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Water quality index of shallow groundwater and assessment for different usages in El-Obour city, Egypt

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Abstract

A lot of wells (about 846) were drilled in El-Obour city for gathering water and injecting it into Miocene aquifer as a solution for waterlogging problem, but this doesn't solve the problem. So, the main aim of this work is to find a safe solution for this problem through studying the possibility of using this water for drinking, agricultural and industrial uses. Forty-eight representative samples were collected from various locations and analyzed for physical and chemical characteristics. As well as the calculation of water quality index (WQI) by the analysis of twelve physicochemical parameters on the basis of Weighted Arithmetic Index. The results indicate that 54.2% of the samples according to WHO specification for drinking water can be used for drinking after physical simple treatment.The WQI showed that 44% of water samples are excellent and 15% are good for human consumption.The measured electric conductivity and calculated values for sodium absorption ratio (SAR), soluble sodium percentage (SSP) and Mg-hazard for most samples indicate well to permissible use of water for irrigation purposes. In addition, about 10%to 50% of samples can be used for paper, wood, canned and frozen fruits and vegetables, leather tanning and rubber industries according to every industrial application standard. Finally, the results indicate the possibility of using the studied water for different purposes in the study area and its surroundings after primary treatment.

1. Introduction

Water is the most precious gifts of nature and is absolutely vital for the life sustain. It becomes one of the most demands in recent years due to the population increase, intense agricultural, urbanization and industrialization activities. Water shortness and pollution become one of the most hazards facing Egypt in recent year [1, 2] owing to instructions of dams on the River Nile stream and over population. The disposal of chemicals and microbial waste and wastewater without proper treatment directly or indirectly into water resources led to the chemical and biological pollution [3- 5]. The degree of water quality is depending on the chemical, physical, and biological characteristics of water [6- 8]. Moreover, different uses need different criteria of water quality as well as standard methods for correlation of water analysis results [9].

The evaluation of water quality is essential to human life because it is one of the most important factors that influence human health [5, 7, 10, 11]. Water quality index is widely applied for assessing water suitability for drinking. It is integratinga large among of water physicochemical parameters into a single number and accordingly classified water into excellent, good, fair, marginal and poor water [12- 16]. The quality of soil and crops are related to the irrigation water quality, if the quality of irrigation water is unfit, the soil structure deteriorates and ultimately reduce crop yield [17, 18].

The study area is considered a newly constructed city in the north-eastern desert of Egypt, approximately 25 km from Cairo, located between latitudes 30° 09' 00" and 30° 17' 00"N and longitudes 31° 25' 00" and 31° 31' 30" E (Figure 1). The study area contains different activities; great residential, industrial and agricultural areas. The city covers almost 64.8 km^2 and is characterized by significant variations in topography and geology. These

variations play an important role in drainage of sewage and irrigation water from the elevated part of the city at 173 m (a.m.s.l) to the mainly sandy dune bed rock in the lower region at 30 m (a.m.s.l) elevation which led to arise of waterlogging problem [8, 19].
The government tried to solve the waterlogging problem in El-Obour city through drilling a lot of shallow and deep wells (846 wells), with depths varying from 3m up to 264 m. These wells were drilled for collecting water from the surface layer and were injected it into the underline Miocene aquifer [11, 20- 22] without any reference to their chemical or biological constituents. As a consequent of huge quantity of water, large number of wells was blocked up leading to the increase of water again [23- 25].
Urban and agricultural expansion in Egypt desert (For facing population growth and decreased food) requires an abundant amount of water for different uses like irrigation, drinking, domestic and industrial. The scope of the present study is the evaluation of water from the drilled wells (about 846 wells) in the El-Obour city for different uses to provide the adjacent area with their water needs.

