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Ground Water Quality Evaluation for Drinking Purposes in Sabratha City, Libya

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A B S T R A C T

The Water Quality Index reduces the large number of indicators used in the assessment to a simpler mathematical expression allowing easy interpretation of the monitoring data. The Canadian Council of Ministers of the Environment WQI (CCMEWQI) and the Weighted Arithmetic WQI (WAWQI) were used to assess the groundwater quality for drinking purposes in Sabratha City. Ten samples were collected from different sites of the study area. Eleven significant parameters were considered for calculating the WQI which are pH, total dissolved solids (TDS), calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), potassium (K^{+}), Chloride (Cl^{-}), bicarbonate (HCO_3^{-}), Sulfate (SO_4^{--}), nitrate (NO_3^{-}) and Total Hardness (HD). The drinking water quality analysis by CCMEWQI and WAWQI shows that more than 60% of the samples described the groundwater quality in the study area as poor and unsuitable and cannot be used for drinking propose, only 20% of the samples was classified as suitable for direct consumption.

1 Introduction

Declining water quality has become a issue of concern due to unprecedented increase in population and rapid rate of urbanization as well as the intensification and expansion in agricultural practices. This has led to progressive and continual degradation of resources especially ground water (Adelagun *et al*., 2021). The Water quality is characterized on the basis of water parameters (physical, chemical, and microbiological), the human health is at risk if those values exceed acceptable limits (WHO, 2012; Libyan standard, 1992). Water quality index (WQI) is considered as the most effective technique to assess the quality of water through a single value. Several parameters are included in a mathematical equation, that expresses the overall water quality (Uddin *et al*., 2018; Uddin *et al*., 2021; Gaytán-Alarcón *et al*., 2022). Commonly, water quality index (WQI) is based on the following four steps: - selection of the parameters, - determination of the quality function for each parameter, - calculation of the parameter weighting values and - aggregation through mathematical equation (Sutadian *et al*., 2018; Abbasi and Abbasi, 2012).

The present study measures drinking water quality with the application of weighted arithmetic WQI and Canadian Council of Ministers of the Environment WQI methods based on some chemical and physical parameters.

2 Materials and Methods

The study area is in the north western part of Libya in Sabratha city, and is located between latitudes 32°43'20.30"N to 32°48'24.84"N North and Longitude 12°19'27.00"E to 12°31'26.83"E, Table (1). The collected ten (10) boreholes of groundwater samples were selected randomly from both private and public water sources.

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Table (1): Location of the study area.

Well	Latitudes	Longitude
1	32°47'59.41"N	12°26'50.93"E
2	32°44'15.63"N	12°25'52.43"E
3	32°43'20.30"N	12°19'27.00"E
4	32°43'21.50"N	12°19'27.77"E
5	32°44'4.81"N	12°29'15.85"E
6	32°47'13.11"N	12°28'36.04"E
7	32°48'24.84"N	12°25'12.51"E
8	32°46'24.64"N	12°31'26.83"E
9	32°48'7.31"N	12°23'51.76"E
10	32°45'1.62"N	12°28'21.05"E

At each borehole location, the sample bottles were washed and rinsed thoroughly with the sample water before being sampled. The boreholes were allowed to flow for about 5 minutes to ensure stable conditions before samples were collected. The water samples were analyzed for different drinking and agricultural parameters which include pH, electrical conductivity (EC), total dissolved solids (TDS), concentration of cations such as calcium, magnesium, sodium and potassium and concentration of anions such as Chloride, bicarbonate, Sulfate and nitrate. The concentration of Sodium and Potassium were measured using Flame photometer. The total hardness calcium and magnesium were determined by EDTA titrimetric method. The concentration of Chloride was determined with silver nitrate titration. The concentrations of Carbonate and bicarbonate were determined by sulfuric acid. Whereas, the concentrations of sulfate and nitrate were determined using spectro-photometer. The Salinity refers to the amount of total dissolved solids (TDS) in the water and is frequently measured by electrical conductivity (EC). Waters with higher TDS concentrations will be relatively conductive. The general formula adopted to calculate the TDS (Kelly, 1946) is

$$TDS\left(\frac{mg}{L}\right) = 0.64 \cdot EC\left[\frac{\mu S}{cm}\right] \ldots\ldots\ldots \quad (1)$$

The statistical parameters and the major ion-concentrations (mg/L) in capering with the Libyan standard (1992), are tabulated in Table (2).

Table 2: Groundwater chemical analyses (mg/L).

