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Assessment of Groundwater Quality for Drinking Purpose in Tajura Municipality, Libya

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تقييم جودة المياه الجوفية لأغراض الشرب في بلدية تاجوراء، ليبيا

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Abstract:
Sustainable development in semi-arid and dry regions relies on maintaining freshwater resources, which necessitates thoughtful management of groundwater. This research was conducted to determine the suitability and quality of groundwater for drinking in several wells located in the Tajura area of Tripoli, Libya. Thirty samples were collected at three random intervals from the coast. Physical and chemical analyses were performed on these samples, using eleven key parameters to calculate water quality indicators. These parameters include pH, total dissolved solids (TDS), total hardness (TH), calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), bicarbonate (HCO_3^{-}), sulfate (SO_4^{--}), and nitrate (NO_3^{-}). The arithmetic water quality index (WAWQI) and the standard water quality model (SWQM) were used to assess the suitability of the groundwater for drinking in the study area. Most results indicated that the groundwater quality in this area is unsuitable for drinking and therefore cannot be used for direct consumption. One of the most significant factors affecting water quality is the proximity of well locations to the sea coast, as well as their location next to sewage disposal tanks.

Keywords: Water quality indicators, Groundwater quality, Drinking purpose, Tajura, Libya.

الملخص
تعتمد التنمية المستدامة في المناطق شبه القاحلة والجافة على الحفاظ على موارد المياه العذبة، مما يستلزم إدارةً حكيمةً للمياه الجوفية. أجري هذا البحث لتحديد صلاحية المياه الجوفية وجودتها للاستخدام كمياه للشرب في بعض الآبار الموجودة بمنطقة تاجوراء في مدينة طرابلس ليبيا. تم جمع ثلاثين عينة على أبعاد ثلاثة مختلفة من الساحل بتوزيع عشوائي. تم اجراءات التحاليل الفيزيائية والكيميائية لهذه العينات حيث اعتبرت إحدى عشرة مقياسا اساسيا لحساب مؤشرات جودة المياه. هذه المعايير شملت الرقم الهيدروجيني(pH) ، والمواد الصلبة الذائبة الكلية (TDS)، والعسر الكلي (TH)، والكالسيوم (Ca^{++})، والمغنيسيوم (Mg^{++})، والصوديوم (Na^{+})، والبوتاسيوم (K^{+})، والكلوريد (Cl^{-})، والبيكربونات (HCO_3^{-})، والكبريتات (SO_4^{--})، والنترات (NO_3^{-}). حيث استُخدم مؤشر جودة المياه الحسابي (WAWQI) ونموذج جودة المياه القياسي (SWQM) لتقييم مدى صلاحية المياه الجوفية للشرب في منطقة الدراسة. أظهرت معظم النتائج أن نوعية المياه الجوفية في هذه المنطقة تعتبر غير صالحة للشرب، وبالتالي لا يمكن استخدامها للاستهلاك المباشر. من أبرز

العوامل المؤثرة على جودة المياه هو قرب مواقع الآبار من ساحل البحر وكذلك وجودها بجوار خزانات مخصصة لتصريف مياه الصرف الصحي.

الكلمات المفتاحية: مؤشرات جودة المياه، جودة المياه الجوفية، أغراض الشرب، تاجوراء، ليبيا.

Introduction

Groundwater is the primary source of drinking and irrigation water in areas suffering from drought or semi-drought. The quality and quantity of groundwater depend mainly on the geological and geochemical characteristics of the soil and rocks. The chemical composition of groundwater on the other hand, is often heterogeneous and is affected by factors such as flow, geochemical processes, evaporation, and potential sources of pollution [1, 2].

Moreover, hydrogeological processes can play a role in preparing and preserving contaminated sites, in order to protect aquifers from pollution resulting from natural and human activities [3]. Understanding the geochemical processes that affect the chemical composition of groundwater is vital to understanding groundwater quality issues. Therefore, understanding the chemical properties of groundwater and the factors that influence them is crucial for the conservation and management of groundwater resources, and for their sustainable use. Using an effective method to evaluate drinking water quality is important to obtain reliable results, which facilitates sound decision-making [4].

