# Evaluation of Groundwater for Drinking in Alghurayfah Municipality, Libya

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## Abstract

Water quality Indices are a useful and easy techniques used to evaluate water quality through reducing numerous parameters into a simpler expression and enabling easy interpretation of monitoring data. With an effort to quantitatively describe the present situation of groundwater and analyze the specific sources of the main ingredients, fifteen samples from different sites were collected and analyzed for understanding the hydrochemical characteristics and the suitability for drinking purposes in the municipality of Alghurayfah, Libya. Weighted arithmetic water quality index (WAWQI), standard water quality model (SWQM) and synthetic pollution index (SPI) were used to assess the groundwater quality for drinking purposes in the study area. Eleven significant parameters were considered for calculating the water quality indices 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 (TH). The majority of the obtained results described the groundwater quality in the study area as good to excellent for drinking and can be used for direct consumption. Two samples were unsuitable for drinking use, the pH value was higher than the permission limit.

**Keywords:** Alghurayfah, Weighted arithmetic water quality index, standard water quality model, drinking purposes, synthetic pollution index.

# تقييم المياه الجوفية للشرب في بلدية الغريفة، ليبيا


الملخص

مؤشرات جودة المياه هي تقنيات مفيدة وسهلة تستخدم لتقييم جودة المياه من خلال تقليل العديد من المؤشرات إلى تعبير أبسط وإتاحة تفسير أسهل لبيانات المراقبة. في محاولة للوصف الكمي للوضع الحالي للمياه الجوفية وتحليل المصادر المحددة للمكونات الرئيسية، تم جمع وتحليل خمسة عشر عينة من مواقع مختلفة لفهم الخصائص الهيدروكيميائية ومدى ملاءمتها لأغراض الشرب في بلدية الغريفة، ليبيا. تم استخدام مؤشر جودة المياه الحسابي، نموذج جودة المياه القياسي ومؤشر التلوث الاصطناعي لتقييم جودة مياه الشرب في منطقة الدراسة. تم الأخذ في الاعتبار أحد عشر معاملاً هامًا لحساب مؤشرات جودة المياه وهي الأس الهيدروجيني، المواد الصلبة الذائبة الكلية، الكالسيوم، المغنيسيوم، الصوديوم، والبوتاسيوم، الكلوريد، البيكربونات، الكبريات، النترات والعسرة الكلية. غالبية النتائج التي تم الحصول عليها وصفت نوعية المياه الجوفية في منطقة الدراسة بأنها جيدة إلى ممتازة للشرب ويمكن استخدامها للاستهلاك المباشر. كانت عينتان غير صالحتين للشرب، حيث كانت قيمة الرقم الهيدروجيني أعلى من الحد المسموح به.

- ## Introduction

In arid and semi-arid areas groundwater is the main source for drinking, irrigation and other purposes uses. Generally, the quality and quantity of groundwater mainly depends on the geochemistry of soils and rocks. Groundwater chemistry of a region is usually not homogeneous and it is driven by flow, geochemical processes, evaporation and evapotranspiration and possible sources of pollution [1, 2]. Hydrogeochemical processes can help to prepare and maintain polluted sites in order to preserve aquifers that are contaminated by natural and anthropogenic phenomena. Therefore knowledge of geochemical processes that govern groundwater chemistry is therefore important for understanding groundwater quality issues [3]. Therefore, understanding the chemical characteristics of groundwater and its influencing factors is critical to the protection and management of groundwater resources and the sustainable use of groundwater. Using a feasible and effective drinking water quality assessment method is critical to achieve reliable results, facilitating wise decision-making [4]. The water quality indices (WQI) and the synthetic pollution index (SPI) are an effective technique for evaluating the suitability of drinking water quality for human consumption in any area and communicating the overall water quality [5]. These indices are often based on the varying number and types of water quality parameters as compared with respective local standards, to estimate water quality through a single numerical value. WQI has the capability to reduce the bulk of the information into a single value to express the data in a simplified and logical form. It takes information from a number of sources and combines them to develop an overall status of a water system. They increase the understanding ability of highlighted water quality issues by the policy makers as well as for the general public as users of the water resources [6-11].

