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Using Hydrogeochemical and Geographic Information System Methods as an Environmental Approach for Evaluating of Coastal Aquifers in West Northern Coast of Egypt

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The objective of the current investigation is to get sufficient understanding of the groundwater's geochemical peculiarities and its quality at the area of Egypt's coastline in the northwest. 14 Samples of groundwater have been gathered from 14 wells in various sections of the investigation region, and examined. The pH level within the samples of groundwater reflecting slightly alkaline nature while salinity varies widely from slightly, moderately to very saline water. The spatial distributions of the major ions, except HCO_3^- demonstrate an overall increase in the center of the region being researched while HCO_3^- increases in the direction of the northwest (Ghemama area). The major cations in the samples of groundwater decrease in the following order: $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ while the major anions following order: $Cl^- > SO_4^{2-} > HCO_3^-$. The spatial distribution of studied heavy metals decrease toward center of the area being researched and slightly increase toward east, and west which could be brought on by local human influence. The heavy metals that were examined for the samples of groundwater can be ordered as follow, Zn > Ba > As > Pb > Ni > Cd > Co > Mn > Cr > Cu. Based on Piper and Schoeller diagram, the samples of groundwater reflect the marine origin. An evaluation quality of the water for the purposes of irrigation and drinking reveals that the samples of groundwater in the research region are not appropriate for irrigation and drinking. Where the concentrations of Cd, Pb and As in the samples of groundwater reveal higher values than those advised by Egyptian and Worldwide Health Organization. Those increased concentrations may be attributed to agrochemical effects and human activities in the research area.

Keywords: Health risk assessment, Groundwater quality, Heavy metals, Drinking water, Irrigation parameter.

1. Introduction

Groundwater is the principal source for locations that are dry and semi-dry for household, industrial, and agricultural uses (Wu et al. 2017). It is used to produce about 40% of the food and 30% of the drinkable water (Amiri et al. 2021; Nickson et al. 2005). Aquifer sediments and water feeding channels are the primary variables influencing the quality of groundwater (Kohlhepp et al. 2017; Liu et al. 2017; Gu et al. 2017; Kumar et al. 2019). As a result of the increasing population in this region, a wide variety of anthropogenic activities, including transportation networks, residential domestic waste, and sewage sludge effluents originating from within or from nearby urban areas potentially toxic elements are being dispersed in groundwater. When groundwater moves from recharge to discharge locations, its physical and chemical specifications are altered, which could make the water unfit for irrigation and drinking (Abd El-Aziz 2017; Dehnavi et al. 2011; Farid et al. 2017; Ali et al. 2018). Contamination of groundwater by heavy metals may be brought on by human influence like mining and industry (Zhao et al. 2021; Wang et al. 2021; Li et al. 2021). For Egypt's Northwestern region, groundwater is the principal exporter of water for consumption and cultivation. It is the natural supply required in this region for almost any type of development. Egyptian coastline's northwest is planned to host many industrial and developmental projects such as seaports on the

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Mediterranean Sea and the setting up nuclear power plant (NPP) to generate electricity. Moreover, it is considered to have been among Egypt's greatest important recreational sites, so the evaluation groundwater quality and its convenience for different purposes is of crucial importance for the sustainable development of the area. Therefore, this work objective is to assess the groundwater's geochemical properties and its content of some heavy metals in order to assess its quality and the associated health risks

2. Materials and Methods

2.1 Study area and geologic setting

The investigation region is situated northwest of the Egyptian coastline between latitudes 30° 50' - 31° 05' N and longitude 28° 20' - 28° 35' E. It is roughly 200 km2 area and is bordered in the north with the Mediterranean Sea, in the south by the Qattara Depression and Limestone Plateau, in the east is Alexandria town and in the west is Marsa Matrouh town (Fig. 1). The area has semi-arid climate, which features long, hot, rainless summers and short, rainy winters (about 140 mm/year). The region also has high rates of evaporation (2.7 - 5.9 mm/day), with highest and lowest air temperatures of approximately 27°C and 21°C, respectively (Monged et al., 2020). The region is characterized morphologically by a plain of the seashore in the north and four separate parallel limestone ridges rising to 100 m above sea level to the south. This ridges are separated by long depressions which included of Sabkha and alluvial deposits, as well as lagoonal deposits. Many studies have looked into the geology of the study area such as Shukri et al., 1955; Said, 1962, 1990; Abu El-Ella 1987, 1992; Abd El-Khalek, 1992; El-Asmar and Wood, 2000; Yousif et al., 2016). Ages of the sedimentary units that cover it range from the Miocene to the Quaternary. The Miocene can be divided into middle and lower. The middle Miocene is represented by Marmarica Formation which composed of limestone, dolomitic limestone and shale sequence, while the Lower Miocene is defined by Moghra Formation that consist of clastic fluvio-marine deposits which experienced lateral shift to the true fluviatile red beds of Gebel Khesheb in the south and to the marine Mamura Formation in the north and west (Said, 1990). The Quaternary is divided into Holocene, Pleistocene and Plio-Pleistocene deposits. The Holocene consists of beach, aeolian, coastal sabkha and alluvial or loam deposits (Fig. 2) (El-Bayoum, 2009). The Pleistocene deposits is represented by oolitic gravelly limestone while Plio-Pleistocene is defined by Kalakh Formation which consists mainly of Limestone and chalky limestone.