The water quality indices (WQI) are effective tools for examining the suitability of drinking water for human use in an area, as well as for indicating the overall status of water quality [5]. These indicators typically rely on a variety of water quality parameters compared to local standards, to assess quality through a single numerical value. The water quality index is characterized by its ability to simplify large amounts of information into a single value, allowing the data to be presented in a simple and rational way. It combines information from multiple sources to create a comprehensive view of the status of the water system. As this helps enhance the understanding of policy makers and ordinary people, as individuals who use water resources, of the water quality issues being emphasized [6-11].

Thus, this study aims to evaluate the groundwater resources used for drinking purpose in Tajura-Libya, through the use of a weighted arithmetic water quality index (WAWQI) and the standard water quality model (SWQM).

Material and methods

The study area was conducted in the coastal municipality of Tajura, located in northern Libya. The investigated area extends approximately 10 kilometers along the shoreline (width) and 4.5 kilometers inland (length), parallel to the Mediterranean coast, Figure 1.

Figure 1: boundaries of the study area

Samples were systematically collected and categorized based on their increasing distance from the Mediterranean shoreline. The sampling zones were defined as follows:

- **Samples 1–10:** Located between 200 and 900 meters from the coast.
- **Samples 11–20:** Located between 900 and 2000 meters from the coast.
- **Samples 21–30:** Located between 2000 and 4000 meters from the coast.

The study area encompasses several local landmarks and localities, including Elatamana, Sidi Khelifa, Bilashhar, Alhmadie and Alandalse, as referenced in the accompanying map. The region is also in proximity to the National Heart Center, which serves as a key geographical reference point, Figure 2.

Figure 2: Location of the study area, showing the 30 sampled water wells in Tajura

Thirty samples of private well water located in the Tajura area at varying distances from the coast were collected and analyzed to assess their quality and suitability for consumption. Polyethylene bottles were used, and the wells were allowed to run for approximately five minutes to ensure stable conditions before sampling. The bottles were thoroughly cleaned and rinsed with the sample water before collection. Analysis was performed immediately after sample collection to avoid any changes that might affect the results. The following indicators were prepared for the analyses: phenolphthalein, Calcon, chromate, methyl orange, and EBT. The required solutions for the experiments were also prepared: buffer solution, 0.05N standard sodium chloride solution, 0.1N standard potassium chloride solution, 0.1N hydrochloric acid solution, 0.2M 5% barium chloride solution, 0.05N standard silver nitrate solution, 0.1N sodium hydroxide solution, and 0.02N standard EDTA solution.

As for the instruments used, a conductivity and total dissolved solids (TDS), a pH meter, an atomic emission spectrometer, a flame spectrometer, a combustion furnace, and a sensitive balance were employed. Water samples were analyzed to determine various drinking water parameters, including pH, TDS, electrical conductivity, cation concentrations (such as sodium, potassium, calcium, and magnesium), and anion concentrations (such as chloride, bicarbonate, sulfate, and nitrate). Using a flame spectrometer, the concentrations of sodium and potassium ions were measured. The total hardness of calcium and magnesium was determined by a complexity titration method using EDTA., while the concentrations of chloride and bicarbonate ions were measured by volumetric titration. The concentrations of sulfate ions were estimated by gravimetric analysis, and nitrate ions by UV spectroscopy. Salinity refers to the amount of total dissolved solids (TDS) in water, which is typically measured using electrical conductivity (EC), as water with higher TDS concentrations is a better conductor of electricity. The general equation used to calculate TDS as following [12].

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

The statistical parameters and the major ion-concentrations (mg/L) in capering with the Libyan standard [13], are tabulated in Table (1).