This study was conducted to evaluate the quality of the groundwater in the municipality of Alghurayfah, Libya. Further, to identify groundwater quality and its suitability for drinking proposes using weighted arithmetic water quality index (WAWQI), standard water quality model (SWQM) and synthetic pollution index (SPI).

## Materials and Methods

The study area is in the south western part of Libya in the municipality of Alghurayfah and located between the following latitudes and Longitude:

Table (1): *Location of the study area.*

| Well | Latitudes | Longitude | Town |
|---|---|---|---|
| W1 | 26°31'37.25"N | 12°58'26.80"E | Qwirat-القعيرات |
| W2 | 26°31'24.88"N | 12°58'39.19"E | Qwirat-القعيرات |
| W3 | 26°31'05.28"N | 13° 0'17.59"E | Alghurayfah - الغريفة |
| W4 | 26°31'20.08"N | 13° 0'38.47"E | Alghurayfah - الغريفة |
| W5 | 26°31'34.80"N | 13° 01'3.81"E | Alghurayfah - الغريفة |
| W6 | 26°31'33.94"N | 13° 2'41.47"E | Germa - جرمة |
| W7 | 26°32'20.88"N | 13° 3'50.84"E | Germa - جرمة |
| W8 | 26°31'30.73"N | 13° 4'40.92"E | Germa - جرمة |
| W9 | 26°32'23.59"N | 13° 5'60.00"E | Twash - توش |
| W10 | 26°33'09.61"N | 13° 6'41.56"E | Burik - ابريك |
| W11 | 26°33'41.42"N | 13° 7'32.57"E | Fakhfakha - الفخفاخة |
| W12 | 26°33'34.32"N | 13° 09'8.26"E | Tweewa - تويوة |
| W13 | 26°33'15.93"N | 13°10'18.58"E | Tweewa - تويوة |
| W14 | 26°33'25.67"N | 13°11'13.29"E | Khariq - الخرائق |
| W15 | 26°33'02.55"N | 13°12'49.09"E | Garagra - قراقرة |

The collected fifteen (15) boreholes of groundwater samples were selected randomly from both private and public water sources. 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 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 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 TDS [12] is

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

The statistical parameters and the major ion-concentrations (mg/L) in capering with the Libyan standard [13], are tabulated in Table (2).

Table (2): *Chemical analyses of Groundwater in (mg/L).*

| Well | pH | TDS | $Ca^{2+}$ | $Na^{+}$ | $Mg^{2+}$ | $K^{+}$ | $HCO_3^-$ | $NO_3^-$ | $Cl^-$ | TH | $SO_4^{2-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| limit | 7.5 | 1000 | 200 | 200 | 150 | 40 | 200 | 45 | 250 | 500 | 250 |
| 1 | 6.60 | 73.75 | 16.80 | 30.00 | 18.24 | 7.18 | 0.80 | 2.22 | 65.07 | 118.00 | 10.16 |
| 2 | 8.75 | 164.37 | 5.50 | 31.66 | 7.80 | 7.18 | 2.40 | 0.02 | 50.05 | 40.00 | 5.33 |
| 3 | 8.60 | 156.76 | 4.80 | 30.00 | 7.68 | 7.18 | 2.40 | 0.02 | 55.06 | 44.00 | 5.83 |
| 4 | 7.20 | 73.49 | 27.20 | 1.67 | 31.20 | 7.81 | 0.80 | 2.42 | 50.05 | 198.00 | 15.16 |
| 5 | 7.10 | 80.77 | 9.60 | 1.67 | 2.88 | 6.53 | 1.08 | 0.13 | 60.06 | 36.00 | 9.33 |
| 6 | 6.80 | 86.86 | 16.80 | 11.67 | 9.60 | 7.18 | 1.12 | 0.13 | 65.07 | 64.00 | 8.83 |
| 7 | 6.60 | 66.97 | 8.00 | 5.00 | 13.92 | 7.18 | 0.84 | 0.42 | 60.06 | 78.00 | 5.25 |
| 8 | 6.60 | 93.51 | 14.40 | 10.00 | 0.96 | 7.18 | 7.36 | 0.25 | 60.06 | 40.00 | 11.16 |
| 9 | 6.90 | 83.82 | 6.40 | 16.67 | 4.80 | 5.88 | 7.08 | 0.76 | 65.06 | 36.00 | 5.66 |
| 10 | 6.80 | 65.66 | 11.20 | 8.33 | 3.84 | 6.53 | 0.84 | 0.28 | 55.06 | 44.00 | 6.83 |
| 11 | 6.70 | 81.60 | 8.80 | 8.33 | 10.08 | 7.84 | 0.80 | 0.68 | 50.05 | 64.00 | 7.16 |
| 12 | 6.70 | 108.80 | 12.00 | 13.33 | 12.00 | 8.49 | 0.60 | 0.25 | 70.07 | 80.00 | 7.00 |
| 13 | 6.70 | 63.25 | 4.00 | 5.00 | 13.44 | 7.84 | 0.80 | 0.53 | 55.06 | 66.00 | 7.75 |
| 14 | 6.80 | 63.74 | 5.60 | 6.67 | 16.32 | 7.18 | 0.64 | 0.26 | 50.05 | 82.00 | 8.33 |
| 15 | 6.90 | 64.88 | 5.60 | 8.33 | 8.64 | 7.18 | 0.88 | 0.13 | 55.06 | 50.00 | 6.66 |

