Original

Evaluation of Groundwater Quality Drinking Purposes using Water Quality Index: A Case Study at Abu Guta area, Gezira Scheme

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Abstract:

In this study, researchers delve into the assessment of groundwater quality for drinking purposes in the Abu Guta area within the Gezira Scheme. They shed light on the growing demand for water driven by population growth and economic development, underlining the crucial role of groundwater as the primary water source in the region, emphasizing its importance for sustaining life. The article emphasizes the significance of water quality assessment in determining its suitability for human consumption, taking into account both natural processes and human activities. To comprehensively evaluate water quality, the researchers employ the Water Quality Index (WQI), a tool that provides a holistic analysis based on various parameters and allows for comparisons against established guidelines.

The study meticulously outlines the methodology for calculating WQI scores, focusing on parameters like pH, chlorides, hardness, and conductivity, among others. Through rigorous sampling and laboratory analysis of water samples from 22 locations, the researchers uncover a spectrum of water quality ranging from poor to good for drinking purposes, with variations observed across different samples and seasons.

Key parameters influencing water quality, such as pH, hardness, and chloride levels, are identified and discussed in detail. While most parameters meet recommended standards, deviations are noted in certain samples, highlighting the need for continuous monitoring and management efforts to address water quality challenges effectively.

In essence, the study provides valuable insights into groundwater quality assessment using the WQI methodology, emphasizing the importance of ongoing monitoring and management practices to ensure a safe and sustainable drinking water supply in the region. Through their research, the authors advocate for a holistic approach to water management, underscoring the imperative of safeguarding this vital resource for present and future generations.

Keywords: Abu Guta region, Gezira aquifer, Gezira scheme, Water Quality Index.

1. Introduction

In addition to being essential to maintaining life on our planet, water is the foundation of all life. It is regarded as the most energetic solvent and a fantastic energy source for chemical reactions. In most nations throughout the world, water demands are rising at an alarming rate due to population growth and economic expansion, along with groundwater use, which is thought to be vital to human life[3]. The area's greatest source of fresh water is underground, and the only practical way to get it is through boring wells through the aquifer layer[4].

The quality of drinking water indicates water acceptability for human consumption. Water quality depends on water composition as influenced by natural processes and human activities. Water quality is characterized based on water parameters (physical, chemical, and microbiological), and human health is at risk if values exceed acceptable limits[1, 2].

The water Quality Index allows for a general analysis of water quality on many levels that affect a stream’s ability to host life and whether the overall quality of water bodies poses a potential threat to various uses of water within the average WQI.

Essentially the WQI is calculated by comparing the water quality data to "Guidelines for Canadian Drinking Water Quality". The WQI measures the scope, frequency, and amplitude of water quality exceedances and then combines the three measures into one score. This calculation produces a score between 0 and 100. The higher the score the better the quality of the water. The scores are then ranked into one of the five categories described as presented in Table (1).

Table (1): WQI ranking following Guidelines for Canadian Drinking Water Quality[6]

WQI rank	**Value**	**Description**
Excellent	95 - 100	Water quality is protected with a virtual absence of impairment; conditions are very close to pristine levels. These index values can only be obtained if all measurements meet recommended guidelines virtually all of the time.
Very Good	89 - 94	Water quality is protected with a slight presence of impairment; conditions are close to pristine levels.
Good	80 - 88	Water quality is protected with only a minor degree of impairment; conditions rarely depart from desirable levels.
Fair	65 - 79	Water quality is usually protected but occasionally impaired; conditions sometimes depart from desirable levels
Marginal	45 - 64	Water quality is frequently impaired; conditions often depart from desirable levels
Poor	0 - 44	Water quality is almost always impaired; conditions usually depart from desirable levels.

Water quality parameters must have a standard limit prescribed by WHO / BIS / ICMR.
Selection of the WQI method may follow any of the following:

Weighted Arithmetic index method (Brown et.al., 1972)

The Canadian council of ministers of the environment water quality index (CCME WQI)

National sanitation foundation water quality index (NSF WQI) and many more.

