Groundwater Pollution in Enjela Area- Southern Janzour City

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Abstract:

The goal of this study is to investigate groundwater contamination from sewage disposal lake in Enjela area. In the study, twenty nine wells are assigned in seven sectors surrounding the sewage disposal area. The wells cover around 77 square kilometres. During this study, field and laboratory measurements are conducted. The field measurements include determining the location of wells related to the lagoon and the water depth related to mean sea level. The laboratory measurements include chemical and biological analyses for samples collected from the wells and sewage lagoon. Chemical analyses include determination of pH, EC, TDS, K^+, Na^+, Ca^{2+}, Mg^{2+}, NO_3^-, PO_4^{3-}, HCO_3^-, and Cl^-. The indicators of biological contamination included coliform bacteria, COD, and BOD. According to the conducted analyses and measurements, the following results can be summarized. The study area is distinguished by the natural groundwater movement in the northeast direction. Concerning the chemical pollution, most of the wells are contaminated by potassium especially in the vicinity of sewage lagoon. For biological contamination, the wells are highly contaminated except those are far from lagoon. Due to its location and according to Simpson ratio, the groundwater in the study area is affected by seawater intrusion. Finally, based on this study, some recommendations are listed that might minimize the effect of this pollution if they are implemented.

Keywords: *Groundwater, aquifer, sewage water, chemical contamination, biological contamination.*

تلوث المياه الجوفية في منطقة إنجيله- جنوبي جنزور

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الملخص:

تهدف هذه الدراسة إلى التحقق من تلوث المياه الجوفية من بحيرة صرف مياه الصرف الصحي في منطقة إنجيله. تم تخصيص تسعة وعشرين بئراً في سبعة قطاعات محيطة بمنطقة الصرف الصحي. تغطي الآبار حوالي 77 كيلومتراً مربعاً. خلال هذه الدراسة، تم إجراء القياسات الميدانية والمختبرية. شملت القياسات الميدانية تحديد موقع الآبار المتعلقة بالبحيرة وعمق المياه المرتبط بمتوسط مستوى سطح البحر. كما اشتملت القياسات المختبرية على تحليلات كيميائية وبيولوجية للعينات التي تم جمعها من الآبار وبحيرة الصرف الصحي. تضمنت التحليلات الكيميائية تحديد pH و EC و TDS و K^+ و Na^+ و Ca^{2+} و Mg^{2+} و NO_3^- و PO_4^{3-} و HCO_3^- و Cl^-. تضمنت

مؤشرات التلوث البيولوجي بكتيريا القولون، COD، و BOD. وفقًا للتحليلات والقياسات التي تم إجراؤها، يمكن تلخيص النتائج التالية. تتميز منطقة الدراسة بأن حركة المياه الجوفية الطبيعية كانت في اتجاه الشمال الشرقي. وفيما يتعلق بالتلوث الكيميائي، فإن معظم الآبار ملوثة بالبوتاسيوم، خاصة بالقرب من بحيرة الصرف الصحي. أما بالنسبة للتلوث البيولوجي، فإن أغلب الآبار شديدة التلوث باستثناء تلك البعيدة عن البحيرة. نظرًا لموقعها ووفقًا لنسبة سيمبسون، فقد تأثرت المياه الجوفية في منطقة الدراسة من تسرب مياه البحر. أخيرًا، بناءً على هذه الدراسة، تم سرد بعض التوصيات عند الأخذ بها قد تقلل من تأثير هذا التلوث إذا تم تنفيذها.

كلمات مفتاحية: *مياه الصرف الصحي، الخزان الجوفي، التلوث الكيميائي، التلوث البيولوجي.*

Introduction:

During the past 100 years, groundwater has become an increasingly important source of water supply worldwide for domestic, agricultural, and industrial uses (Freez & Cherry, 1979; Schwartz & Zhang, 2003). Since it is naturally protected, groundwater has been immune from contamination for a long time. It has been cleaner and more transparent than surface water. Lately, however, groundwater quality has worsened in many regions, with sometimes serious consequences. When groundwater becomes contaminated, it is difficult and expensive to clean up. Depends on sources of contamination, groundwater can be contaminated with verities of chemical elements, heavy metals and biological pollution(Adekunle *et al*., 2007; Oyeku & Eludoyin, 2010; Afzal *et al*., 2014)