- **Water quality index methods**

Assessment of the water quality is difficult simply from elemental concentrations of various water quality parameters. Thus, water quality indices are applied to assess the overall effects of contamination. The water quality index reduces the bulk number of parameters used and provides a single value of multiple water quality parameters into a mathematical equation that rates the health of water quality with number [14]. Most of the models employed eight to eleven water quality parameters. In this study, eleven important parameters Table (2) were chosen to measures drinking water quality with the application of the following methods and models:

1. **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 [15-17]. The method has been widely used by many scientists and the calculation of WQI was obtained by using the following equation:

$$\mathrm{WQI} = \frac{\sum \mathrm{Q_n} \cdot \mathrm{W_n}}{\sum \mathrm{W_n}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . (2)$$

The quality rating scale $\mathrm{Q_n}$ for each parameter is calculated by using this expression:

$$\mathrm{Q_n} = \left[\frac{\mathrm{V_n} - \mathrm{V_0}}{\mathrm{S_n} - \mathrm{V_0}}\right] \cdot 100 \ldots \ldots \ldots \ldots \ldots \ldots . . (3)$$

$\mathrm{V_n}$ The concentration of each chemical parameter in each sample (mg/L).

$\mathrm{V_0}$ Ideal value of this parameter in pure water = 0 (except for pH =7.0).

$\mathrm{S_n}$ The standard limit for each chemical parameter (mg/L).

The unit weight $\mathrm{W_n}$ for each water quality parameter is calculated by using the following formula:

$$\mathrm{W_n} = \frac{\mathrm{K}}{\mathrm{S_n}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . (4)$$

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

$$\mathrm{K} = \frac{1}{\sum \frac{1}{\mathrm{S_n}}} \ldots \ldots \ldots \ldots \ldots \ldots . . \ldots \ldots \ldots (5)$$

2. **Standard water quality model**

The standard water quality model (SWQM) was computed using the 11 various water quality parameters and their relevant Libyan guidelines. According to [18-21], physicochemical parameters were assigned a weight ($w_i$) from 1 to 5 depending upon their significance in water quality evaluation for human health. In this study, the highest weight of 5 was assigned to nitrates because of its higher impact on human health. To calculate SWQM, three steps were followed [19]:

- Relative weight ($W_i$) was computed using equation (6)

$$W_i = \frac{w_i}{\sum w_i} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (6)$$

- Quality rating ($Q_i$) for each of the observed parameters was calculated using equation (7).

$$Q_i = \left[\frac{V_n}{S_s}\right] \cdot 100 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (7)$$

where $Q_i$ represents the quality rating, $V_n$ is the concentration of each chemical parameter in each sample (mg/L), and $S_n$ refers to the standard limit for each chemical parameter (mg/L) according to the guidelines of the Libyan standard.

- The Standard water quality model (SWQM) was calculated using equation (8).

$$SWQM = \sum_{i}^{11} (W_i \cdot Q_i) \ldots \ldots \ldots \ldots \ldots (8)$$

3. **Synthetic pollution index (SPI) models**

The Synthetic pollution index (SPI) model [22] is used to evaluate the pollution degree of the sampled groundwater. The SPI can calculated using the following equations:

$$SPI = \sum_{n=1}^{11} \frac{V_n}{S_n} \cdot W_n \ldots \ldots \ldots \ldots \ldots \ldots \ldots (9)$$

Where $W_n$ is the unit weight for each water quality parameter equation (4), K is the Proportionality constant equations (5), $V_n$ is the estimated concentration of $n^{th}$ parameter in the analyzed water and $S_n$ is the recommended standard value of $n^{th}$ parameter.