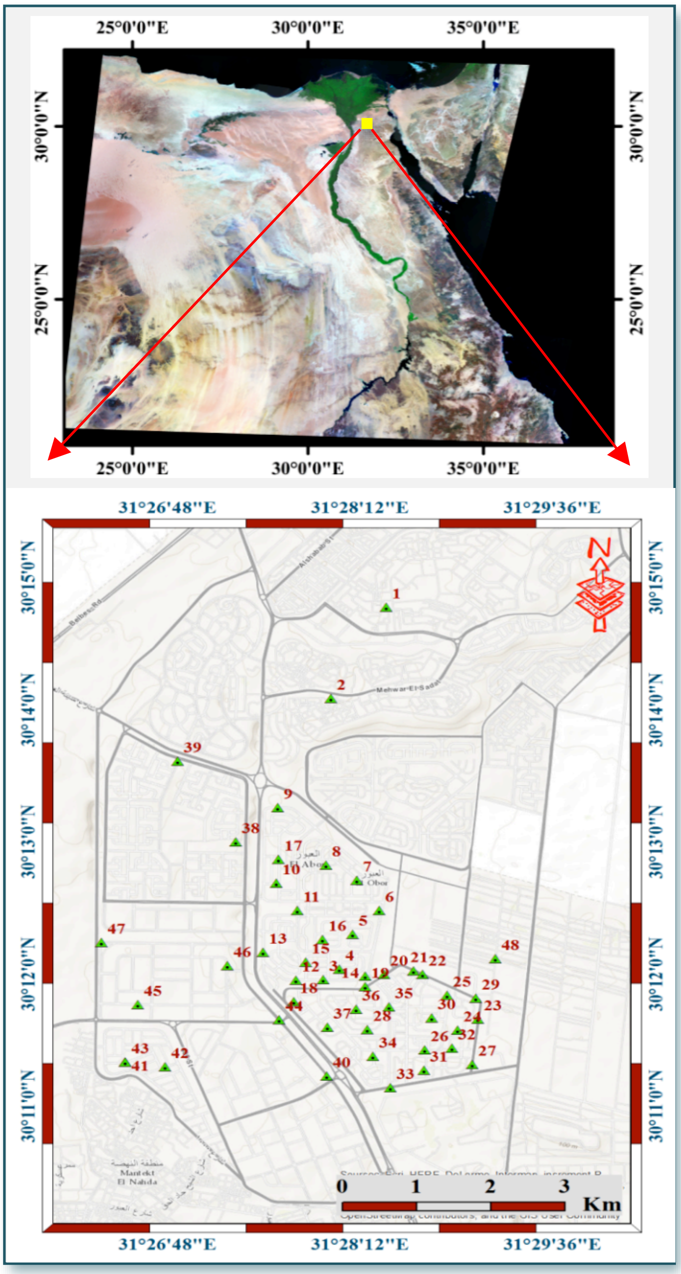

Figure 1: Location map of the collected water samples in the study area.

2. Material and Methods

2.1. Sampling and methods for physicochemical analysis

Water samples were collected from 48 boreholes inwinter of the year 2015 from different locations of El-Obour city (Figure 1). The samples were collected and put in well cleaned 1liter polythene bottles. The temperature (t°), hydrogen ion concentration (pH), Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were determined at the site with the help of digital HANNA pH meter (HI 991300) which was calibrated prior to taking of readings.

The samples were filtered and analyzed for chemical constituents by using standard procedures (APHA 2005) in the laboratory of geological sciences department, National Research Centre (NRC). Na^+ and K^+ were determined by flame photometer (Jenway PFP7), appropriate filters and standard curves. Total Hardness (TH) as $CaCO_3$, carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and chloride (Cl^-) were analyzed by volumetric methods. Sulfates (SO_4^{2-}) and nitrates (NO_3^-) were estimated by using the calorimetric technique. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined by using Atomic Absorption Spectrophotometer. The analytical precision for the measurements of ions was determined by the ionic balances, which was ±5.

2.2. Calculation of the Water Quality Index

The Canadian (CCME) Water Quality Index was used in the present study for evaluating quality of water for drinking [14, 26]. The (CCME WQI) was calculated according to the following equation:

$$WQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right)$$

Where, F_1 (**Scope**) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration (failed variables), relative to the total number of variables measured.

$$F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables} \right) \times 100$$

F_2**(Frequency)** represents the percentage of individual tests that do not meet objectives (failed test).

$$F_2 = \left(\frac{Number\ of\ failed\ testes}{Total\ number\ of\ testes} \right) \times 100$$

F_3 **(Amplitude)** represents the amount by which failed test values do not meet their objectives. F_3 is calculated in three steps. When the test value must not exceed the objective:

1- The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as follows

$$Excursion\ (i) = \left(\frac{Failed\ test\ value}{Objective} \right) - 1$$

2- The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or **nse**, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} excursion\ (i)}{Total\ number\ of\ testes}$$

3- F_3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (**nse**) to yield a range between 0 and 100.

$$F_3 = \frac{nse}{0.01 nse + 0.01}$$

The divisor **1.732** normalizes the resultant values to a range between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best" water quality [26].

Once the WQI value has been determined, water quality is ranked into five categories by [27]: WQI<45, poor quality; 45≤WQI<65, Marginal; 65≤WQI<80, Fair; 80≤WQI<95, Good; and WQI≥95, Excellent quality.

3. Results and discussion

Safe drinking water is an essential to human life. The WHO [28] specification for drinking water quality were used to study the suitability of analyzed water for drinking purposes in the study area. As well as the water quality index was calculated. The results of the physiochemical analysis of collected water samples and WHO [28] guidelines are presented in Table 1.

Table 1: Descriptive statistics of the physicochemical parameters, SAR, SSP and MH of water in El-Obour city compared with WHO [28] specification

Parameter	pH	TDS mg/l	EC µS/cm	TH mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^+ mg/l	k^+ mg/l	HCO_3^- mg/l	SO_4^{2-} mg/l	Cl^- mg/l	NO_3^- mg/l	SAR	SSP	MH
Mean	7.66	1148.6	2254.6	290.3	78.8	31.3	398.97	6.2	236.97	421.5	331.7	32.12	8.423	62.497	40.34
Median	7.60	656.4	1323.2	200.1	60	20	143.1	6.4	237.9	162.5	99.7	15.4	5.55	66.99	42.23
SD	0.45	1304.3	2565.9	238.9	67.1	28.6	597.5	3.3	57.4	541.99	708.2	59.8	8.657	17.456	13.25
Range	3.26	7557.8	14795.1	981.4	337.3	135	3611.9	14.5	290.7	2675	4579.3	346.5	47.63	72.02	67.89
Min.	6.97	280.4	574.8	62.3	5.4	5	30	0.55	79.3	25	26	0.00	0.742	19.347	14.15
Max.	10.23	7838.2	15369.8	1043.7	342.7	140	3641.9	15	370	2700	4605.3	346.5	48.37	91.36	82.04
Q1	7.49	420.6	822.7	125.6	32.2	15	79.8	3.9	204.2	50	56.8	3.8	2.546	49.295	29.05
Q3	7.81	1236.3	2357.8	339.7	99.5	42.5	462.5	8.5	273.6	618.5	294.5	25.3	12.36	74.918	47.05
WHO [28]	**6.5-8.5**	**1000**	**---**	**500**	**75**	**100**	**250**	**--**	**--**	**250**	**250**	**50**	**----**	**----**	**----**

