Assessment of Ground Water Quality through WQI in Mitrid, Libya

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Abstract

Water Quality Indices aim at giving a single value to water quality of a source reducing numerous parameters into a simpler expression and enabling easy interpretation of monitoring data. Weighted arithmetic water quality index (WAWQI) was used to assess the groundwater quality for drinking purposes in Mitrid City. Fifteen samples were collected from different sites of the study area. Eleven significant parameters have been considered for calculating the WQI such as; pH, electrical conductivity (EC), total dissolved solids (TDS), calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), potassium (K^{+}), Chloride (Cl^{-}), bicarbonate (HCO_3^{-}), Sulfate (SO_4^{--}) and nitrate (NO_3^{-}). The water quality index calculated from the observed parameters ranges from 33.4 to 121.6. The majority of the samples described the groundwater quality in the study area as good to moderate, except of well numbered 2 is unsuitable for drinking purposes.

الملخص

تهدف مؤشرات جودة المياه إلى إعطاء قيمة واحدة لجودة المياه وتقليل عدد البرامتر، مما يتيح تفسير اسهل للبيانات. تم استخدام مؤشر جودة المياه الحسابي لتقييم جودة المياه الجوفية لأغراض الشرب في مدينة المطرد، وذلك لخمسة عشر عينة من مواقع مختلفة من منطقة الدراسة. تم اختيار أحد عشر بارامتر لحساب مؤشر جودة المياه مثل؛ الأس الهيدروجيني، الموصلية الكهربائية، المواد الصلبة الذائبة الكلية، الكالسيوم، المغنيسيوم، الصوديوم، والبوتاسيوم، الكلوريد، البيكربونات، الكبريات والنترات. تراوحت القيم المحسوبة لمؤشر جودة المياه ما بين 33.4 إلى 121.6. وصفت غالبية العينات جودة المياه الجوفية في منطقة الدراسة بأنها جيدة إلى متوسطة ، باستثناء البئر رقم 2، فإن نوعية المياه الجوفية غير مناسبة للشرب.

Keywords: WQI, WAWQI, drinking purposes, very poor, unsuitable.

- **Introduction**

The most important drinking water resources in the world are the surface water and groundwater. The Quality of drinking water indicates water acceptability for human consumption. Water quality status is professional communicated by comparing the individual parameters (physical, chemical and biological parameters) with guideline values. The limits of those parameters that are harmful to human health have been established at national or international level by various laws, regulations, normatives [1–2]. The water quality index aims at assessing the quality of water through a single numerical value, calculated on the basis of one system which convert all the individual parameters and their concentrations, present in a sample into a single value. Initially, water quality index (WQI) was developed by Horton (1965) [3] in United States by selecting 10 most commonly used water quality variables like dissolved oxygen, pH, coliforms, specific conductance, alkalinity and chloride. A new WQI similar to Horton's index has also been developed by the group of Brown in 1970 [4], which was based on weights to individual parameter. The assigned weight reflected significance of a parameter for a particular use and has considerable impact on the index. This is an effective method that allows to compare the quality of various water samples based on a single numerical value and not only the parameters values of each sample [5-7].

Many modifications have been considered for WQI concept through various scientists and experts [8-15]. A general water quality index (WQI) is based on the most common factors, which are described in the following four steps: (1) selection of parameters, (2) determination of quality function for each parameter, and (3) aggregation through mathematical equation [7]. However, there are a large number of water quality indicators such as:

- Weight Arithmetic Water Quality Index (WAWQI),
- National Sanitation Foundation Water Quality Index (NSFWQI),
- Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI),
- Oregon Water Quality Index (OWQI) etc. have been formulated by several national and international organizations.

These WQIs were applied for evaluation of water quality in a particular area. Moreover, these indices are often based on the varying number and types of water quality parameters as compared with respective standards of a particular region.

The present study measures drinking water quality with the application of weighted arithmetic WQI method based on some chemical parameters.

• Study area

The study area is in the western side of Azawia in Mitrid city, and is located between latitudes 32°47'13.37"N to 32°41'34.52"North and Longitude 12°35'10.68" to 12°37'59.60"E, Figure (1).