The following procedure outlines the calculation of the Weighted Arithmetic index method (Brown et.al., 1972)[7]:

Step 1: calculate the unit weight (Wn) factors for each parameter by using equation (1).

$$W_n = \frac{K}{Sn} \quad \text{..(1)}$$

$$K = \frac{1}{\frac{1}{S_1}+\frac{1}{S_2}+\frac{1}{S_3}\cdots\cdots\frac{1}{S_n}} = \frac{1}{\sum 1/S_n} \quad \text{.......(2)}$$

Where:

Sn = Standard desirable value of the nth parameters

On summation of all selected parameters unit weight factors Wn = 1 (unity)

Step 2: Calculate the sub-Index (Qn) value by using equation (3).

$$Q_n = \frac{[(V_n - V_0)]}{[(S_n - V_0)]} \times 100 \text{..........................(3)}$$

Where:

Vn = mean concentration of the nth parameters

Sn = standard desirable value of the nth parameters

V0 = Actual values of the parameters in pure water (V0 = 01 for most)

Parameters except for pH

$$Q_n = \frac{[(VpH - 7)]}{[(8.5 - 7)]} \times 100 \text{.....................(4)}$$

Step 3: combining steps 1 and step 2, WQI is calculated as presented in equation (5).

$$Overall\ WQI = \frac{\sum W_n Q_n}{\sum W_n} \text{....................(5)}$$

Table (2): Water quality index and quality of water[10]

Water quality index level	Water quality status
0 - 25	Excellent water quality
25 - 50	Good water quality
51 - 75	Poor water quality
76 - 100	Very poor water quality
> 100	Unsuitable for drinking

The main objective of this work is to measure water quality using a stochastic index built with tools of Probability Theory. Its great advantage is that it accounts for the underlying uncertainty in quality classification that results from variations in the data for individual physical and chemical characteristics, considering them as random variables. The results obtained by measuring water quality were compared with this index and a classical deterministic index (the general quality index, WHO)[5].

WQI scores are computed for each public water supply system that has been sampled in a sampling season. The same variables are used in the computation of the WQI for all public water supply systems and the nineparameters are used. However, if a public water supply system is on a Boil Water Order, it has a current contaminant exceedance or has a THMs average above the drinking water quality guideline a WQI score is not computed.

2. Materials and methods

2.1 Description of the study area

The study area is located in the west northern part of Gezira State, between latitudes 14o: 40′ - 150: 25′N and longitudes 320: 20′ - 33o: 18′ E, with an area of about 2890 square kilometers in an arid sub-Saharan region (See Figure 1).

The high salinity zone covers most of the area at the upper saturated zone within the upper Gezira aquifer as well as the lower Gezira aquifer. Fresh groundwater can only be exploited from the lower zone of the Cretaceous sedimentary formation in the study area.

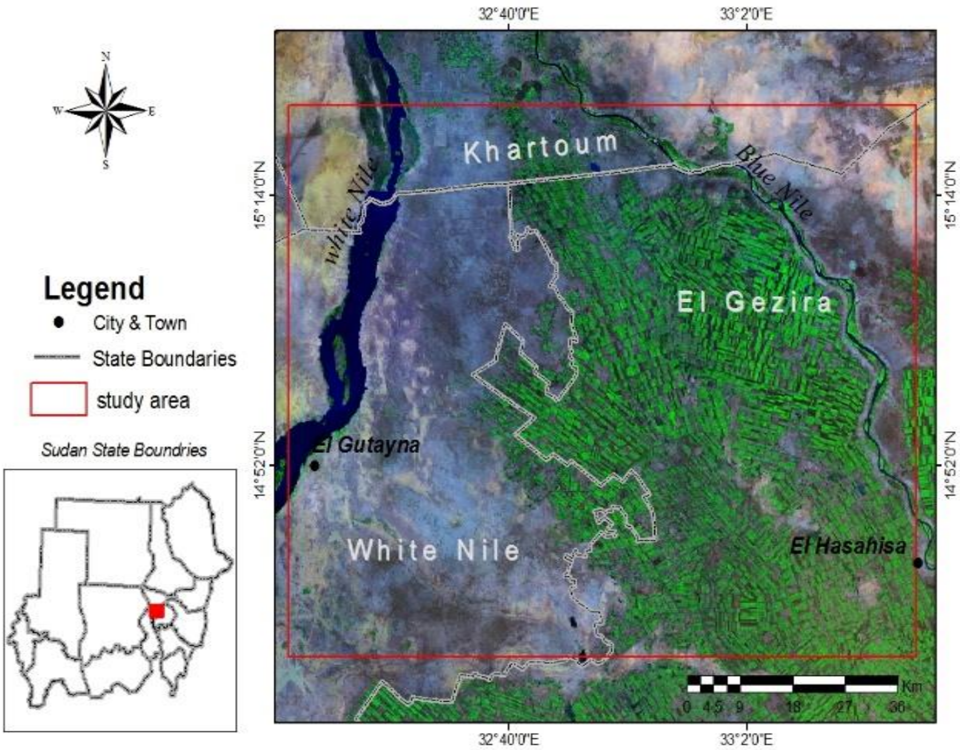

Figure (1): The study area.