SD: Standard Deviation Min: Minimum Max: Maximum Q1: 1st Quartile Q3: 3rd Quartile
EC: Electrical Conductivity TH: Total Hardness SAR: Sodium Absorption Ratio SSP: Soluble Sodium Percentage MH: Magnesium Hazard

3.1. Water geochemistry and suitability for drinking purpose

The pH values of the collected water samples are ranged from 6.97 to 10.23 with a mean value of 7.66, this indicating that the studied water is neutral to slightly alkaline in nature. According to the pH values all the samples are suitable for drink except one sample (No. 22) (Figure 2a). The electrical conductivity is ranged from 574.8 to 15369.8 µS/cm; around 75% of samples have EC ≤2357.8µS/cm. These variations in the EC are basically related to geochemical process such as reverse exchange, ion exchange, silicate weathering, evaporation, sulfate reduction-oxidation, rock water interaction processes and human activities [7, 29]. Total Dissolved Solids (TDS) in the study area is varied between 280.4 and 7838.2 mg/l with an average value of 1148.6 mg/l. The recorded high TDS values may be attributed to the leakage of wastewater and from rising water table close to the ground surface that suffered from dust fall and contact with surrounding. According to the WHO criteria, 18 samples are exceeding the safe limits for TDS (1000 mg/l) (Figure 2b).

Furthermore, the Total Hardness (TH) values are ranging between 62.3 and 1043.7 mg/l with a mean value of 290.3 (Table 1), which probably is due to the presence of $Ca^{2+}$and Mg^{2+} in the country rocks. Nearly all the samples (except six samples) are within the drinking permissible limit for TH (<500 mg/l) (Figure 2c).

The major cations; Ca^{2+}, Mg^{2+}, Na^+ and K^+ are flocculated around 78.8, 31.3, 398.97 and 6.2 mg/l; respectively (Table 1). The presence of cations in water is necessary in an adequate amount. Na^+ has a large variation in analyzed samples, where 22 water samples have inadequate levels of Na^+ ion in comparison with the WHO [28] specification for drinking water (Figure 2d). The high Na^+ concentrations make water unfit for human consumption [30] and may cause high blood pressure and hypertension for the human [31] as well as nausea, vomiting, convulsions, muscular twitching and rigidity, and cerebral and pulmonary oedema [32, 33]. About 17 water samples have inadequate levels of Ca^{2+} ion in comparison with WHO [28] specification for drinking water (Figure 2e). The main cause of Na^+ and Ca^{2+} ascending is the presence of halite and calcite, respectively in the current rock of the study area [8, 34]. Unlike Na^+ and Ca^{2+}, the concentration of $Mg^{2+}$is within the WHO [28] specification in the all samples except two samples (Nos. 1 and 10) (Figure 3a).

The major anions; Cl^-, SO_4^{2-} , HCO_3^- and NO_3^- are flocculated around 331.7, 421.5, 236.97 and 32.12 mg/l; respectively (Table 1). The CO_3^{2-} anion was absent in the all analyzed samples. The geochemical composition for analyzed water indicates a strong relation between the lithology and relative abundance of ions. Where, the dominance of Na^+ and Cl^- as well as Ca^{2+} and SO_4^{2-} ions in the water of the study area is related to leaching processes of highly soluble minerals salts such as halite and gypsum, respectively which are presented in the study area sediments [34, 35]. Water contains low concentrations of NO_3^-, 41 samples fall in the permissible limit of [28] (Figure 3b), but can reach to the high values due to leakage of wastewater and run off or leaching from farm lands [36]. High levels of NO_3^- can also be the cause of increased risk for respiratory tract infections and goiter development in children [37- 39]. In addition, NO_3^- has a significant influence on plant growth [40]. Also, more than 50% of samples contain suitable levels of Cl^- and SO_4^{2-} for drinking (Figures 3c, d). Drinking water with Cl^- content has a salty taste and a laxative effect [41] while, the excess of SO_4^{2-} probably causes diarrhea [42, 43].