Table 1: *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	6.72	3028	420.1	784.9	13.4	36.9	1120.6	127.6	1597.5	1103.2	193.5
2	7.13	3283	653.9	492.7	14.5	11.0	259.9	114.4	1880.8	1700.5	142.4
3	7.02	2084	215.5	432.2	46.3	10.1	322.7	63.8	1061.0	731.6	81.1
4	6.97	8284	697.0	1415.1	26.7	11.0	534.9	83.6	3375.8	1851.1	498.0
5	7.08	10800	760.6	3031.9	288.5	74.3	619.3	189.2	6323.6	3100.8	716.2
6	7.45	4809	216.4	90.6	13.4	6.2	285.9	242.0	422.0	596.7	23.1
7	7.34	9983	759.0	1581.0	220.9	88.7	658.3	250.8	5256.6	2818.0	663.1
8	7.27	3153	339.5	724.4	9.2	103.1	749.3	215.6	1452.8	887.1	227.2

9	7.33	2424	307.1	784.9	20.3	9.1	387.6	132.0	1181.5	849.6	229.3
10	7.73	2455	395.7	482.6	9.6	12.0	632.3	88.0	1042.9	1029.0	245.7
11	7.38	1715	216.4	502.8	22.9	24.4	465.6	125.4	904.2	636.5	215.3
12	7.05	4912	774.9	764.7	48.7	52.3	684.3	6.6	2519.8	2137.5	346.6
13	6.77	3339	632.2	653.9	7.6	80.1	1037.3	46.2	1862.7	1615.1	106.6
14	7.33	4201	496.5	613.6	24.4	35.0	939.8	171.6	1398.5	1341.9	119.4
15	6.78	6752	757.4	1077.1	259.5	22.5	446.1	277.0	3954.5	2974.8	346.6
16	6.87	2995	595.1	543.1	8.3	77.2	1007.0	33.0	1597.5	1522.3	286.9
17	6.91	1421	219.6	381.8	25.8	43.6	576.0	83.6	614.9	655.0	232.6
18	7.6	3546	62.2	69.5	11.6	3.3	309.7	11.9	90.4	209.0	18.5
19	6.91	2978	540.0	522.9	13.4	44.6	725.4	143.0	1422.7	1410.9	192.6
20	6.86	5489	688.2	1097.3	22.2	23.5	751.4	180.4	2899.6	1817.0	278.2
21	7.25	1507	283.0	154.1	21.2	5.3	229.5	154.0	693.2	793.3	66.3
22	7.04	1578	307.6	174.3	4.5	6.2	298.8	134.2	735.4	787.6	52.7
23	7.68	1690	333.1	188.4	24.8	19.7	602.0	250.8	572.7	936.2	192.6
24	6.95	1080	736.5	885.7	104.2	38.8	582.5	154.0	2863.4	2275.3	239.6
25	7.98	607	149.6	68.5	19.1	3.3	437.4	116.6	186.9	453.5	17.7
26	7.42	1204	222.8	265.3	21.0	9.1	450.4	127.6	446.1	645.8	278.2
27	6.9	2272	569.2	191.4	21.2	21.6	749.3	6.6	771.6	1507.5	655.3
28	7.32	730	119.9	80.5	23.2	9.1	329.2	101.2	229.1	396.5	43.6
29	6.94	3011	545.1	452.4	31.8	12.0	398.5	277.0	1434.7	1495.4	190.6
30	6.96	3077	747.7	986.4	164.0	17.7	448.3	180.4	3399.9	2551.4	244.1

- **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 evaluate water quality through reducing numerous parameters into a simple mathematical expression and enabling easy interpretation of monitoring data [14]. Most of the models employed eight to eleven water quality parameters. In this study, eleven important parameters Table (1) were chosen to measure 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:

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

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 [18-22], 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]:

- Quality rating (Q_i) for each of the observed parameters was calculated using equation (6).

$$Q_i = \left[\frac{V_n}{S_s}\right] \cdot 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

- Relative weight (W_i) was computed using equation (7)

$$W_i = \frac{w_i}{\sum w_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

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).

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

Table 2: Rating of water quality according to WQI.