Sampling and sample treatment

Water quality is monitored and assessed at numerous locations that represent the source. Water samples from 22 chosen study locations' groundwater aquifer sources were collected for laboratory investigation. Groundwater samples were handled with care to avoid cross-contamination by following procedures for equipment storage and transportation, not contaminating equipment or sample bottles on location, not handling bottles or equipment with contaminated hands or gloves, and thoroughly cleaning all non-disposable well purging or sampling devices. Tests were carried out following standard methods for the examination of water and wastewater[8].Results were obtained using protocols that are typically used in university laboratories to examine water and wastewater.

2.2 Experimental or theoretical investigations

Groundwater and canal water samples were collected from various sites in the Abu Guta area. All plastic and glassware used were pre-treated by washing with dilute HCl (0.05M) and then rinsed with distilled water. They were subsequently air-dried in a dust-free environment. At the collection point, containers were rinsed twice with the respective samples, filled, and tightly corked.

The key tests for water quality monitoring or quality control in small communities include microbiological quality assessment (measuring indicator bacteria), turbidity, free chlorine residual, and pH (especially in chlorinated water systems). These tests should be conducted with every sample, regardless of the number of other physical or chemical variables being measured. Figure (2) shows water samples and laboratory testing equipment used in the study.

a. Water samples

b. pH meter test

c. Palin test spectrophotometer

Figure (2): Instrumentation for Water Testing.

3. Results and Discussion

The results obtained for the WQI from the different sampling stations were found to vary from 36.785 to 70.3 for well sample water. The results indicate that the different water samples analyzed from ground well samples are of poor and good water quality for both human consumption and other domestic purposes. While the samples analyzed from canal water are of good water quality.

The above water quality index is supported by the following physicochemical parameters, namely pH, chlorides, total hardness, calcium, magnesium, electrical conductivity, total dissolved solids, degree of acidity, Nephelometric turbidity units, and calcium carbonate (See Figure 3). The variations of the above physicochemical parameters observed among the different water samples were all within the recommended standards.

Among all the physicochemical parameters selected for the WQI calculations, pH is an important parameter that determines the suitability of water for various purposes. In the present study, pH ranges from 7.17 to 8.30. For the entire well water, the borehole canal water sample was 7.82 analyzed respectively. This shows that the pH range obtained for the well water samples (7.17 to 8.30) was outside the recommended range of 6.50 to 8.50. High pH levels are undesirable since they may impart a bitter taste to the water.

Hardness is a measure of the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap solutions. The total hardness values of the present study were found to range between 32 to 214 but SO_3 was found to be 432 mg/l for the canal water was 136. As such, water samples were all within the recommended standards, except SO_3.

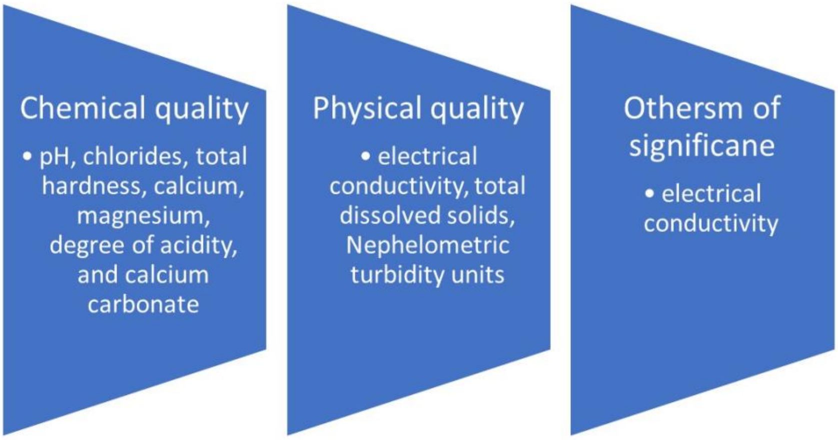

Figure (3): Parameters influencing WQI.

Magnesium is often associated with calcium in all kinds of water. In the present study, Mg ranges from 3.36 to 27.3for the well water, the borehole, and the canal water sample was 10.08. Even SO_3 was 72.4 among the different water, samples were all within the recommended standards.

The quantities of Calcium in natural water depend upon the type of rocks. In the present study, Ca ranges from 11.2 to 52 for the well water, and the borehole. The canal water sample was 37.6 among the different water, samples were all within the recommended standards.