2.2 Sample collection and analysis

Fourteen wells were sampled (Fig. 2), an electric line sounder was utilized to define the depths to water. GPS devices were utilized to determine the groundwater sample locations, and map of the sampling sites was then formed utilized the ArcGIS 10.5 software program. One-liter bottle were used to collect the sample which was then divided in half. The initial sample without adding nitric acid for measuring the concentrations of main cations and anions. The second sample was prepared by adding nitric acid (1%), acidified to determining the concentrations heavy metal. The pH value was measured in field using pH meter. The chemical analyses of the samples of groundwater that were gathered were examined in the laboratory of national center for isotopes and elements analysis at Egyptian Atomic Energy Authority. The major cations and anions elements analysis include (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-}) while the heavy metal analysis includes (Cd, Co, Cu, Zn, Pb, Mn, Ni, As, Ba and Cr). Titration used to estimate CO_3^{2-}, HCO_3^{-} and Cl^{-}. Atomic Absorption Spectroscopy were used to analyze the major cations (e.g. Na^{+}, Ca^{2+}, Mg^{2+} and K^{+}) while inductively coupled plasma mass spectrometry (ICP-MS) was utilized to define the heavy metal. Several indices were utilized to evaluation the quality of the groundwater. The results have been compared to Egyptian drinking water quality requirements (EWQS, 2007) and Worldwide Health Organization standards (WHO 2017). The formulae in Table (1) were utilized to calculate of characteristics the quality of irrigation water, including total dissolved solids (TDS), sodium absorption ratio (SAR), and chloride content (Cl). Piper (1953), Schoeller diagram (1962) and US salinity diagram 1954 are applied in this investigation to recognize the properties of groundwater and its appropriate to various purposes (He and Li 2020). Water quality indices such as Contamination Degree (Cd), Heavy metal pollution and Heavy metal evaluation (HEI) were utilized to determine the groundwater pollution and calculated using the equations in Table (1).

3. Results and Discussions

3.1 Hydrochemical characteristics

Table (2) provides a summary of the minimum, maximum, average, and standard deviation results for the physical and chemical characteristics of the groundwater samples.

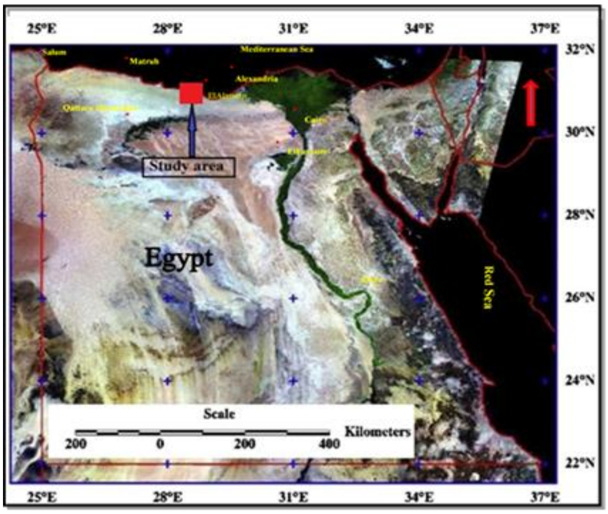


Fig. 1. Location map of the study area.

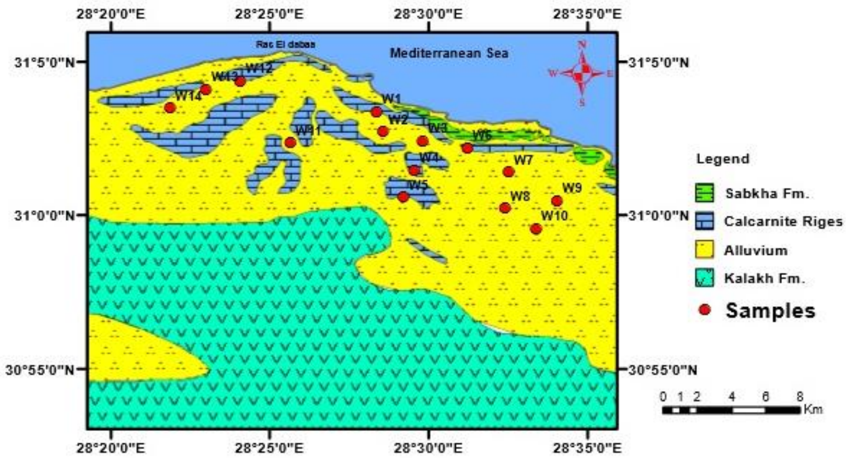


Fig. 2. Geological map and location samples of groundwater in the research area (Egyptian geological survey, 1986).

Table 1. Equations for estimating water contamination and the quality of irrigation.

Item	Equations	References	Used
SAR	SAR= $Na^+/((1/2(Ca^{2+} + Mg^{2+}))^{1/2}$	**U.S salinity laboratory (1954)**	Irrigation Water Quality
CD	$C_d \sum_{i=1}^{n} C_{fi}$	**Backman et al. 1998**	Water pollution
HPI	$\mathrm{HPI} = \frac{\sum_{i=1}^{i=n} (Q_i \times W_i)}{\sum_{i=1}^{i=n} W_i}$	**Mohan et al. 1996**	Water pollution
HEI	$HEI = \sum_{i=1}^{n} H_c/H_{mac}$	**Edet and Offiong 2002**	Water pollution