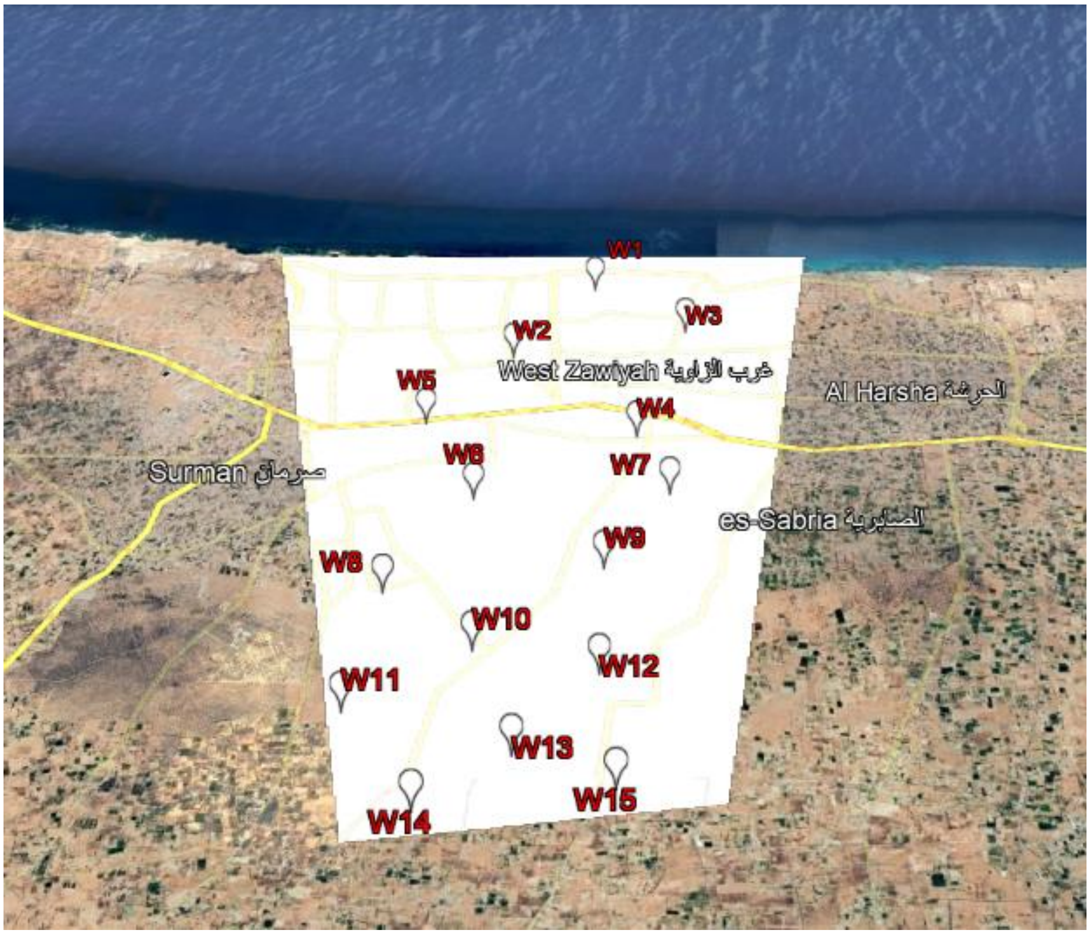

Figure (1): The location of the study area.

• Material and Methods

The methods of collection of samples play an important role in maintaining a high degree of accuracy of analytical data and its application to hydro chemical studies. Fifteen samples of groundwater were collected from the wells of some houses, farms and schools. The location of the study area is shown in Figure (1). The groundwater samples were collected in pre-cleaned polyethylene bottles from bore wells as per the standard procedures. The samples were collected, after 5 minutes of run-off water drawn from wells. The water samples were analyzed, within 24 hours, for various physic-chemical parameters which include pH, electrical conductivity (EC), total dissolved solids (TDS), cations such as calcium ions (Ca^{++}), magnesium ions (Mg^{++}), sodium ions (Na^{+}) and potassium ions (K^{+}); and anions as Chloride ions (Cl^{-}), bicarbonate ions (HCO_3^{-}), Sulfate ions (SO_4^{--}) and nitrate ions (NO_3^{-}). The cations such as Sodium (Na^{+}) and Potassium (K^{+}) were measured using Flame photometer.