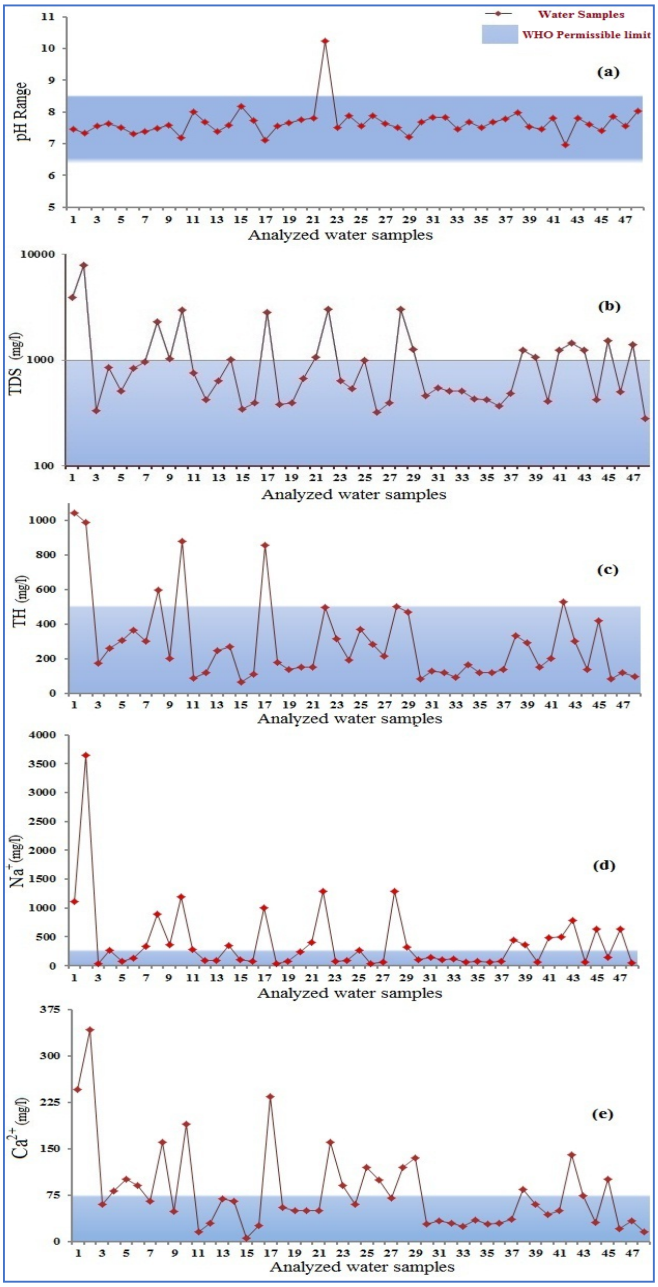

Figure 2: Comparison between WHO standard and [pH (a), TDS (b), TH(c), Na^+ (d) and Ca^{2+} (e)] values.

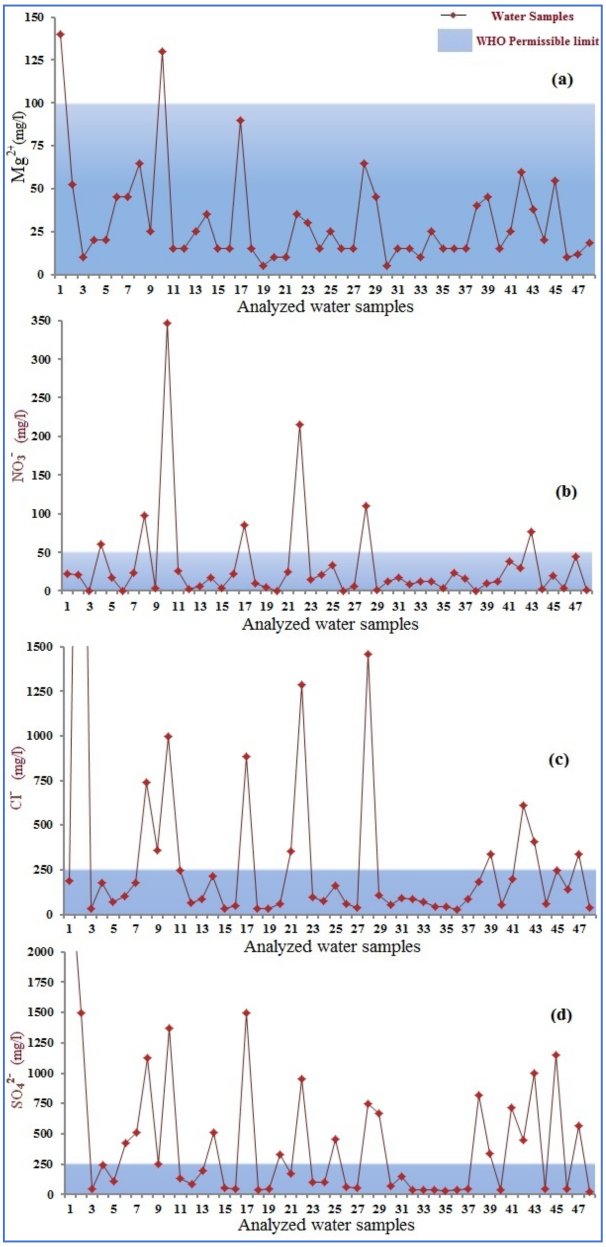

Figure 3: Comparison between WHO standard and [Mg^{2+} (a), NO_3^- (b), Cl^- (c) and SO_4^{2-} (d)] values.

3.2. Water Quality Index (WQI)

Water Quality Index is a good method that converts complex water parameters into a simple indicator of water quality by using twelve physicochemical parameters on the basis of Weighted Arithmetic Index method [16, 26]. Table (2) and Figure (4) illustrate the values of the WQI of water samples. The WQI for 48 samples ranges from 30 to 100. The calculated WQI indicates that the majority of water samples (44%) are excellent for human uses. Nearly 15% of the samples fall in good class of WQI; moreover, 21% of samples lie in fair water class. Approximately 8% of water samples fall in marginal class. Eventually, about 12% of samples lie in poor class. The decrease in WQI values indicates the pollution of water with the discharge of domestic and industrial waste water [44].

3.3. Hierarchial cluster analysis

Hierarchial Cluster Analysis (HCA) is commonly used to discriminate and interpret geochemical data in the environmental studies and to define and group variables [45, 46]. The resulting data were represented as a branching diagram called dendrogram that represents the relationships of similarity among group of samples.