WQI_{WA}	Rating [16]		$SWQM$	Rating [19]
0 – 25	excellent		< 50	excellent
26 – 50	good		50 – <100	good
51 – 75	moderate		100 – < 200	poor
76 – 100	poor		200 – < 300	very poor
> 100	unsuitable		≥ 300	unfit

Results and discussion

The statistical summary of observed concentrations of various physicochemical parameters in the sampled groundwater with their standards is described in Table (1). Water samples collected from thirty (30) different locations in the municipality of Tajura Libya were tested to determine the Water quality. Different levels of water quality rating WQI_{WA} and $SWQM$ and their respective water quality condition were given in Table (2).

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 (3).

Standard 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 (3) presents analyzed physicochemical parameters and their respective assigned, the highest weight of 5 was assigned to nitrates and Potassium. 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 (6 and 7) respectively and summarized in Table (3).

Table 3: WQI Calculation for Well 1 as example.

Weighted arithmetic water quality index							Standard water quality model			
par.	S_n	V_n	W_n	Q_n	$W_n \cdot Q_n$		w_i	W_i	Q_i	$W_i \cdot Q_i$
pH	7.5	6.72	0.6253	56.00	35.018		3	0.0938	89.60	8.40
TDS	1000	3028.0	0.0047	302.80	1.420		3	0.0938	302.80	28.39
Ca^{++}	200	420.1	0.0234	210.04	4.925		3	0.0938	210.04	19.69
Na^{+}	200	784.9	0.0234	392.45	9.203		2	0.0625	392.45	24.53
Mg^{++}	150	13.4	0.0313	8.91	0.279		2	0.0625	8.91	0.56
K^{+}	40	36.9	0.1172	92.30	10.822		5	0.1563	92.30	14.42
HCO_3^-	200	1120.6	0.0234	560.32	13.139		1	0.0313	560.32	17.51
NO_3^-	45	127.6	0.1042	283.56	29.552		5	0.1563	283.56	44.31
Cl^-	250	1597.5	0.0188	638.99	11.987		3	0.0938	638.99	59.91
HD	500	1103.23	0.0188	77.38	1.452		2	0.0625	220.65	13.79
SO_4^{--}	250	193.5	0.0094	220.65	2.070		3	0.0938	77.38	7.25
WAWQI					119.9		SWQM			238.75

Analog calculations for all other wells, for both WAWQI and SWQM, are summarized in the Table (4) and depicted in Figures (3) and (4). The Analysis of drinking water quality using Weighted arithmetic water quality index (WAWQI) revealed that over 75% of samples were unsuitable for drinking, as concentration of the majortity of parameters exceeded permissible limits. The remaining samples fell within the moderate to poor water quality (51 - 100).

Analysis of the drinking water quality using the Standard water quality model (SWQI) revealed that 75% of the samples were of poor to very poor quality (100-300), while the remaining samples fell into the unfit for consumption category (>300).

Table 4: WQI Calculation for all Wells.

Well	SWQM	Rating		WAWQI	Rating	Grading
1	238.8	Very poor		119.9	Unsuitable	E
2	231.6	Very poor		92.3	Poor	D
3	136.9	Poor		47.6	Good	B
4	374.5	Unfit		104.8	Unsuitable	E
5	659.7	Unfit		214.5	Unsuitable	E
6	183.0	Poor		131.5	Unsuitable	E
7	586.2	Unfit		236.6	Unsuitable	E
8	278.5	Very poor		156.1	Unsuitable	E
9	190.6	Poor		110.4	Unsuitable	E
10	173.0	Poor		151.6	Unsuitable	E
11	162.4	Poor		112.1	Unsuitable	E
12	284.7	Very poor		90.0	Poor	D
13	247.7	Very poor		118.8	Unsuitable	E
14	253.6	Very poor		139.2	Unsuitable	E
15	462.2	Unfit		188.2	Unsuitable	E
16	228.9	Very poor		98.8	Poor	D
17	140.3	Poor		69.7	Moderate	C
18	65.3	Good		88.2	Poor	D
19	235.4	Very poor		102.8	Unsuitable	E
20	352.9	Unfit		136.4	Unsuitable	E
21	139.7	Poor		89.1	Poor	D
22	136.7	Poor		59.7	Moderate	C
23	192.5	Poor		176.1	Unsuitable	E
24	307.9	Unfit		122.2	Unsuitable	E
25	87.6	Good		163.9	Unsuitable	E
26	130.3	Poor		107.0	Unsuitable	E
27	158.2	Poor		61.6	Moderate	C
28	84.1	Good		78.2	Poor	D
29	264.6	Very poor		117.0	Unsuitable	E
30	355.4	Unfit		128.9	Unsuitable	E