The physical parameters (pH, TDS and TH) of samples of groundwater ranging from 7.1-7.9 for pH with an average 7.4, 2265-30270 ppm for TDS with an average 14203 ppm, 610-6080 ppm for TH with an average 2809 ppm. The pH contents of the samples of groundwater reflecting slightly alkaline water while salinity is changes widely from slightly, moderately to very saline water types based on categorization of Robinove et.al. (1958). From the iso-salinity contour map (Fig. 3) where apparent that, the salinity of the groundwater increases toward the north and central portions of the research area and decrease toward east (Ghazhla area) and west direction (Gemma area) to indicates that, increasing the salinity of the samples of groundwater in the research region perhaps attributed to seawater intrusion and leaching and dissolution processes of the aquifer limestone during the groundwater flow. The values of the major cations Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} range from 111-928 , 28–988, 625–9311, and 31–216 ppm with an average values of 478, 389, 4158 and 90.2 ppm, respectively. On the other hand, the concentrations of major anions such as HCO_3^{-}, Cl^{-}, and SO_4^{2-} found between 64 and 805 ppm, 880 and 16000 ppm and 220 and 3790 ppm with an average values of 255, 6781 and 1981 ppm respectively. The order of the principal cations in the groundwater samples is $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$ and the order of the anions is $Cl^{-} > SO_4^{2-} > HCO_3^{-}$.The high amounts of Na^{+} and Cl- suggest that seawater intrusion may have had an impact on the groundwater samples in the research area. The spatial distributions for major elements except HCO_3^{-} (Fig. 3) demonstrate an overall increase toward the central portions of the research area while HCO_3^{-} increases toward northwest direction (Ghemama area). Increasing the major elements toward the central part referred to seawater intrusion and calcite, dolomite leaching processes as well as sulphate leaching (gypsum and anhydrite) which influence the geochemistry of the groundwater through its flow path. Increases HCO_3^{-} toward northwest direction (Ghemama area) my ascribed to the relative higher rainfall in this region than the others. The levels of heavy metals in groundwater; Cd, Co, Cu, Zn, Pb, Mn, Ni, As, Ba and Cr varies from 0.04-0.05, 0.04-0.05, 0.004-0.03, 0.04-0.26, 0.04-0.12, 0.01-0.19, 0.04-0.09, 0.005-0.28, 0.1-0.25 and 0.02-0.03 ppm, respectively. The examined heavy metals can be ordered in the samples of groundwater as the following Zn > Ba > As > Pb > Ni > Cd > Co > Mn > Cr > Cu. Fig (4) illustrates the spatial distribution of the studied elements which shows decrease toward center portions of the research area and slightly increase toward east, and west which may be could be brought on by local human influence.

3.2 Hydrogeochemical facies

To evaluate the hydrochemical properties of the samples of groundwater in the research area, Piper, 1953 and Schoeller, 1962 diagrams were used. The Piper trilinear diagram is composed of three separated fields; two triangular fields, one at the lower left side and other at lower right side. The two triangular fields are combined to show an intervening in a diamond-shaped field which divided into 9 sub areas (Fig.5). The representation of the groundwater chemical analyses on piper diagram gives an indicator about the type and genesis of the groundwater. From the plotted results shown in (Fig. 6). It reveals that, the groundwater samples for research area occupy the upper right side of the diamond figure (sub-areas7) (Table 3), 'which apparent that chemical characteristics of groundwater samples are mostly prevalent by the primary salinity and distinguished by non-carbonate alkalis above 50%, meaning that alkalis and strong acids predominate in these characteristics and by $SO_4^{2-} + Cl^{-} > Na^{+} + k^{+}$, showing that salts in the water bearing deposits and seawater intrusion have the greatest impact on the chemical composition and water quality. According to Schoeller diagram, the predominant cation is sodium in all samples of groundwater, while chlorides are the predominant anion in all of them, which reflects the marine origin of the groundwater in the study area (Fig. 7).

3.3 Evaluation of water quality

3.3.1 Drinking water quality

Table (4) reveals that TDS and Major ions content exceed the WHO (2017) and EHCW (2007) maximum permissible level that recommended for water of drinking. These elements directly affect people's health where if drinking water contains toxic salts and/or ions, it can cause laxative or constipation problems, coronary heart disease, arteriosclerotic heart disease, cardiovascular disease, gallbladder inflammation and gallstones, cancer, and mortality. It is also harmful to kidney patients and heart disease sufferers (WHO 2017 and Sasikaran etal. 2012). Heavy metals such as Co, Cu, Zn, Mn, Ni, Ba and Cr show concentrations lower than Maximum permissible limit recommended for water of drinking.

Table 2. Physical and chemical characteristic of the samples of groundwater (ppm).

Parameter	Min*	Max**	Ave***	SD****
pH	7.1	7.9	7.4	0.27
TDS	2265	30270	14203	10539
TH	610	6080	2809	1965
Ca	111	928	478	290
Mg	28	988	389	327
Na	625	9311	4158	3208
K	31	216	90.28	56
Cl	880	16000	6781	5539
SO_4	220	3790	1918	1286
HCO_3	64	805	255	243
Cd	0.04	0.05	0.04	0.002
Co	0.04	0.05	0.04	0.003
Cu	0.004	0.03	0.01	0.008
Zn	0.04	0.26	0.17	0.06
Pb	0.04	0.12	0.07	0.02
Mn	0.01	0.19	0.03	0.05
Ni	0.04	0.09	0.07	0.01
As	0.005	0.28	0.11	0.08
Ba	0.1	0.25	0.16	0.041
Cr	0.025	0.039	0.03	0.004

*= Minimum, ** = Maximum, *** = Average, **** = Stander deviation

Table 3. Groundwater quality type for Sub-areas of diamond-shaped field of Piper Trilinear Diagram (Piper, 1953).

Sub-areas	**Description**	**Well No.**
S1	alkaline earths (Ca, Mg) exceed alkalies (Na, K)	------
S2	Alkalies are superior to alkaline earths.	------
S3	Weak acids (HCO_3, CO_3) overtake potent acids (SO_4 , Cl)	------
S4	potent acids overtake weak acids	------
S5	The groundwater's chemical characteristics are prevalent by alkaline earths and low acids, with hardness of carbonate (secondary alkalinity) exceeds 50%.	------
S6	More than 50% of noncarbonate's hardness (secondary salinity)	------
S7	noncarbonate alkali (primary salinity) overtake 50% - where alkalies and potent acids prevalent the chemical qualities here, along with ocean water and several brines, which are located close to the right-hand vertex.	W1-W14
S8	Greater than 50% in terms of carbonate alkali (primary alkalinity). Plot the groundwater that is excessively soft in relation to its concentration of dissolved solids here.	------
S9	No single cation-anion pair has a greater percentage than 50%.	------