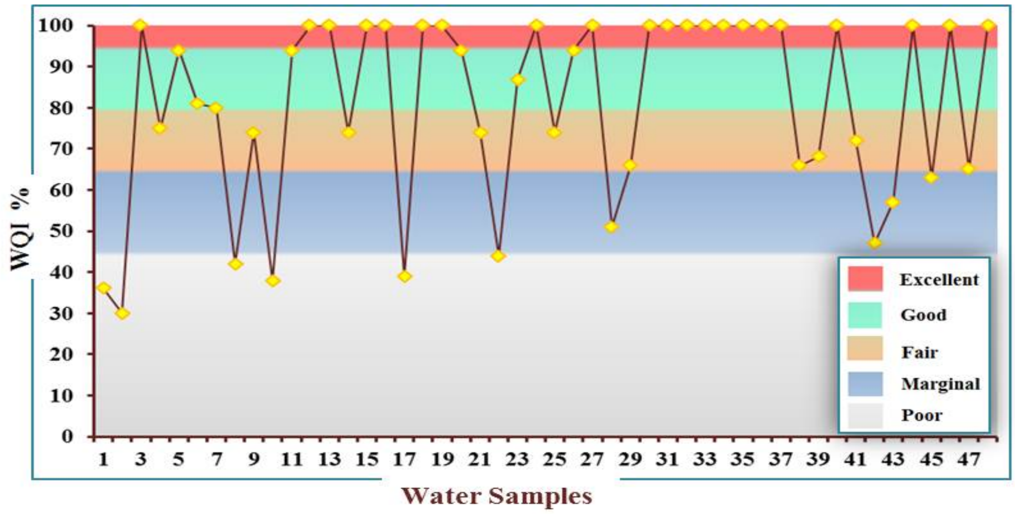

Figure 4: The quality of water according to WQI forthe studiedsamples.

This dendrogram (Figure 5) is based on Ward's method, shows a Euclidean distance of 25, indicating a fair degree of similarity between the analyzed samples, in which two clusters are existed.

Cluster A was subdivided into two sub-clusters (**A-I**) and (**A-II**). Sub-cluster (**A-I**) consists of TDS, EC, Na^+, Cl^- and NO_3^-. It indicates the main role of Na^+, Cl^- and NO_3^- in the high salinity, this is supported by the presence of halite in the lithology of the study area [8, 34, 35, 47]; in addition, the presence of NO_3^- reflects the effect of human activity as artificial factor. Sub-cluster (**A- II**) comprises Ca^{2+}, Mg^{2+}, SO_4^{2-} and TH, Ca^{2+} is strongly correlated with Mg^{2+} and altogether are linked with SO_4^{2-} reflect the role mineralogic sources, through dissolution of anhydrite and gypsum from source rock.

Cluster B was subdivided into two sub-clusters. Sub-cluster (**B-II**) includes the HCO_3^- and K^+, reflects the anthropogenic source (agricultural wastewater) [48]. While sub-cluster (**B-I**) reveals the strong relations between temperature and pH condition.

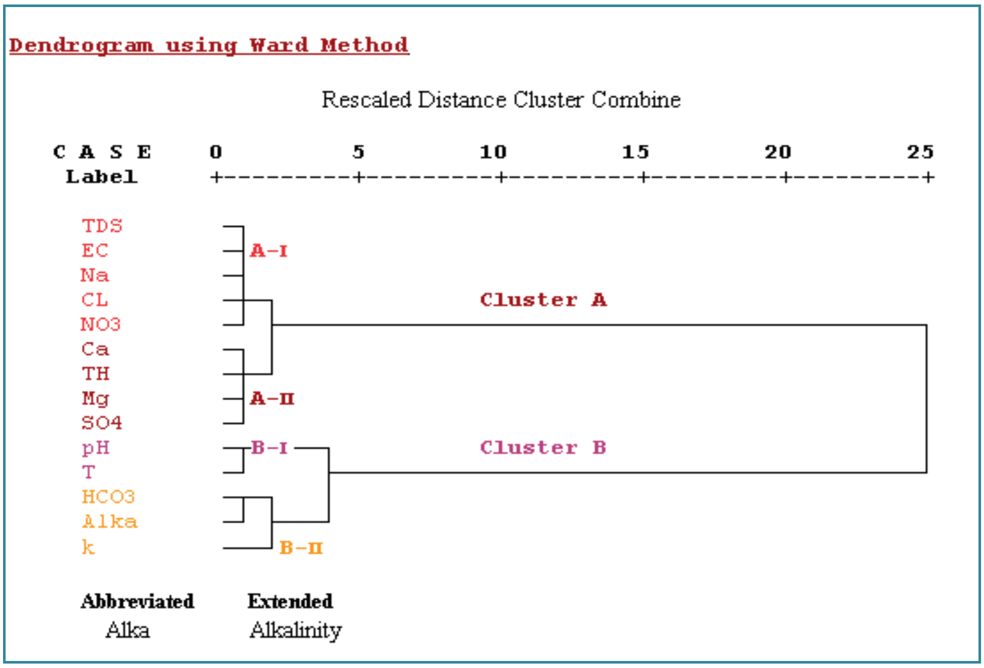

Figure 5: The HCA dendrogram diagram showing main clusters in the study area.

3.4. Evaluation of Water Quality for Irrigation

In order to evaluate the suitability of water for irrigation, the chemical analysis of water in El-Obour city has been recorded and evaluated. Evaluation of Water Quality for Irrigation depends upon many factors, including: Salinity, Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP) and Magnesium Hazard (MH).

Table 2: Quality of water samples relative to Water Quality Index (WQI) values.