The total hardness calcium (Ca^{++}) and magnesium ions (Mg^{++}) were determined by EDTA titrimetric method. Chloride ions (Cl^{-}) was determined by silver nitrate titration. Carbonate ions (CO_3^{--}) and bicarbonate ions (HCO_3^{-}) were determined by sulfuric acid. Whereas, sulfate ions (SO_4^{--}) and nitrate ions (NO_3^{-}) were determined using spectro-photometer.

- **Water Quality Index**

WQI's aim at giving a single value to the Water quality of a source reducing great amount of parameters into a simpler expression and enabling easy interpretation of monitoring data [8]. In this study, eleven important parameters were chosen for the calculation of water quality index. The WQI has been calculated by using the weighted Arithmetic index method and according to the standards of drinking water quality recommended by Libyan Standards (LYS-82). Weighted arithmetic water quality index method classified the water quality according to the degree of purity by using the most commonly measured water quality variables. The method has been widely used by the various scientists and the calculations were prepared using the following equation [5, 6]:

$$WQI = \frac{\sum Q_n \cdot W_n}{\sum W_n} \tag{1}$$

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

$$Q_n = \left[\frac{V_n - V_0}{S_n - V_0}\right] \cdot 100 \tag{2}$$

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:

$$W_n = \frac{K}{S_n} \tag{3}$$

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

$$K = \frac{1}{\sum \frac{1}{S_n}} \tag{4}$$

The weights for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters $\frac{1}{S_n}$. Different levels of water quality index and their respective water quality status were given in Table (1).

Table (1): Water Quality Rating.

WQI Value	Rating of water quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Moderate Water Quality	C
76-100	Poor water quality	D
Above 100	Unsuitable for drinking purpose	E

- ## Results and Discussion

Table (2) shows the results obtained through chemical analyzes of water samples that taken from the wells of the study area. The quality of groundwater of the study area was assessed as per standard specification given by Libyan standard [1] and World Health Organization [2].

Table (2): Water Quality Standards.

Parameter	Libyan Standard	WHO Standard
	mg/l	
pH	7.5	6.5 - 8.5
EC	1600	1500
TDS	1000	500-1000
Ca^{2+}	200	75-200
Na^{+}	200	200-400
Mg^{2+}	150	30-150
K^{+}	40	12
HCO_3^{-}	200	10
SO_4^{2-}	250	200-400
NO_3^{-}	45	10-45

Cl^-	250	200-600

The measured concentrations of the eleven parameters and their recommended value according to the Libyan standard are summarized in Table (2).

- **Hydrogen ion concentration (pH):**

The pH of the water samples in the study area varies from 7.1 to 7.5. The results of power of hydrogen (pH) show that the water of the area located within the permissible limits which come in accordance with the Libyan Standard No. 82 of drinking water.

- **Electrical conductivity (EC):**

EC is an assessment of all soluble salts in samples. The electrical conductivity (EC) of the groundwater in the study area varies from 1150 to 7500 µS/cm, Table (3). The samples show high and very high salinity.

Table (3): Characterization of water samples.

Well	**pH**	**EC**	**TDS**	Ca^{2+}	Na^+	Mg^{2+}	K^+	HCO_3^-	SO_4^{2-}	NO_3^-	Cl^-
Limit no.	**7.5**	**1600** µS/cm	**1000** mg/L	**200** mg/L	**200** mg/L	**150** mg/L	**40** mg/L	**200** mg/L	**250** mg/L	**45** mg/L	**250** mg/L
1	7.3	6900	4416	380.1	470.1	134.2	13.5	410.8	345	44	950.5
2	7.5	7500	4800	450.5	552.5	465.5	25.5	341.19	550	48	865
3	7.4	5480	3507.2	358.4	556.9	265.5	27.8	264.5	450	35	830
4	7.2	4660	2982.4	420.5	420.5	105.5	11.5	142.42	495	48	750
5	7.3	1400	896	230.4	133	58.5	7.5	162.77	285	35.5	178.7
6	7.1	1150	736	178.5	163	23.81	7.5	152.59	245	33.5	275.5
7	7. 3	1550	992	145.5	125.5	64.5	3.8	203.46	160	44.5	188.5
8	7.3	2460	1574.4	138.5	128.5	28.4	6.1	132.25	128	49.8	255.7
9	7.2	1310	838.4	145.2	110	20.5	6.4	152.59	115	34.5	223.6
10	7.2	2470	1580.8	177.4	108.2	37.5	6.2	142.42	195	33.5	296.59
11	7.4	4300	2752	265.5	193	81	7.8	203.46	450	31.5	278.4