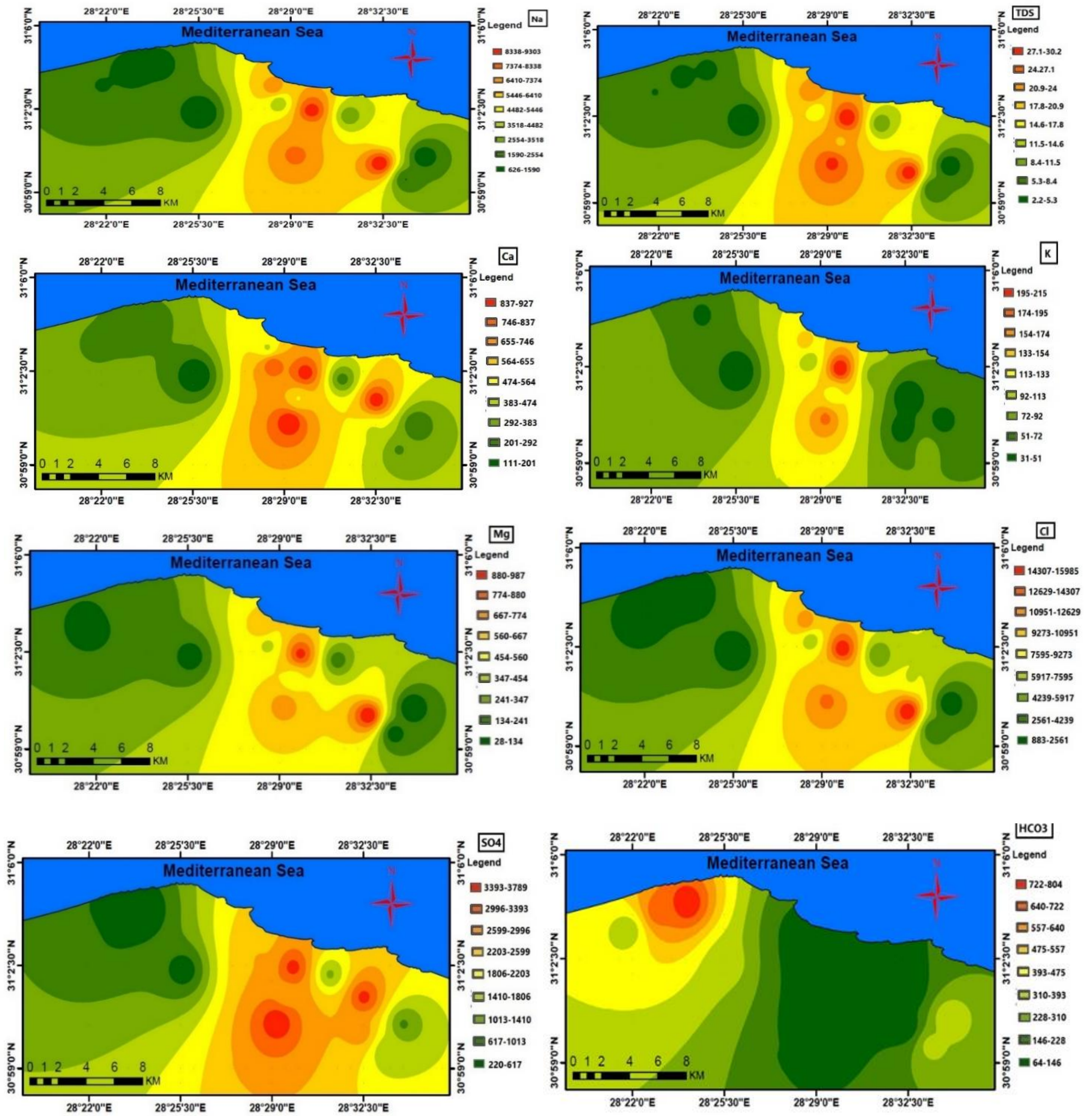


Fig. 3. TDS and major elements distributions in the research area.

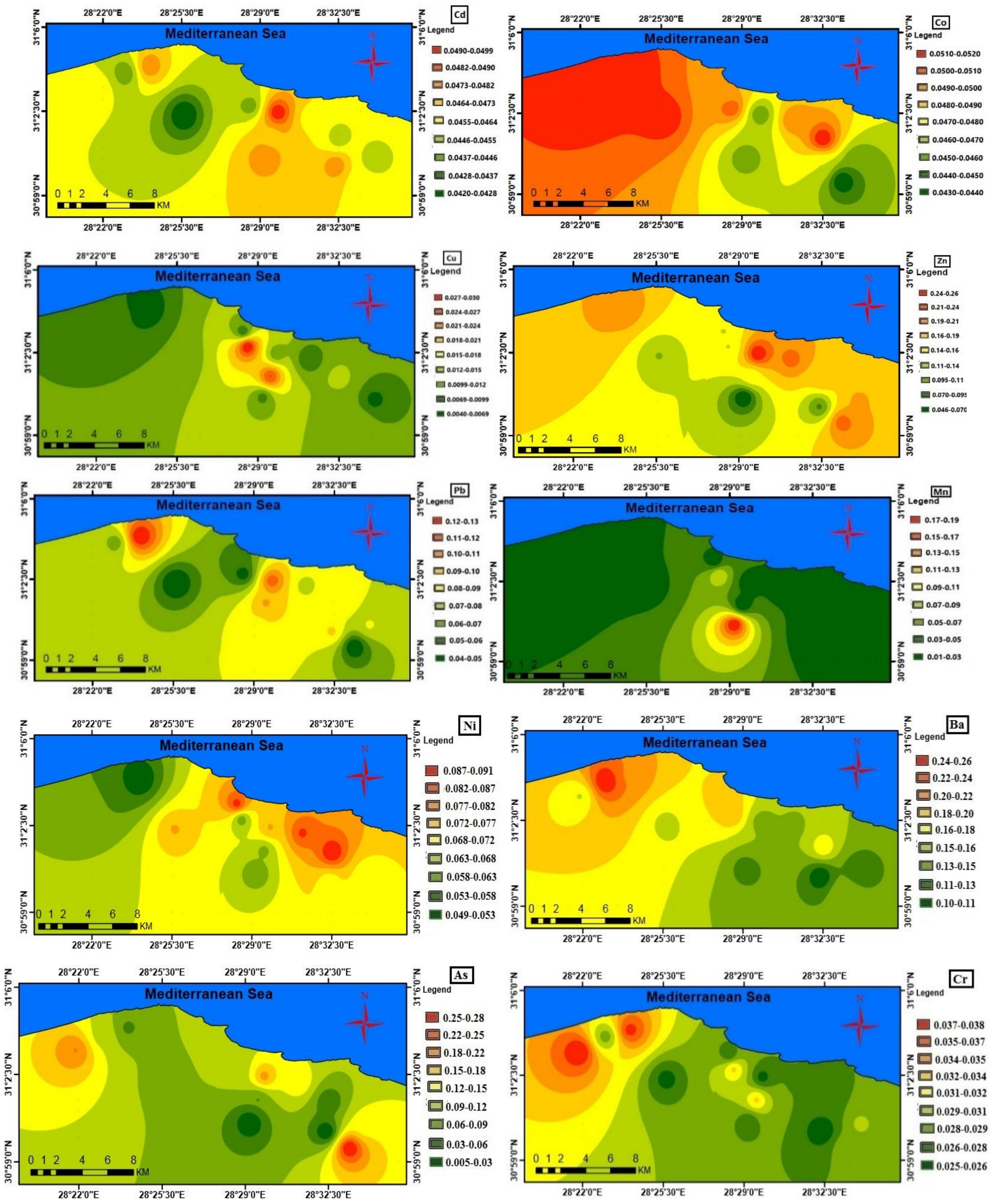
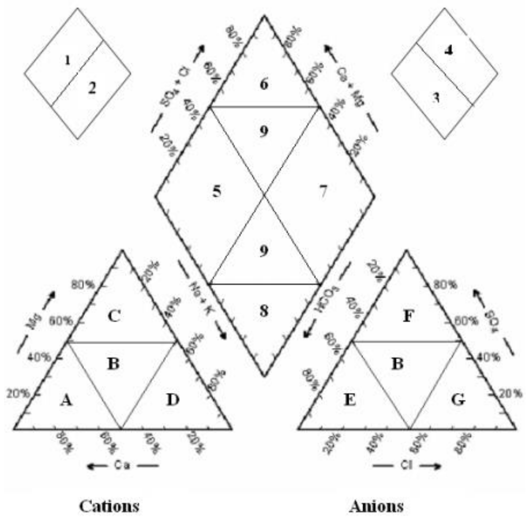


