irrigation by computing WQI, SAR, and Na% indices. She concluded that WQI values indicated that the groundwater in the investigated wells is restricted for human use, while most of these wells can be used for irrigation purposes depending on values SAR [3]. Moreover, Hamdan studied groundwater quality in west of Basrah and concluded that the groundwater was unsuitable to domestic purposes and far from drinking water standards [2].

This study aimed at applying the CCMEWQI to assess the water quality of the groundwater in Al'am District for drinking water abstraction. CCMEWQI was selected due to its advantages such as a variety of parameters can be included in the estimation steps of CCMEWQI, and its flexibility of selection the water quality standards.

II. MATERIALS AND METHODS

1. *Study Area*

The study area is a part of Salah al-Din Governorate. It is located between latitudes (35° 16′ 20" - 35° 32′ 33"), and longitudes (43° 45′ 50" - 44° 10′ 12"),Al-a'lam District is located between Northern latitudes 6° 47' to 7° 05' and Eastern longitudes 79° 52' to 80° 13'.

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2. Sampling

Monthly sampling was carried out for six wells for one year period (Fig.1). Before sampling, the wells were pumped for several minutes until the temperature, conductivity, and pH were stabilized [11].Pre-cleaned polypropylene bottles were used to collect water samples for chemical analysis. Water samples were transported to the laboratory in the cold box within 10 hours after collection and stored under cold room condition. Chemical analysis was carried out within two days of sampling [12].

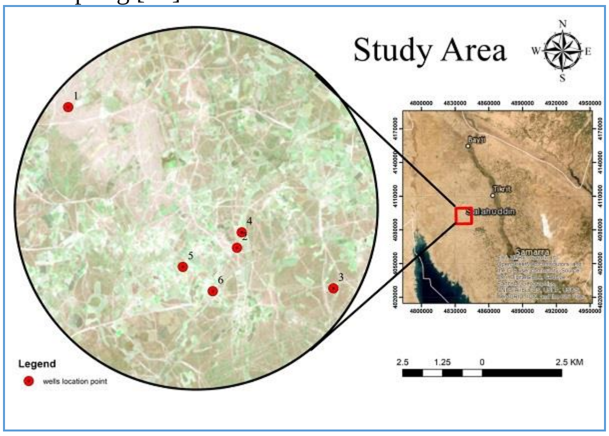

Fig.1: Sampling six wells in a study area

III. WATER QUALITY ANALYSIS

Standard methods were followed during sample collection, preservation and analysis for all water quality parameters which include; total dissolved solids (TDS), electrical conductivity (EC), pH, and dissolved oxygen (DO) were measured immediately after sampling in the field using a portable conductivity meter and pH-meter (HQD portable multi meter) respectively, whereas the total hardness (TH) were analyzed in the laboratory using the standard methods of American Public Health Association (APHA) [2, 13].

3. Theoretical Summary of the CCMEWQI

Calculations of CCMEWQI are based on Factor 1 which also known as scope (F1); Factor 2; frequency (F2) and Factor 3; amplitude (F3). Sampling procedure demands at least four parameters, collected at least four times and no maximum parameters has been set. The calculated value of the index can be rendered to a standard table which represents numerical values ranging between 0 to 100 with a rating of excellent, good, fare, marginal and poor. Deviating parameters can be monitored [14]. F1 (scope) represents the percentage of parameters that not within the guideline and can be calculated as follows [12]:

$$F_1 = \left[\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right] * 100 \quad \text{.... (1)}$$

The number of failed variables represents the percentage of variables, which exceed the allowable limit value at least once at which time of the monitoring period, relative to the total number of measured variables [14]. F2 (frequency) signifies the percentage of individual tests within each variable that exceeded the guideline and can be computed as follows [12]:

$$F_2 = \left[\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right] * 100 \quad \text{.... (2)}$$

The number of failed tests represents the percentage of individual tests that exceed the allowable limit value, relative to the total number of tests conducted during the monitoring period. The calculation of F1 and F2 is relatively straight forward; while F3 involves some additional steps. F3 (Amplitude) represents the extent (excursion) to which the failed test exceeds the guideline. This can be estimated in three steps where first is the excursion; the number of times by which an individual concentration is greater than the objective is termed an "excursion" and is expressed as follows [12, 15]:

1. The calculation of the excursion: Excursion represents the number of times that the value of the variable exceeds the allowable limit value (objective). When the test value must not exceed the objective [12, 15]:

$$Excursion = \left[\frac{\text{Failed test value}}{\text{Guideline value}}\right] - 1 \quad \text{.... (3)}$$

For the issues in which the test value must not downfall below the objective, the equation is followed [12]:

$$Excursion = \left[\frac{\text{Guideline value}}{\text{Failed test value}}\right] - 1 \quad \text{.... (4)}$$

2. The evaluation of normalized sum of excursions (nse): the normalized sum of excursions (nse) is the ratio of the sum of excursions obtained for individual tests dividing by the total number of tests. The (nse) is calculated as follows [12, 15]:

$$nse = \frac{\sum_{i=1}^{n} Excursion_i}{\text{Total number test}} \quad \text{.... (5)}$$

3. The calculation of F3: F3 is then computed by an asymptotic function that scales nse to output a range between 0 and 100 [14] as follows:

$$F_3 = \left[\frac{nse}{0.01\,nse - 0.01}\right] - 1 \quad \text{.... (6)}$$

When the values of the three factors were computed, the index itself can be obtained by sum the three factors. The CCMEWQI is finally calculated as [12, 14]:

$$CCMEWQI = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right] \quad \text{.... (7)}$$

The values of CCMEWQI are transformed into orders by using the index classifications showed in Table.1 [14].