12	7.2	2080	1331.2	275.5	188.5	28.5	5.6	193.28	465	41.5	375.5
13	7.2	2235	1430.4	335.5	165	157	10.7	193.28	550	23.5	560.1
14	7.1	1645	1052.8	188.5	146.5	40.5	9.8	122.08	380	35.5	358.4
15	7.2	1290	825.6	88.5	163.5	19.5	8.8	152.59	419	44.5	325.4

- **Total Dissolved Solids (TDS):**

In natural water, dissolved solids consists mainly of inorganic salts. The general formula adopted to calculate the TDS [7],

$$TDS\left[\frac{mg}{l}\right] = 0.64 \cdot EC\left[\frac{\mu S}{cm}\right] \qquad (4)$$

The concentrations of TDS decrease as the distance increases between the sea and the well positions, with some exceptions in the wells w1 and w15. The measured values of TDS are acceptable in W5, W6, W7, W9, W14 and W15 as shown in Table (3).

- **Anions**

As shown Table (3), about 80% of the Chloride concentrations and 70% of sulphate were above the maximum limit allowed by the Libyan Standard. Of the other side the Concentration of bicarbonate and nitrate were in the permissible limit.

- **Cations**

As shown Table (3), about 50% of the calcium concentrations and 30% of sodium were above the maximum limit allowed by the Libyan Standard. Of the other side the Concentration of magnesium and potassium were in the permissible limit.

- **WQI**

Calculation for Well 1 as example, the Proportionality constant K of 11 standard parameter S_n

$$K = \frac{1}{\sum \frac{1}{S_n}} = \frac{1}{0.211847} = 4.72038$$

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	Unit weight W_n	Quality rating Q_n	$W_n \cdot Q_n$
pH	7.5	7.3	0.62938	60.00	37.763
EC	1600	6900	0.00295	431.25	1.2723
TDS	1000	4416	0.00472	441.60	2.0845
Ca^{2+}	200	380.1	0.02360	190.05	4.4855
Na^{+}	200	470.1	0.02360	235.05	5.5476
Mg^{2+}	150	134.2	0.03147	89.47	2.8154
K^{+}	40	13.5	0.11801	33.75	3.9828
HCO_3^-	200	410.8	0.02360	205.40	4.8478
SO_4^{2-}	250	345	0.01888	138.00	2.6056
NO_3^-	45	44	0.10490	97.78	10.257
Cl^-	250	950.5	0.01888	380.20	7.1788

The water quality index WQI for well 1 is then calculated as following:

$$WQI = \frac{\sum Q_n \cdot W_n}{\sum W_n} = \frac{82.84}{1} = 82.84$$

Analog calculations for the other wells are summarized in the Table (5).

Table (5): Summarized WQI for the 15 wells.

Well	WQI	Quality	Grading
1	82.84	Poor Water Quality	D
2	121.6	Unsuitable for drinking	E
3	98.5	Poor Water Quality	D
4	65.2	Moderate Water Quality	C
5	59.9	Moderate Water Quality	C
6	33.4	Good Water Quality	B
7	59.6	Moderate Water Quality	C
8	60.6	Moderate Water Quality	C
9	43.5	Good Water Quality	B
10	45.6	Good Water Quality	B
11	77.1	Poor Water Quality	D
12	52.2	Moderate Water Quality	C
13	54.8	Moderate Water Quality	C
14	36.4	Good Water Quality	B
15	49.6	Good Water Quality	B

Conclusion

The water quality index aims at assessing the quality of water through a single numerical value. Weighted arithmetic water quality index (WAWQI) was used to assess the groundwater quality for drinking purposes in Mitrid City. Fifteen Groundwater samples were collected from different locations of some houses, farms and schools. Eleven significant parameters were considered for calculating the WQI such as; pH, EC, TDS, Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, SO_4^{--} and NO_3^{-}. The water quality analysis shows that 67 % of samples described the groundwater quality in the study area as good to moderate water and can be used for direct consumption.

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