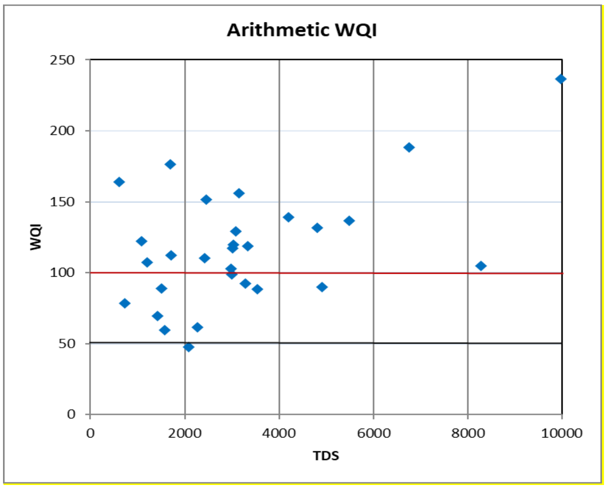

Figure 3: WAWQI Correlation of Groundwater TDS versus WQI.

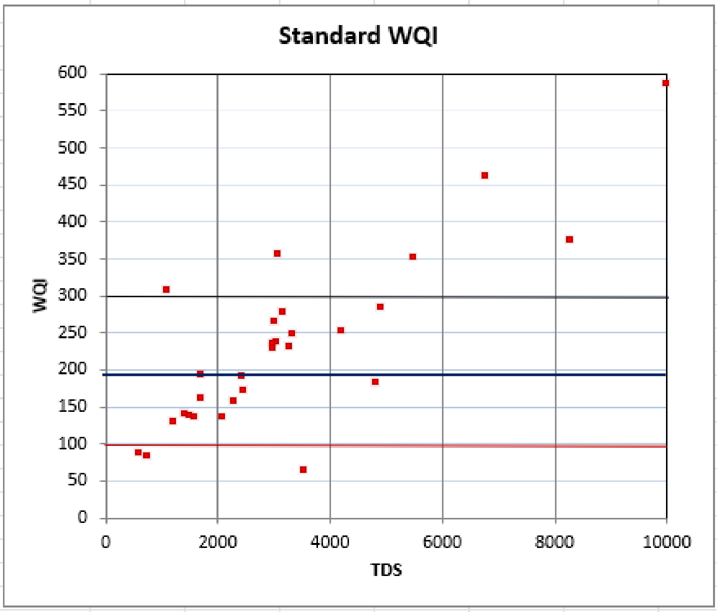

Figure 4: SWQM Co rrelation of Groundwater TDS versus WQI.

Conclusion

The groundwater quality in the municipality of Tajura, Libya, was evaluated for its chemical composition and suitability for drinking purposes using water quality indices (WAWQI and SWQM). A total of thirty (30) water samples were collected from various locations and analyzed for physico-chemical parameters. Analysis based on the applied WQI models revealed that the majority of the groundwater samples fell within the "very poor" to "unsuitable" categories for human consumption. Consequently, the water from the studied wells is deemed not suitable for drinking. The study further identified seawater intrusion as a significant factor adversely affecting groundwater quality. This phenomenon has a clear and substantial impact on elevating the concentrations of various chemical parameters and increasing salinity, particularly in wells located near the coast.

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