Based on the water quality indices, the water quality rating is classified into five categories, Table (3).

Table (3): *Water quality rating.*

| $WQI_{WA}$ | Rating [16] | | $SWQM$ | Rating [19] | | SPI | Rating [20] |
|---|---|---|---|---|---|---|---|
| 0 – 25 | excellent | | < 50 | excellent | | < 0.2 | suitable |
| 26 – 50 | good | | 50 – <100 | good | | 0.2 – 0.5 | slightly polluted |
| 51 – 75 | moderate | | 100 – < 200 | poor | | 0.5 – 1.0 | moderately polluted |
| 76 – 100 | poor | | 200 – < 300 | very poor | | 1.0 – 3.0 | highly polluted |
| > 100 | unsuitable | | ≥ 300 | unfit | | > 3.0 | unsuitable |

## Results and Discussion

The statistical summary of observed concentrations of various physicochemical parameters in the sampled groundwater with their standards is described in Table (2). Water samples collected from fifteen (15) different locations in the municipality of Alghurayfah Libya were tested to determine the Water quality. Different levels of water quality rating $WQI_{WA}$, $SWQM$ $and$ SPI and their respective water quality condition were given in Table (3).

**Weighted arithmetic water quality index:** the rating of water quality according to WAWQI is given Table (3). Calculation for Well 1 as example, the Proportionality constant K for 11 standard parameter $S_n$:

$$K = \frac{1}{\sum \frac{1}{S_n}} = \frac{1}{0.213222} = 4.68994$$

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

S**tandard water quality model:** Various physicochemical parameters were assigned a weight ($w_i$) from 1 to 5 depending upon their significance in water quality evaluation for human health. Table (4) presents analyzed physicochemical parameters and their respective assigned, the highest weight of 5 was assigned to nitrates. Calculation for Well 1 as example, the quality rating scale $Q_i$ and the unit relative weight $W_i$ for each parameter were calculated using equation (7 and 6) respectively and summarized in Table (4).

Table (4): *Calculation of WAWQI, SWQM and SPI for well 1 as example.*

| Weighted arithmetic water quality index | | | | | | | Standard water quality model | | | | | SPI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| par. | $S_n$ | $V_n$ | $W_n$ | $Q_n$ | $W_n \cdot Q_n$ | | $w_i$ | $W_i$ | $Q_i$ | $W_i \cdot Q_i$ | | $\frac{V_n}{S_n} \cdot W_n$ |
| pH | 7.5 | 6.6 | 0.6253 | 80.00 | 50.026 | | 3 | 0.1000 | 88.00 | 8.800 | | 0.55029 |
| TDS | 1000 | 73.75 | 0.0047 | 7.38 | 0.035 | | 3 | 0.1000 | 7.38 | 0.738 | | 0.00035 |
| $Ca^{++}$ | 200 | 16.8 | 0.0235 | 8.40 | 0.197 | | 3 | 0.1000 | 8.40 | 0.840 | | 0.00197 |
| $Na^{+}$ | 200 | 30 | 0.0235 | 15.00 | 0.352 | | 2 | 0.0667 | 15.00 | 1.000 | | 0.00352 |
| $Mg^{++}$ | 150 | 18.24 | 0.0313 | 12.16 | 0.380 | | 2 | 0.0667 | 12.16 | 0.811 | | 0.00380 |
| $K^{+}$ | 40 | 7.18 | 0.1173 | 17.95 | 2.105 | | 3 | 0.1000 | 17.95 | 1.795 | | 0.02105 |
| $HCO_3^-$ | 200 | 0.8 | 0.0235 | 0.40 | 0.009 | | 1 | 0.0333 | 0.40 | 0.013 | | 0.00009 |
| $NO_3^-$ | 45 | 2.22 | 0.1042 | 4.93 | 0.514 | | 5 | 0.1667 | 4.93 | 0.822 | | 0.00514 |
| $Cl^-$ | 250 | 65.07 | 0.0188 | 26.03 | 0.488 | | 3 | 0.1000 | 26.03 | 2.603 | | 0.00488 |
| HD | 500 | 118 | 0.0094 | 23.60 | 0.221 | | 2 | 0.0667 | 23.60 | 1.573 | | 0.00221 |
| $SO_4^{--}$ | 250 | 10.16 | 0.0188 | 4.06 | 0.076 | | 3 | 0.1000 | 4.06 | 0.406 | | 0.00076 |
| AWWQI | | | | | 54.400 | | SWQM | | | 19.401 | | 0.5941 |