Fig. 4. Spatial distributions of the heavy metals in the research area.



Legend

A- Calcium type, B-No Dominant type,C- Magnesium type, D- Sodium and potassium type, E- Bicarbonate type, F- Sulphate type, G- Chloride type.

Fig. 5. Classification diagram for anion and cation facies in the form of major-ion percentages (Piper, 1953).

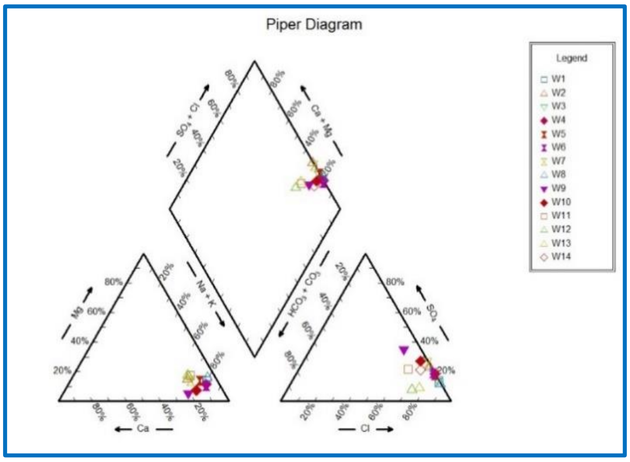


Fig. 6. Piper Trilinear diagram for samples of groundwater in the research area.

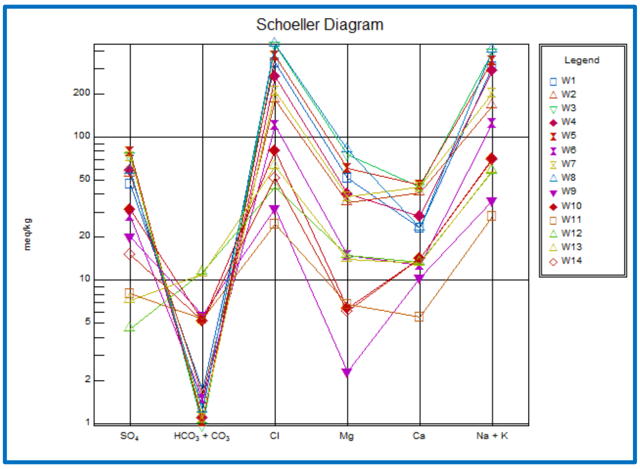


Fig. 7. Schoeller graph for samples of groundwater in the research area.

These elements under these concentrations possess none directly affect people's health. On the other hand, Cd, Pb and As have a direct impact on human health where recorded values higher than Maximum permissible limit recommended for water of drinking. Increased levels of cadmium, lead, and arsenic in water of drinking can result in number of health issues for people, including hyper and hypopigmented cutaneous lesions, lung and bladder cancer, peripheral vascular disease, peripheral neuropathy, and skin cancer. (WHO, 2017).