The EC values recorded in drinking water than the chloride, no significant taste effects are detected below 300 mg/L. In the present study, EC ranges from 215 to 58z for the well water, borehole canal water sample was 467 among the different water samples some of them within the recommended standards.

Excess chloride in inland water is usually taken as the index of pollution. The Cl values recorded in drinking water taste effects are detected below 250 mg/L. In the present study, Cl ranges from 2 to 245 for the well water, borehole canal water sample was 11 among the different water samples all of them within the recommended standards.

The $CaCO_3$ values recorded in drinking water taste effects are detected below 305 mg/L. In the present study, $CaCO_3$ ranges from 74 to 190 for the well water, borehole canal water sample was 180 among the different water samples were all of them within the recommended standards.

The NTU values recorded in drinking water taste effects are detected below 5 units which are known as the Nephelometric Turbidity unit. In the present study, NTU ranges from 0.3 to 2.18 but so6 was 11 for the well water, borehole canal water sample was 0.36. Among the different water samples were all of them within the recommended standards.

The TDS values recorded in drinking water taste effects are detected below 500 mg/L. In the present study, TDE ranges from 122.1 to 460.35 for the well water, SO3 was 1161.1 borehole canal water sample was 256.8. Among the different water samples were some of them within the recommended standards.

Therefore, the observation that's found from a search such as the inaccurate time analysis for wells sample (per season, or year, even per 2 years) so means the well-used was open from drilling to infinity.

There was no fully accurate information or data at the Ministry of Irrigation and Electricity. There were a lot of wells made by donating firms and associates. A condition that yielded the data not being found in the ministry.

Table (4): The model of WQI parameters for Abu Guta region

Samples	**NTU**	**PH**	**EC**	**TDS**	**$CaCO_3$**	**Cl**	**Mg**	**Ca**	**T.H**	**WQI**
S01	0.23	8.31	837	460.35	190	44	7.2	29.6	104	38.48
S02	0.17	7.34	473	260.2	160	4	3.36	36	104	38.008
S03	0.3	7.61	2112	1161.6	164	245	72.4	52	432	3.4767
S04	34	7.58	552	303.6	140	27	10.56	26.4	110	64.22
S05	0.36	7.82	467	256.8	180	11	10.08	37.6	136	48.36

S06	11	7.9	501	275.5	74	2	6.72	27.2	96	55.22
S07	0.36	7.87	905	497.7	166	74	34.08	28.8	214	38.55
S08	0.29	7.95	434	238.7	140	7	7.2	14.4	66	43.96
S09	0.52	7.8	495	272.2	168	11	4.8	18.4	66	70.3
S10	0.39	7.66	488	268.4	122	40	12.96	11.2	82	44.78
S11	0.81	7.79	458	251.9	150	9	12.96	38.4	150	38.16
S12	0.33	7.17	222	122.1	190	22	18.29	33.4	160	45.5
S13	0.72	7.7	469	257.9	164	5	15.36	32	144	53.4
S14	2.18	7.88	458	251.9	160	10	1.56	10.2	32	40.13
S15	0.77	7.18	459	252.4	208	20	16.32	26.4	134	39.75
S16	0.32	8.1	459	252.4	158	14	8.16	13.6	68	86.8
S17	0.44	7.33	638	350.9	188	16	16.38	38.4	164	55.36
S18	0.32	8	215	118.25	140	16	12	24	110	47.83
S19	1.2	7.75	457	251.3	152	10	8.16	10.4	60	37.25
S20	0.6	7.55	581	319.5	200	17	15.36	25	128	41.19
S21	1.62	7.85	534	293.7	166	19	11.52	34.4	134	43.63
S22	0.83	7.78	446	245.3	145	11	27.3	17.6	158	36.785
Total	2.6255	7.7236	575.45	316.4818	160.23	28.82	15.1241	26.609	129.64	43.315

4. Conclusion

The following conclusion emerged from this research work:

- The water quality in the study region was typically moderate, according to the assessment results based on the water quality index (WQI), but there was a downward trend seen at the inter-annual scale. Seasonally, summer had the highest water quality while winter had the lowest.

- Local management organizations need to focus more on the concentrations of WQI-affecting parameters during monitoring schedules as well as during low-water periods, which show a rather poor state of water quality.
- However, the current study only employed monitoring data from one year, therefore it is important to look into how well they function in multi-year analysis.

Declaration of Competing Interest

The authors claim that they have no known financial conflicts of interest or close personal ties that would have appeared to affect the work described in this study.

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