Sample No.	WQI value	WQI Class	Sample No.	WQI value	WQI Class
1	36	Poor	**25**	74	Fair
2	30	Poor	**26**	94	Good
3	100	Excellent	**27**	100	Excellent
4	75	Fair	**28**	51	Marginal
5	94	Good	**29**	66	Fair
6	81	Good	**30**	100	Excellent
7	80	Good	**31**	100	Excellent
8	42	Poor	**32**	100	Excellent
9	74	Fair	**33**	100	Excellent
10	38	Poor	**34**	100	Excellent
11	94	Good	**35**	100	Excellent
12	100	Excellent	**36**	100	Excellent
13	100	Excellent	**37**	100	Excellent
14	74	Fair	**38**	66	Fair
15	100	Excellent	**39**	68	Fair
16	100	Excellent	**40**	100	Excellent
17	39	Poor water	**41**	72	Fair
18	100	Excellent	**42**	47	Marginal
19	100	Excellent	**43**	57	Marginal
20	94	Good	**44**	100	Excellent
21	74	Fair	**45**	63	Marginal
22	44	Poor	**46**	100	Excellent
23	87	Good	**47**	65	Fair
24	100	Excellent	**48**	100	Excellent

3.4.1. Water Salinity

To evaluate salinity of Water, Electric Conductivity has been measured. The build-up of salinity level in water has a negative effect on both the soil structure and crops grown on this soil, where the skyrocket of salinity in the irrigation water increases the osmotic pressure of the soil solution [17, 49].Richards [50] classified water suitability for irrigation depending upon EC into four classes (Table 3). 71% of the samples are allowable for irrigation with EC <2250 µS /cm. While the rest samples (29%) are unsuitable and need for a good soil permeability and certain type of plants.

3.4.2. Sodium Absorption ratio (SAR)

The sodium adsorption ratio parameter evaluates the sodium hazard in relation to the concentration of Ca^{2+} plus Mg^{2+} in irrigation water [51]. In fact, the high SAR leads to deterioration of physical properties of soil; hydraulic conductivity and clay swelling [52].Richards [50] calculated sodium adsorption ratio by the following formula (All values in meq/l):

$$SAR = Na^{+} \Big/ \left[\left(Ca^{2+} + Mg^{2+}\right)/2\right]^{1/2}$$

The determined value of SAR in the study area were ranged from 0.742 to 48.37 (Table 1). 68.75% (33 samples) of water samples have SAR value less than 10 score (S1 class) indicating an excellent quality for irrigation (Table 4) and can be used safely for all soil types. 20.83% (10 samples) of water samples are less than 18 (S2 class) indicating a good quality for irrigation. Only 8.32% (4 samples) of water samples are less than 26 (S3 class) indicating permissible for irrigation. Eventually one sample is greater than 26 (S4 class) indicating unsuitable for irrigation (Table 4).

The plot of data on U.S. Salinity laboratory classification diagram [50], in which water is classified based upon SAR as alkalinity hazard and EC as salinity hazard, the analyzed water samples (Figure 6) indicate that all samples fall in seven categories, 5 samples lie in the medium salinity and low alkalinity(C2-S1), it can be safely used for all crops; moreover, 18 samples fall in the field of high salinity and low sodium (C3-S1), it can be used in soil of medium texture [48]. On the other hand, 8 samples fall in category of high salinity and medium sodium (C3-S2), it can be used in soil of medium texture and high permeability; in addition, 3 samples fall in category of high salinity and high sodium (C3-S3), this water may be used for irrigation in some selected types of soils with some limitations [53]. Nevertheless, samples belonging to other categories are considered harmful and unsuitable for irrigation use [48, 52, 53, 54].

Table 3: Classification of groundwater samples for Irrigation use based on EC (After Richards [50])

EC µS /cm	Class	Samples
<250	Excellent (C1)	---
250 - 750	Good (C2)	3, 15, 26, 36 and 48.
750 - 2250	Permissible (C3)	4, 5, 6, 7, 9, 11, 12, 13, 14, 16, 18, 19, 20, 21, 23, 24, 25, 27, 30, 31, 32, 33, 34, 35, 37, 39, 40, 44 and 46.
>2250	Unsuitable (C4)	1, 2, 8, 10, 17, 22, 28, 29, 38, 41, 42, 43, 45 and 47.

Table 4: Classification of irrigation water based on SAR values, adapted to Richards [50]

Class	SAR Values	Quality	Samples
S1	0 - 10	Low sodium water	3, 4, 5, 6, 7, 12, 13, 14, 15, 16, 18, 19, 20, 23, 24, 25, 26, 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 39, 40, 42, 44, 46 and 48.
S2	10 - 18	Medium sodium water	1, 8, 9, 10, 11, 17, 21, 38, 41 and 45.
S3	18 - 26	High sodium water	22, 28, 43 and 47.
S4	>26	Very high salinity	2.

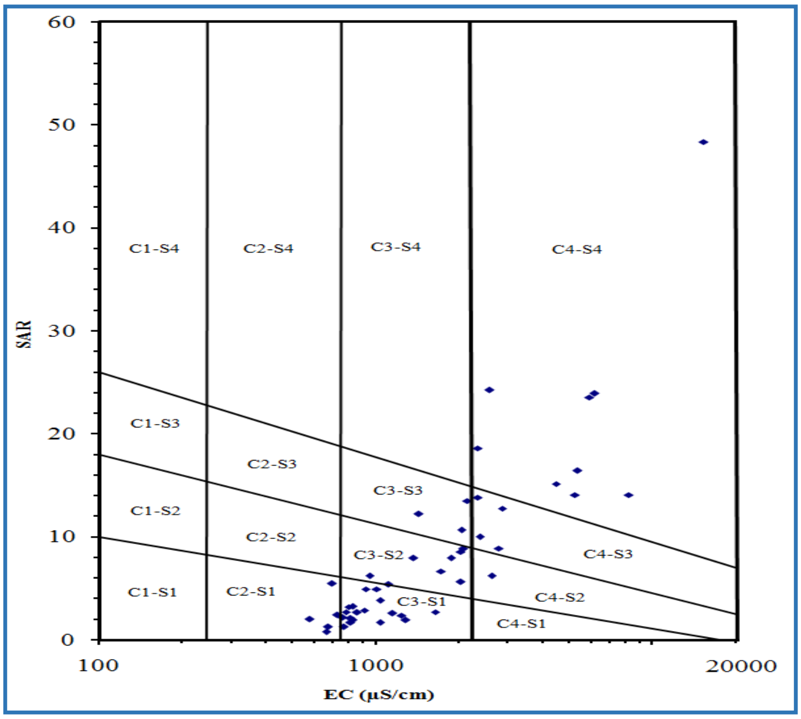

Figure 6: USSL diagram indicating the suitability of water for irrigation, according to Richards [50].