**Synthetic pollution index (SPI):** for Well 1 as example, the SPI equations (9) was calculated using the quality rating scale $Q_n$ and the unit weight $W_n$ for each parameter and summarized in Table (4).

Analog calculations for all other wells for, WAWQI, SWQM and SPI are summarized in the Table (5) and depicted in Figure (1). The drinking water quality analysis by WQI and SWQM shows that majority of the samples described the groundwater quality in the study area as good to excellent for direct consumption. Two samples were unsuitable for drinking, pH value was higher than the permision limits. Drinking water with pH level above 8.5 indicates that a high level of alkalinity minerals are present. High alkalinity does not pose a health risk, but can also cause aesthetic problems, such as an alkali taste to the water that makes coffee taste bitter; scale build up in plumbing, and lower efficiency of electric water heaters. Based on the Synthetic pollution index (SPI), all of the water samples were identified as moderately polluted (0.5 – 1.0).

Table (5): *Summarized SWQM, AWWQI and SPI for the 15 wells.*

| Well | SWQM | Rating | AW WQI | Rating | Grading | SPI |
|---|---|---|---|---|---|---|
| 1 | 19.4 | Excellent | 54.4 | Moderate | C | 0.5941 |
| 2 | 19.6 | Excellent | 222.2 | Unsuitable | E | 0.7626 |
| 3 | 19.5 | Excellent | 203.4 | Unsuitable | E | 0.7502 |
| 4 | 21.2 | Excellent | 29.8 | Good | B | 0.6477 |
| 5 | 15.9 | Excellent | 15.3 | Excellent | A | 0.6197 |
| 6 | 17.3 | Excellent | 28.4 | Good | B | 0.6009 |
| 7 | 16.3 | Excellent | 53.3 | Moderate | C | 0.5835 |
| 8 | 16.2 | Excellent | 53.2 | Moderate | C | 0.5824 |
| 9 | 16.3 | Excellent | 15.5 | Excellent | A | 0.6052 |
| 10 | 15.5 | Excellent | 27.9 | Good | B | 0.5957 |
| 11 | 16.3 | Excellent | 41.0 | Good | B | 0.5933 |
| 12 | 18.0 | Excellent | 41.4 | Good | B | 0.5974 |
| 13 | 16.1 | Excellent | 41.0 | Good | B | 0.5930 |
| 14 | 16.3 | Excellent | 28.3 | Good | B | 0.5998 |
| 15 | 15.8 | Excellent | 15.6 | Excellent | A | 0.6100 |

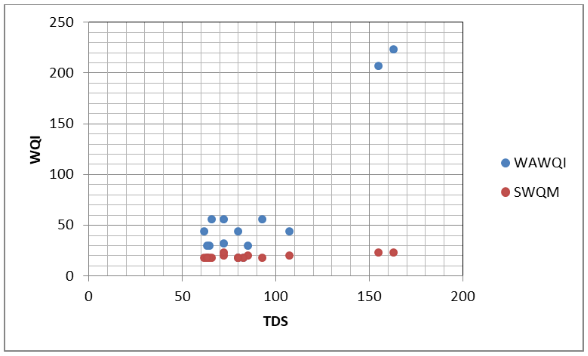

Figure (1): Groundwater TDS versus WQI.

## Conclusions

The aims of this study were to evaluate the groundwater quality status for drinking purpose in the municipality of Alghurayfah, Libya. Fifteen (15) water samples from different locations were collected and analyzed for various physico-chemical parameters. The analysis of water samples based on the WQI models (WAWQI and SWQM) revealed that the majority of the water samples were good to excellent for drinking purposes. Likewise, the SPI model indicated that all water samples were moderately polluted.

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