3.3.2. Irrigation water quality

Three parameters are primarily to be taken into account in controlling the water quality assessment for irrigation are: total dissolved salts (TDS), sodium adsorption ratio (SAR), and chloride content (Cl). High salt content in water makes soil and plant growth less effective. The amount of salts that plants can ingest is nearly all influenced by type of plant and soil in addition, the simplicity of drainage. The total dissolved solids (T.D.S.) should not generally exceed 1000 ppm, but it have been found that this limit does not hold good when salts are present in the form of carbonates and bicarbonates (Singh and Shawla, 1946). The U.S. Salinity Laboratory divides groundwater for appropriate irrigation into five groups based on TDS (Table 5). It is shows that groundwater samples lie in group 4 and 5. This group is typically not suited for irrigation; to forbid severe salinity, a plant with a high tolerance to salt must be chosen, and periodic leaching must be performed. Sodium adsorption ratio (SAR) is frequently utilized to gauge a water's appropriateness for irrigation. High levels of (SAR) point to a risk of sodium replacing the absorption of calcium and magnesium, which damages the soil structure (Srinivas et al. 2017 and Singh 2018). In the samples under study, the content of sodium adsorption ratio ranges between 10.92 (well No. 11) and 56 (well No. 8) with an average of 31.49 (Table 6). Every sample shows greater values than allowed limits (< 10). Generally, the SAR increases toward the El-Dabaa City (Fig. 8). According to U.S. Salinity Laboratory Classification (Fig. 9) and (Table 7): the wells No. 1, 2, 3, 4, 5, 6, 7 and 8 falling in C5-S4 zone with Excessive salinity and very high sodium. Most soils are generally not appropriate for irrigation with this kind of water, which also requires considerable leaching and particular soil management. Moreover, wells No. 10 and 14 falling in C5-S3 zone with excessive salinity and high sodium. The results indicated that, the water in the research area was not appropriate for irrigation under normal situations but may be used on occasion in extremely rare situations. Permeable soil is a requirement, the drainage system to be appropriate, irrigation to be supplied excessively to produce significant leaching, and the use of crops with high salt tolerance. The wells No. 9, 11, 12 and 13 falling in the zone of C4-S2 with very high salinity and medium sodium. This type of water is suitable for crops that can tolerate salt and soils with good permeability and special leaching. Beside the TDS and SAR, chloride level (Cl) is an essential consideration when determining whether groundwater is appropriate for irrigation proposes. The chloride content for the samples of groundwater that were examined range from 880 to 16000 to classify all studied wells (except well No.11) are found within the class IV >1000 where indicate highly undesirable for irrigation water (Table 8).

3.4. Assessment of water Pollution

Contamination Degree (CD), Heavy Metal Pollution Index (HPI), and Heavy Metal Evaluation Index (HEI) are used to calculate the degree of pollution in the samples of water. The contamination degree (CD) of the samples of groundwater in the research area are found between 18.11 and 40.60 with an average of 27.25 (Table 9). The CD content for samples of groundwater are exceed 3 which indicate that water is highly polluted (Table 9). The heavy metal pollution (HPI) for samples of groundwater show values ranged between 1022.7 and 1492.4 with an average of 1210.3 (Table 9). It is shows that HPI for all the samples are higher than 100 (Table 9), thus indicating that samples of groundwater are high polluted. The heavy metal evaluation index values (HEI) varied from 50.60 to 28.11 with an average of 37.25 (Table 9). According to classified in table 11, to confirm the samples of groundwater higher than 20. It is clear that the water falls within high heavy metals. The high pollution is related to pollution of samples of groundwater by Cd, Pb and As which due to agrochemical effects and human activity in the research area.

Table 4. Permissible limit with World Health Organization and Egyptian drinking water quality standards for Major and heavy metal of groundwater samples (ppm).

Parameter	WHO (2017) World Health Organization standards	EWQS (2007) Egyptian drinking water quality standards	Groundwater Samples		
			Min	Max	Average
pH	6.5-8.5	6.5-8.5	7.1	7.9	0.27
TDS	1000	1000	2265	30270	10539
Ca	75	75	111	928	290
Mg	100	50	28	988	327
Na	250	200	625	9311	3208
K	10	10	31	216	56
Cl	250	250	880	16000	5539
SO_4	250	250	220	3790	1286
HCO_3	250	200	64	805	243
Cd	0.003	0.003	0.04	0.05	0.002
Co	0.08	1	0.04	0.05	0.003
Cu	2	2	0.004	0.03	0.008
Zn	3	3	0.04	0.26	0.06
Pb	0.01	0.01	0.04	0.12	0.02
Mn	0.4	0.1	0.01	0.19	0.05
Ni	0.07	0.02	0.04	0.09	0.01
As	0.01	0.01	0.005	0.28	0.08
Ba	0.7	0.7	0.1	0.25	0.041
Cr	0.05	0.05	0.025	0.039	0.004

Table 5. Groundwater classification for irrigation, based on TDS (U.S. Salinity Laboratory 1954).

Class	TDS (ppm)	Quality	Usage	Wells
C1	<200	water is low salinity	**May be utilized for irrigation with the majority of crops when soil salinity is most likely to occur.**	----
C2	200-500	water is medium salinity	**May be applied in cases of mild leaching.**	----
C3	500-1500	water is high salinity	**May not be utilized on soil with poor drainage, even when drainage is adequate; additional salinity control measures may be required, and plants with high salt tolerance should be used.**	----
C4	1500-3000	water is very high salinity	**Do not be appropriate for irrigation under normal circumstances, but it may be utilized periodically under unique circumstances, in which the soil must be permeable, the drainage system must be sufficient, and irrigation must be applied in an amount that causes considerable leaching.**	**9,11**
C5	>3000	Excessive saline	**It is typically not appropriate for irrigation; to avoid major salinity, it is necessary to frequently leach the soil and choose plants with high salt tolerance.**	**1,2,3,4,5,6 7,8,10,14**

Table 6. Results of Sodium Adsorption Ratio (SAR).

Wells	SAR	Wells	SAR
W1	49.84	W8	56.02
W2	26.47	W9	13.83
W3	50.48	W10	21.33
W4	49.73	W11	10.92
W5	46.42	W12	15.03
W6	32.98	W13	15.36
W7	31.18	W14	21.37

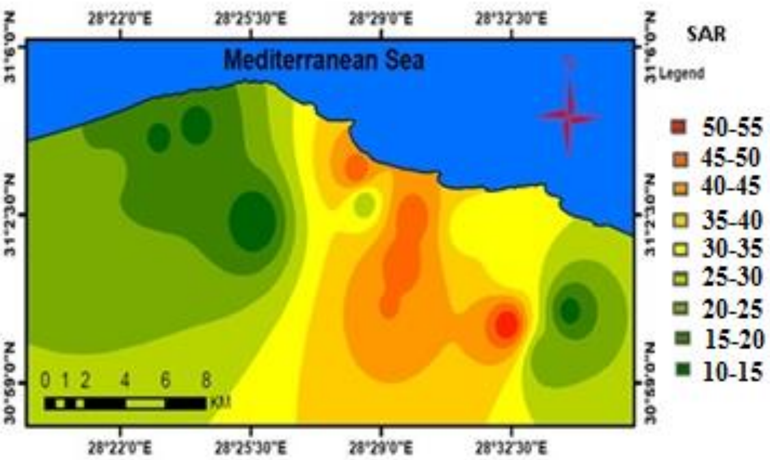


Fig. 8. Sodium Adsorption ratio (SAR) contour map of groundwater samples.