3.4.3. Soluble Sodium Percentage (SSP)

Soluble sodium percentage gives a clear idea about sodium content which is important for studying sodium hazard. High SSP probably hinders the growth of plants and reacts with soil to reduce its permeability [55].
SSP is estimated by using the following equation (All values in meq/l) [56]:

$$SSP = \left[100 \times \left(Na^{+} + K^{+}\right)\right] / \left(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}\right)$$

According to Todd [57] classification of the irrigation water based on SSP, 41.66% (20 samples) of water samples have SSP values less than 60 score indicating permissible irrigation water type (Table 5).
The Wilcox's diagram [56], in which EC is plotted against SSP, was established to evaluate suitability of water for irrigation (Figure 7). Accordingly, 58.3% (28 samples) of the studied samples were laid in fields which are considered as permissible water category for irrigation use. 27.1% (13 samples) of them were fallen in the field of doubtful to unsuitable water. Only 14.6 % of samples considered unsuitable for irrigation. This excess SSP causes osmotic effect on soil-plant system owing to the restriction of air and water circulation during wet conditions and such soils are usually hard when they are dry [58]. Also, excess Na^{+} in water combined with the carbonate forming alkali soil and the saline soil formed when combine with chloride [59].

Table 5: Classification of irrigation water based on SSP (After Todd [57]).

SSP	Class	Samples
<20	Excellent	26.
20 – 40	Good	3, 5, 18, 23 and 27.
40 – 60	Permissible	6, 12, 13, 19, 24, 25, 29, 34, 35, 36, 37, 40, 44 and 48.
60 – 80	Doubtful	1, 4, 7, 8, 9, 10, 14, 15, 16, 17, 20, 30, 31, 32, 33, 38, 39, 42, 45 and 46.
>80	Unsuitable	2, 11, 21, 22, 28, 41, 43 and 47.

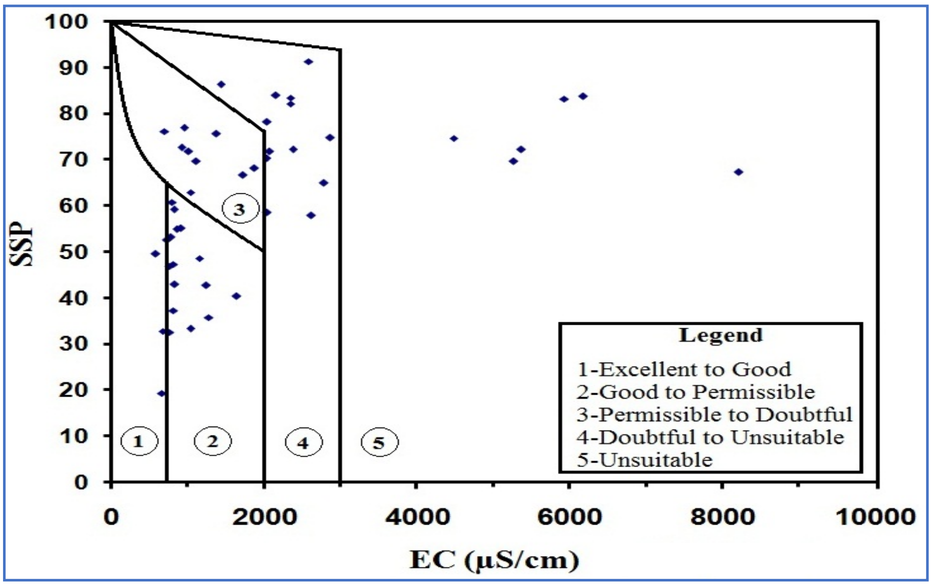

Figure 7: Suitability of groundwater for irrigation in Wilcox diagram.

3.4.4. Magnesium Hazard (MH)

Magnesium hazard is considered as one of the most important parameter in determining the suitability of water for irrigation purpose; moreover, it is necessary for plant growth; however, the high amounts of Mg^{2+} in water will adversely affect crop yields [55, 60, 61]. Magnesium hazard was calculated using the below formula, all values expressed in meq/l [62]:

$$MH = (Mg^{2+} \times 100) / (Ca^{2+} + Mg^{2+})$$

The MH values exceeding 50 are supposed to be harmful and unsuitable for irrigation uses [61, 63]. In the current study, Magnesium hazard ranges from 14.15 to 82.04 with a mean value of 40.34. Figure 8 illustrates that around 83% of water samples have MH below 50.