Well	pH	TDS	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	HCO_3^{-}	SO_4^{2-}	NO_3^{-}	Cl^{-}	HD
limit	7.5	1000	200	200	150	40	200	250	45	250	500
1	6.91	5094	737	862	149	46	129	731	13.3	2480	2453
2	6.86	8928	1291	1511	516	80	227	1599	23.2	4345	5343
3	7.52	1416	187	259	38	11.6	103	186	3.4	629	623
4	6.82	4563	422	796	286	23.8	173	843	7.4	2122	2228
5	6.83	8243	762	1438	261	45.2	131	1599	13.4	3833	2975
6	7.15	1766	163	308	110.6	7.9	128	281	2.9	822	861
7	7.3	6637	613	1158	415.7	36	106	1275	10.8	3086	3237
8	7.2	1670	154.5	291.5	104.6	7.3	126.6	259	2.7	777	815
9	7.2	1577	236	173	71.4	8	204	560	28.2	297	882
10	7.3	835	118	118.5	23.8	7.1	132	113	58.8	264	392

- **Water Quality Index Methods**

The water quality index reduces the bulk number of parameters used in an assessment and provides a single value of multiple water quality parameters into a mathematical equation that rates the health of water quality with number (Brown *et al*., 1970). Most of the models employed eight to eleven water quality parameters. In this study, eleven important parameters were chosen to measures drinking water quality with the application of Canadian Council of Ministers of the Environment WQI (CCMEWQI) and Weighted Arithmetic WQI (WAWQI).

- **Canadian Council of Ministers of the Environmental WQI**

This method was formulated by the CCME (CCME, 1999; Khan, 2003). The calculation of CCME WQI can be obtained by using the following relation:

$$WQI_{CCME} = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right] \ldots\ldots\ldots (2)$$

F1: termed the 'scope', this is the percentage of the total parameters that do not meet with the specified objectives. It is expressed as:

$$F_1 = \left[\frac{Number\ of\ failed\ variables\ (NFV)}{Total\ number\ of\ variables\ (TNV)}\right] x100 .. (3)$$

F_2 represents the percentage of individual tests that do not meet standard.

$$F_2 = \left[\frac{Number\ of\ failed\ tests\ (NFT)}{Total\ number\ of\ tests\ (TNT)}\right]\ x\ 100 \ldots (4)$$

$$F_3 = \frac{nse}{0.01 \cdot nse + 0{,}01} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The number of times by which an individual concentration is greater or less than the objective is termed an "excursion" and is expressed as follows:

$$nse = \frac{\sum_1^n excursion_i}{Total\ number\ of\ tests} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

When the test value must not exceed the objective

$$excursion_i = \frac{Failed\ test\ value_i}{Objective_i} - 1 \ldots\ldots\ldots (7a)$$

For the other case when the test value must not fall below the objective

$$excursion_i = \frac{Objective_i}{Failed\ test\ value_i} - 1 \ldots\ldots (7b)$$

- **Weighted Arithmetic Water Quality Index**

Weighted arithmetic water quality index (WAWQI) method classified the water quality according to the degree of purity by using the most commonly measured water quality variables (Yisa and Jimoh, 2010; Tyagi *et al*., 2014; Aldeeb and Algeidi, 2021). The method has been widely used by many scientists and the calculation of WQI was obtained by using the following equation:

$$WQI = \frac{\sum Q_n \cdot W_n}{\sum W_n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The quality rating scale Q_n for each parameter is calculated by using this expression:

$$Q_n = \left[\frac{V_n - V_0}{S_n - V_0}\right] \cdot 100 \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

V_n Estimated concentration of n^{th} parameter in the analyzed water

V_0 Ideal value of this parameter in pure water = 0 (except for pH =7.0)

S_n Recommended standard value of n^{th} parameter

The unit weight W_n for each water quality parameter is calculated by using the following formula:

$$W_n = \frac{K}{S_n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Where K, Proportionality constant and can also be calculated by using the following equation:

$$K = \frac{1}{\sum \frac{1}{S_n}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Different levels of water quality index and their respective water quality status were given in Table (3). Various parameters with their standards and recommended calculation were summarized in Table (4). The rating of water quality according to this WQI is given below Table (1).

Table (3): Water Quality Rating.

WQI_{WA} Value	Rating	Grading
0-25	Excellent	A
26-50	Good	B
51-75	Moderate	C
76-100	Poor	D
Above 100	Unsuitable	E
(Aldeeb and Algeidi, 2021; Khan, 2003)		

WQI_{CCME}Value	Rating
95-100	Excellent
80-94	Good
65-79	Fair
45-64	Marginal
00- 44	Poor

3 Results and Discussion

Water sample collected from Ten (10) different locations of Sabratha were tested to determine the Water Quality Index (WQI). To calculate desired WQI, each parameter was multiplied by weightage factors according to their relative importance in determining quality index as prescribed in WA and CCME index.