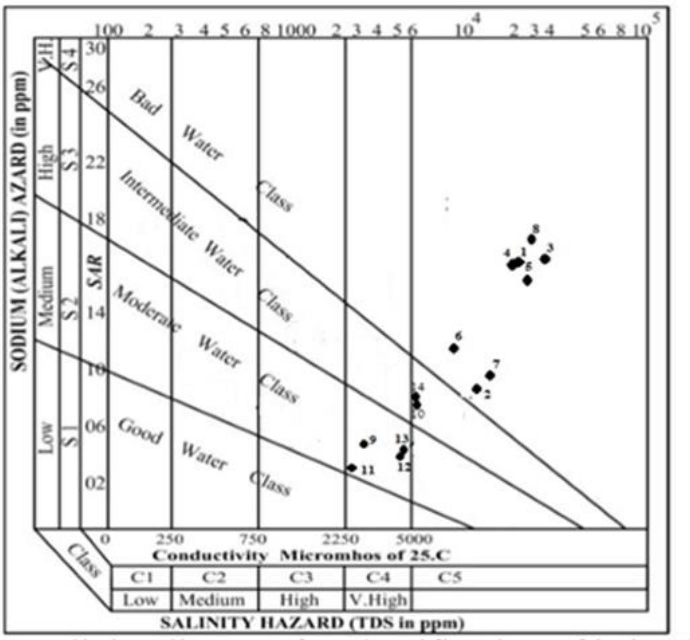


Fig. 9. Groundwater classification according to U.S. Salinity Laboratory, 1954.

Table 7. Groundwater Classes for Irrigation, Based on Sodium adsorption ratio (SAR) (U.S. Salinity Laboratory، 1954).

Sodium	Quality	SAR	Class	Usage	Studied wells
S1	**Low Sodium**	**0-10**	**Excellent**	**Can be utilized on all types of soils, however, sodium sensitive plants are expected to yield good crops.**	**-----**
S2	**Medium Sodium**	**10-18**	**Good**	**Preferred use on coarse textured soils with good permeability and rich in organic matter.**	**9, 11, 12 & 13**
S3	**High Sodium**	**18-26**	**Fair**	**Can have negative impacts on most soils, needs chemical additives and proper drainage.**	**10 & 14**
S4	**Very high Sodium**	**>26**	**Poor**	**Unsuitable for irrigation purposes, requires low salinity water, and chemical amendments and good drainage.**	**1, 2, 3, 4, 5, 6, 7& 8**

Table 8. Groundwater Classes for Irrigation, according to the Chloride level (Taylor and Oza, 1954).

Class	Cl (ppm)	Quality	Studied Wells
I	< 200	Good	
II	200-500	Fair	
III	500-1000	Undesirable	11
IV	>1000	Highly undesirable	All wells except W11

Table 9. Results of Water pollution indices and Groundwater samples classification according to degree of pollution.

	Current study			Indices classes		Studied Wells	References
Parameter	**Min**	**Max**	**Average**	**Classified**	**Degree of Pollution**		
CD	18.11	40.60	27.25	Cd<1	low contamination		**Backman et al. 1998**
				1<Cd<3	moderate contamination		
				Cd<3	high contamination	All Samples	
HPI	1022	1492	1210	HPI <100	low heavy metal contamination		**Mohan et al. 1996**
				HPI = 100	threshold risk		
				HPI> 100	high heavy metal contamination	All Samples	
HEI	28.11	50.60	37.25	HEI <10	low heavy metals		**Edet and Offiong, 2002**

4. Conclusions

The hydrogeochemical properties of the groundwater show that the pH for the samples of groundwater reflecting slightly alkaline water and salinity is changes significantly from slightly, moderately to very saline water types. The major elements except HCO_3^- show increase toward the central portion of the research area, HCO3− increases toward northwest direction (Ghemama area). The order of the principal cations in the groundwater samples is $Na^+ > Ca_2^+ > Mg_2^+ > K^+$ and the order of the anions is $Cl^- > SO_4^{2-} > HCO^{3-}$.The increase elements toward the central part referred to invasion of sea water and calcite, dolomite leaching processes as well as sulphate leaching (gypsum and anhydrite) which influence the geochemistry of the groundwater through its flow path. The heavy metals show decrease toward central portion and slightly increase toward east, and west which could be brought on by local human influence. The heavy metals that were examined can be ordered in samples of groundwater as the following Zn > Ba > As > Pb > Ni > Cd > Co > Mn > Cr > Cu. Piper and Schoeller were applied to assess the hydrochemical properties for samples of groundwater. Piper show that chemical characteristics of groundwater samples are mostly prevalent by the primary salinity and distinguished by non-carbonate alkalis above 50%, meaning that alkalis and strong acids predominate in these characteristics and by $SO_4^{2-} + Cl^- > Na^+ + k^+$, indicating the main influence of invasion of sea water and dissolution of salts in the water bearing deposits on the chemical composition and water quality while Schoeller referred that the predominant cation is sodium in all samples of groundwater, while chlorides are the predominant anion in all of them, which reflects the marine origin of the groundwater in the research area. Total dissolved solids, a metric utilized to assess groundwater quality for drinking, showed that the research area's groundwater was unfit for human consumption. For irrigation purposes, quality of irrigation water indicators including total dissolved solids (TDS), sodium adsorption ratio (SAR), and chloride content (Cl) were assessed. These factors suggested that groundwater was unsuitable for irrigation. The Contamination Degree (CD), Heavy Metal Pollution (HPI) and Heavy Metal Evaluation Index (HEI) are uses to estimate the pollution of the water which indicated that groundwater is highly polluted. The high pollution is related to pollution of samples of groundwater by Cd, Pb and As which due to agrochemical effects and human activity in the research area. This groundwater presents a danger to the health of people where values of major elements and Cd, Pb and As are high than the limit values gives by the World Health Organization and Egyptian drinking water quality standards.