Table.1: CCMEWQI categories

Order	Index Value	Description
Excellent	95 – 100	Water quality is protected with a practical absence of threat; conditions very close to natural or levels.
Good	80 – 94	Water quality is protected with only a slight degree of threat; conditions seldom deviate from natural levels.
Fair	65 – 79	Water quality is usually protected but sometimes threatened; conditions sometimes diverge from natural levels.
Marginal	45 – 64	Water quality is oftentimes threatened; conditions often depart from natural levels.

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Poor	0 - 44	Water quality is virtually threatened; conditions commonly deviate from natural levels.

IV. Results and Discussion

The maximum and minimum physicochemical parameter values for the groundwater samples collected from six wells through six months per year were presented in Table.2.

Table.2: Groundwater quality parameter values; min. and max. ones

Well No.	Parameter	Abbrevia-tion	Unit	Value	
				Min.	Max.
1	pH	pH	-	7.2	7.9
	Total Dissolved Solids	TDS	mg/L	2330	3000
	Electrical Conductivity	EC	µS/cm	4650	6010
	Dissolved Oxygen	DO	mg/L	7.1	8.1
	Total Hardness (as CaCO3)	TH	mg/L	1200	1300
2	pH	pH	-	7	7.8
	Total Dissolved Solids	TDS	mg/L	1998	2780
	Electrical Conductivity	EC	µS/cm	3990	5600
	Dissolved Oxygen	DO	mg/L	6.9	7.9
	Total Hardness (as CaCO3)	TH	mg/L	1380	1460
3	pH	pH	-	7.1	7.9
	Total Dissolved Solids	TDS	mg/L	2180	2560
	Electrical Conductivity	EC	µS/cm	4350	5200
	Dissolved Oxygen	DO	mg/L	5.5	7
	Total Hardness (as CaCO3)	TH	mg/L	1650	2000
4	pH	pH	-	7.3	8
	Total Dissolved Solids	TDS	mg/L	2450	3000
	Electrical Conductivity	EC	µS/cm	4910	6015
	Dissolved Oxygen	DO	mg/L	5.8	7.1
	Total Hardness (as CaCO3)	TH	mg/L	1400	1980
5	pH	pH	-	7.3	8.1
	Total Dissolved Solids	TDS	mg/L	3400	4010
	Electrical Conductivity	EC	µS/cm	6810	8050
	Dissolved Oxygen	DO	mg/L	5.7	6.4
	Total Hardness (as CaCO3)	TH	mg/L	1225	1600
6	pH	pH	-	7.5	8.2
	Total Dissolved Solids	TDS	mg/L	2900	4000
	Electrical Conductivity	EC	µS/cm	5870	8010
	Dissolved Oxygen	DO	mg/L	6.5	7
	Total Hardness (as CaCO3)	TH	mg/L	1400	1890

The pH is considered as the major operational water quality parameter that figures groundwater quality, due to its controlling the amount of chemicals form of organic and inorganic compounds in groundwater [12]. The pH values for the collected samples range from (7 to 8.2). The results figured that the groundwater in the study area tend to be neutralized or little alkaline.

The concentration of TDS ranged from (1998 to 4010) mg/L. Increasing in TDS concentration may be attributed to the geological formation for the aquifer including gypsum soil, and silty claystone in the study area. Electrical conductivity EC is related to the concentration of ionized substances present in water and its values ranged from (3990 to 8050) µS/cm in the collected samples. Dissolved oxygen DO, refers to the volume of oxygen included in water, its values varied from (5.5) to (8.1) mg/L. The relatively low groundwater temperature and its lower salinity result in the availability of more dissolved oxygen [14].The range of total hardness TH was (1200 to 2000) mg/L in wells (1, and 3), respectively. The high concentration of total hardness may cause heart diseases, gastro intestinal diseases, and kidney problems [2, 3]. The prime cause of TH is the excessive concentration of Ca in the aquifer of groundwater. The computation of CCMEWQI data sets of water quality parameters was developed by using Microsoft Excel and its simple method to analyze values. Six groundwater wells and their five variables were computed to calculate CCMEWQIs in the study area to determine the suitability of water for different uses. The investigated water quality parameters were (5), and total number of individual tests was (180). According to the equations mentioned earlier, Values of CCMEWQI computed in this study were (34, 30, 29, 35, 36 and 33) for wells (1, 2, 3, 4, 5, and 6), respectively. These values indicated that groundwater quality can be rated as poor according to **Table.1**. The low values of CCMEWQI have been attributed to high levels of groundwater quality parameters that exceed the permissible limits most of time. The results clearly draw attention to the necessity of groundwater treatment to remove the physical and chemical impurities.

V. CONCLUSION

The values of CCMEWQI revealed that the six wells from which the samples collected were in poor rank for drinking purpose. The investigation reveals that the groundwater of the study area in Al'am District requires some point of treatment before drinking and should aware about the physical and chemical impurities found into the groundwater from anthropological activities, and land-use practices.

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