• Canadian WQI (CCMEWQI)

Calculation for Well 1 as example, in this case there is only one test for each Well. F1 represents the percentage of variables that do not meet their Objective or standard (failed variables), relative to the total number of variables measured and F2 represents the percentage of individual tests that do not meet standard

$$F_1 = \left[\frac{NFV = 7}{TNV = 10}\right] x\ 100 = 70$$

$$F_2 = \left[\frac{NFT = 7}{TNT = 10}\right] x\ 100 = 70$$

The test value must not exceed the objective

$$excursion_{TDS} = \frac{Failed\ test\ value_i}{Objective_i} - 1$$

$$= \frac{5094.4}{1000} - 1 = 4.0944$$

$$nse = \frac{\sum_1^n excursion_i}{Total\ number\ of\ tests} = \frac{21.08}{10} = 2.108$$

$$F_3 = \frac{nse}{0.01 \cdot nse + 0{,}01} = \frac{2.108}{0.01\ x\ 2.108 + 0.01} = 67.83$$

$$WQI_{CCME} = 100 - \left[\frac{\sqrt{70^2 + 70^2 + 67.83^2}}{1.732}\right] = 30.7$$

Well	pH	TDS	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	HCO_3^-	SO_4^{2-}	NO_3^-	Cl^-	HD
limit	7.5	1000	200	200	150	40	200	250	45	250	500
1	6.91	5094	737	862	149	46	129	731	13.3	2480	2453

- **Weighted Arithmetic WQI (WAWQI)**

Calculation for Well 1 as example, the Proportionality constant K of 10 standard parameter S_n:

$$K = \frac{1}{\sum \frac{1}{S_n}} = \frac{1}{0.213222} = 4.689943$$

The quality rating scale Q_n and the unit weight W_n for each parameter were calculated and summarized in Table (4).

Table (4): Calculation of Q_n and W_n for well 1.

parameter	standard	experimental	W_n	Q_n	$W_n \cdot Q_n$
pH	7.5	6.91	0.625326	18.00	11.256
TDS	1000	5,094.4	0.00469	509.4	2.389
Ca^{++}	200	737	0.02345	368.5	8.641
Na^{+}	200	862	0.02345	431	10.106
Mg^{++}	150	149	0.03127	99.3	3.106
K^{+}	40	46	0.11725	115	13.484
HCO_3^-	200	129.3	0.02345	64.65	1.560
SO_4^{--}	250	731.3	0.01876	292.5	5.488
NO_3^-	45	13.3	0.10422	29.56	3.080
Cl^-	250	2,480	0.01876	992	18.609
HD	500	2,453	0.00938	490.7	4.603
WQI					82.3

Analog calculations for the other wells for both, CCMEWQI and WAWQI are summarized in the Table (5). Different levels of water quality index (WQI_{CCME} & WQI_{WA}) and their respective water quality condition were given in Table (3). The drinking water quality analysis by CCMEWQI and WAWQI shows that more than 60% of the samples described the groundwater quality in the study area as poor to unsuitable and cannot be used for drinking propose, only 20% of the samples was classified as good for direct consumption.

Table (5): Summarized WQIs for the 10 wells.

Well	CCME WQI	Rating	Well	AW WQI	Rating	Grading
1	30.7	Poor	1	82.3	Poor	D
2	12.6	Poor	2	151.4	Unsuitable	E
3	65.7	Fair	3	84.4	Poor	D
4	24.8	Poor	4	82.0	Poor	D
5	20.4	Poor	5	120.6	Unsuitable	E
6	56.3	Marginal	6	41.8	Good	B
7	28.4	Poor	7	123.2	Unsuitable	E
8	56.8	Marginal	8	46.8	Good	B
9	49.9	Marginal	9	51.4	Moderate	C
10	83.5	Good	10	62.0	Moderate	C

4 Conclusions

The groundwater of the study area in Sabratha region were evaluated for their chemical composition and suitability for drinking purpose using the water quality indices (CCMEWQI & WA). Groundwater samples were collected from ten (10) boreholes in Sabratha Libya at random. The drinking water quality analysis by WAWQI and CCMEWQI shows that 50% of samples described the groundwater quality in the study area as poor to unsuitable and 40% of samples described it as good to moderate water and can be used for direct consumption.

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