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استخدام نظام المعلومات الجغرافية والهيدروجيوكيميائية كنهج بيئي لتقييم المياه الجوفية الساحلية في الساحل الشمالي الغربي لمصر

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يهدف العمل الحالي إلى الحصول على المعرفة الكافية حول الخصائص الجيوكيميائية للمياه الجوفية وجودتها في المنطقة الساحلية الشمالية الغربية لمصر. كما تم تقييم العلاقات بين نوعية المياه الجوفية المتنوعة، وتلوث المياه الجوفية، والمخاطر الصحية العامة. تم جمع أربعة عشر عينة من المياه الجوفية من ١٤ بئراً في مواقع مختلفة من منطقة الدراسة وتم تحليلها في معمل المركز القومي لتحليل النظائر والعناصر بهيئة الطاقة الذرية المصرية. يشمل تحليل عينات المياه الجوفية لتحديد الكاتيونات والأنيونات الرئيسية مثل (الكالسيوم، الماغنسيوم الصوديوم، البوتاسيوم، الكلور، الكربونات، البيكربونات، الكبريتات) وكذلك العناصر المعدنية الثقيلة (الكادميوم، الكوبالت، النحاس، الخارصين، الرصاص، المنجنيز، النيكل، الزرنيخ، الباريوم والكروم). توضح العناصر الفيزيائية (الأس الهيدروجيني، الملوحة (مجموع الاملاح الذائبة) والصلادة الكلية (عسر المياه الكلى) لعينات المياه الجوفية ان درجة الحموضة تشير إلى المياه القلوية بينما الملوحة تتغير على نطاق واسع من الطفيفة والمتوسطة إلى شديدة الملوحة. وتزداد ملوحة عينات المياه الجوفية في منطقة الدراسة باتجاه الأجزاء الشمالية والوسطى من منطقة الدراسة (مدينة الضبعة) وتنخفض باتجاه الشرق (منطقة غزالة) والاتجاه الغربي (منطقة جميمة) مما يدل على أن زيادة ملوحة المياه الجوفية في هذه المنطقة قد تكون بسبب تسرب مياه البحر ورشح من الصخور الكربونية الموجودة فى المنطقة. أظهرت التوزيعات المكانية للعناصر الرئيسية لعينات المياه الجوفية ماعدا البيكربونات زيادة عامة باتجاه الجزء الأوسط من منطقة الدراسة (منطقة الضبعة) بينما يزداد البيكربونات باتجاه الشمال الغربي (منطقة جميمة). الكاتيونات الرئيسية السائدة في عينات المياه الجوفية ترتب من الزيادة الى النقصان كالاتى: الصوديوم < الكالسيوم < الماغنسيوم < البوتاسيوم، بينما الأنيونات السائدة ترتب كالأتي: الكالسيوم < الكبريتات <البيكربونات. زيادة العناصر الرئيسية تجاة منطقة الضبعة قد تكون بسبب تسرب مياه البحر فى هذة المنطقة. يظهر التوزيع المكاني للعناصر الثقيلة لعينات المياه الجوفية زيادة باتجاه الشرق، والغرب قد يكون بسبب الأنشطة البشرية في هذه المنطقة. العناصر الثقيلة ترتب من الزيادة إلى النقصان في عينات المياه الجوفية كالأتي: الخارصين< الباريوم < الزرنيخ < الرصاص < النيكل < الكادميوم < الكوبالت< المنجنيز < الكروم < النحاس. تظهر العناصر التالية (الباريوم والكروم والنحاس والكوبالت والمنجنيز والنيكل والخارصين) قيمًا أقل من الحد الأقصى المسموح به بينما تتجاوز عناصر الكادميوم والرصاص والزرنيخ الحد الأقصى المسموح به لمياه الشرب من قبل منظمة الصحة العالمية بسبب التأثيرات الكيميائية الزراعية والنشاط البشريى. تم تطبيق مخططات بايبر وشولر لتقييم الخصائص الهيدروكيميائية لعينات المياه الجوفية في منطقة الدراسة. يشير مخطط بايبر إلى أن جميع عينات المياه الجوفية تسودها الملوحة الأولية وتتميز بقلويات غير كربونية تتجاوز ٥٠٪، وهي خواص كيميائية وتكون سائدة بواسطة القلويات والأحماض القوية وكذلك الكبريتات + الكلور < الصوديوم + البوتاسيوم، مما يشير إلى التأثير الرئيسي لتداخل مياه البحر وانحلال الأملاح في الرواسب الحاملة للمياه على التركيب الكيميائي وجودة المياه بينما يشير مخطط شولر إلى أن الكاتيون السائد هو الصوديوم في جميع عينات المياه الجوفية، في حين أن الكلوريدات هي الأنيون السائد في جميع عينات المياه الجوفية، مما يدل على الأصل البحري للمياه الجوفية في منطقة الدراسة. تم تطبيق درجة التلوث (Cd) ومؤشر التلوث بالمعادن الثقيلة (HPI) ومؤشر تقييم المعادن الثقيلة (HEI) لتقييم تلوث المياه في منطقة الدراسة والذي يكشف عن تلوث شديد نتيجة تلوث عينات المياه الجوفية بواسطة الكادميوم والرصاص والزرنيخ مما يشكل خطرا على صحة الإنسان. تم تقييم جودة المياه للشرب والري بواسطة طرق عديدة حيث تبين أن المياه الجوفية في منطقة الدراسة غير صالحة للشرب والري.