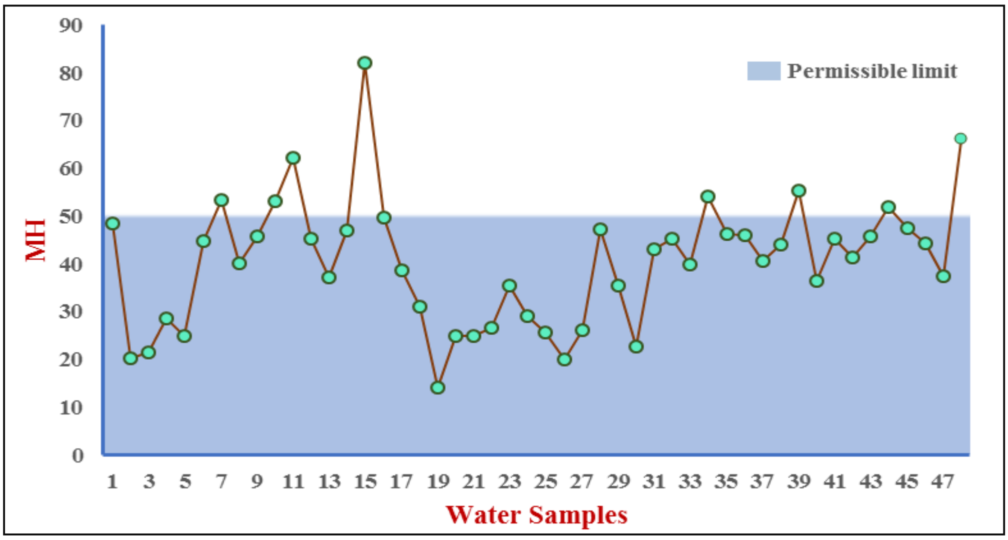

Figure 8: Water samples based on magnesium hazard(MH) values.

3.5. Evaluation of Water Suitability for industry

The quality requirements for industrial water supplies are ranged widely [64], and almost every industrial application has its own standards (Table 6). The quality of water that touches the product is very important. Where, impurities in the water for some uses would seriously affect the quality of the product. The industrial expansion in the study area needs huge amount of water. As a consequent of water shortage, the search about new water resources is vital.

After comparing the parameters of samples with industrial standards given in Table 6, only 10% of the studied samples are suitable for paper industry (Figure 9a). However, 50% of the studied samples are considered as suitable for rubber industry (Figure 9b). Wood chemicals diagram illustrates that approximately 28% of the water samples are suitable (Figure 9c). In addition, canned and frozen fruits diagram shows that nearly 34% of the water samples are permissible (Figure 9d); moreover, approximately 50% of the water samples are acceptable for leather tanning industry (Figure 9e).

Table 6: Industrial water-quality requirements, adapted to Hem [64].

Constituent	Paper	Wood chemicals	Synthetic rubber	Canned and frozen fruits and vegetables	Leather tanning
pH	6-10	6.5-8	6.2-8.3	6.5-8.5	6-8
TDS mg/l	--	1000	--	500	--
Hardness as $CaCO_3$ mg/l	100	900	350	250	--
Ca^{2+} mg/l	20	100	80	--	--
Mg^{2+} mg/l	12	50	36	--	--
HCO_3^- mg/l	--	250	--	--	--
NO_3^- mg/l	--	5	--	10	--
Cl^- mg/l	200	500	--	250	250
SO_4^{2-} mg/l	--	100	--	250	250

Note: The absence values in table 6 indicates either that no limit for the constituent or that the constituent can't attain objectionable levels if the water meets the other specifications

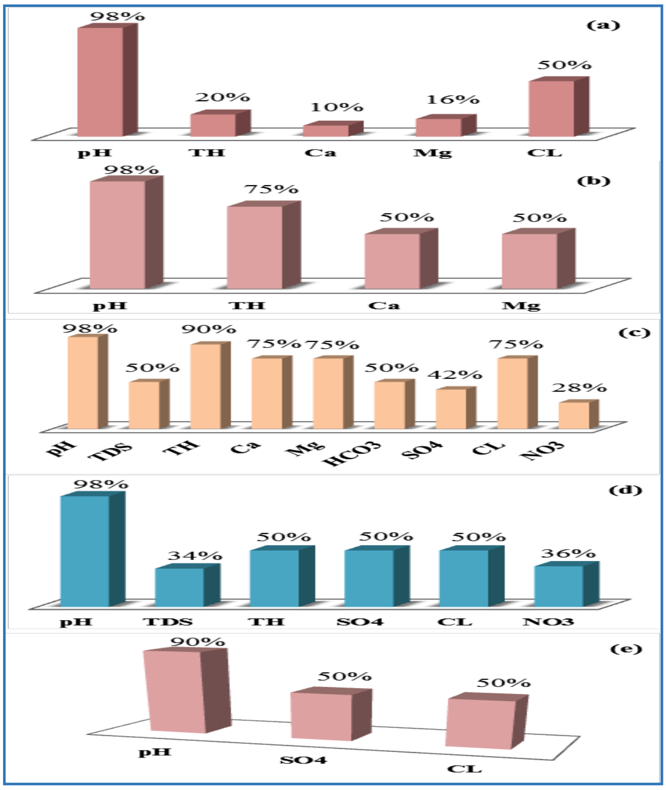

Figure 9: Percentage of parameters which suitable for paper (a), rubber (b), wood (c), canned (d) and leather (e) industries.

Conclusion

As a result of this study, it is found that the studied water is neutral to slightly alkaline in nature. Sodium and sulfate are the main ions constituents of examined wells as a result of dissolution of current rock and human activity. The calculated WQI and comparing with the WHO specification indicates the suitability of more than 50% of the studied samples for drinking. The degradation of water quality in some samples may be resulted from the leakage of irrigation and industrial waste water. The injection of this water into the underline Miocene aquifer could lead to diverse impact on its quality. In addition, SAR, SSP, and MH values indicate that most of the water samples are suitable for irrigation purposes. Analyzed water samples for some industries showed significant variations of percentages from 10 percentup to 50 percent according to every industrial application standard. The results revealed that all the studied water samples can be used for different purposes instead of injection into the underline aquifer.

Thus, the present results play an important role to determine water quality and it can help the local authorities to take an action in term of remediation purposes.

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