Major causes of groundwater contamination are because of poor management and the lack of regulations and control over the use and disposal of contaminants. Groundwater can become contaminated from different sources. Natural sources where some substances that found in rocks or soil such as iron, manganese, arsenic, and many other elements can become dissolved in groundwater. Other naturally occurring substances, such as decaying organic matter, can move in groundwater as particles (Schleyer *et al*., 1992; Alloway & Ayres, 1997; Fetter, 1999). Pollution of groundwater sources by leachate from landfills have been recognized by several researchers (Abu-Rukah &Al-Kofahi, 2001; Badmus *et al*., 2001; Sia, 2008). Agricultural practices, with frequently excessive use of fertilizers, herbicides, and pesticides, are among the most relevant sources of groundwater contamination (Chatupote & Panapitukkul, 2005). One of the main causes of groundwater contamination is the seepage from septic tanks and ponds of disposal liquid wastes sites that are improperly constructed. These systems can contaminate ground water with bacteria, viruses, nitrates, detergents, oils, and chemicals. Groundwater can be contaminated by leaking and spills from underground storage tanks that used to store gasoline, diesel fuel and other chemicals. Some structures beneath the water table such as recharge wells can be a source of groundwater contamination. In the coastal areas, excessive groundwater pumping decreases the pressure in the aquifer that leads to contaminate the aquifer by sea water (Ashim et al., 1982).

Groundwater contamination can be caused of many health problems. Drinking water contamination by bacteria and viruses can result in illnesses such as hepatitis, cholera, or giardiasis. Also, drinking water that is high in nitrates can result in illnesses affecting infants such as Methemoglobinemia or “blue baby syndrome” and the serious health effects of lead (Craun, 1985; Schmoll *et al*., 2006). Many other health effects due to chemical contamination are unknown or not well understood. Therefore, preventing contaminants from reaching the ground water is the best way to reduce the health risks associated with poor drinking water quality.

Because there is no sewage system in Enjela community, the municipal and industrial liquid solids are disposal in a depression making a sewage lagoon through which sewage water arrives to the groundwater through deep infiltration. The aim of this study is investigating the chemical and biological contamination of groundwater that caused by sewage polluted water. The seawater intrusion into the study area was also investigated.

Materials and Methods:

Study area

Enjela is a resident area located about 25 km south west of Tripoli where around 30,0000 Capita live in 5000 units. The town’s sewage system drains out in a collection basin making a sewage lagoon with more than 1.2 hectare and a depth reaches around 6 m in some places.

The study area is located between longitudes (12.55^o – 13.05^o E) and latitudes (32.48^o – 33.44^o N) as shown in Figure 1. The agriculture is considered the main activity in the area, even though there are industrial and commercial activities on a small scale. Because of its location, the climate is the Mediterranean Sea with an average annual rainfall around 200 mm. Therefore, most of the human activities depend on groundwater. The geological structure of the region is a sedimentary rock belongs to Pliocene era and consists of eolian deposits, alluvial deposits, and sand dunes. Concerning with groundwater in the area, there are two aquifers. The upper one is located in the Pliocene formation and the second in the Miocene formation (GWA, 2002). According to the technical reports of the General Water Authority for well No.A4 which located in the center of the study area revealed that the first layer of the hydrogeological structure, which is between 5 and 7 meters thick, consists of fine sand of a light brown in colour, followed by a layer of fine sandstone to medium light brown in colour extending to a depth of 30 meters, i.e. with a thickness varies from 23 to 25 meters, then a layer of clay with the light brown in colour with sandstone, limestone and silt interactions up to 30 meters thick, extending to a depth of about 60 meters. Then a layer of about 90 meters in deep and 30 meters thick consisting of light brown clay and sand with thin interactions of limestone and sandstone. Finally, a layer with a depth of about 110 meters and a thickness of 20 meters, is characterized by the presence of limestone with white sand and interactions of brown to light clay, as shown in Figure 1. Most of the water in the area is pumped from the upper aquifer because of water quality and low cost.

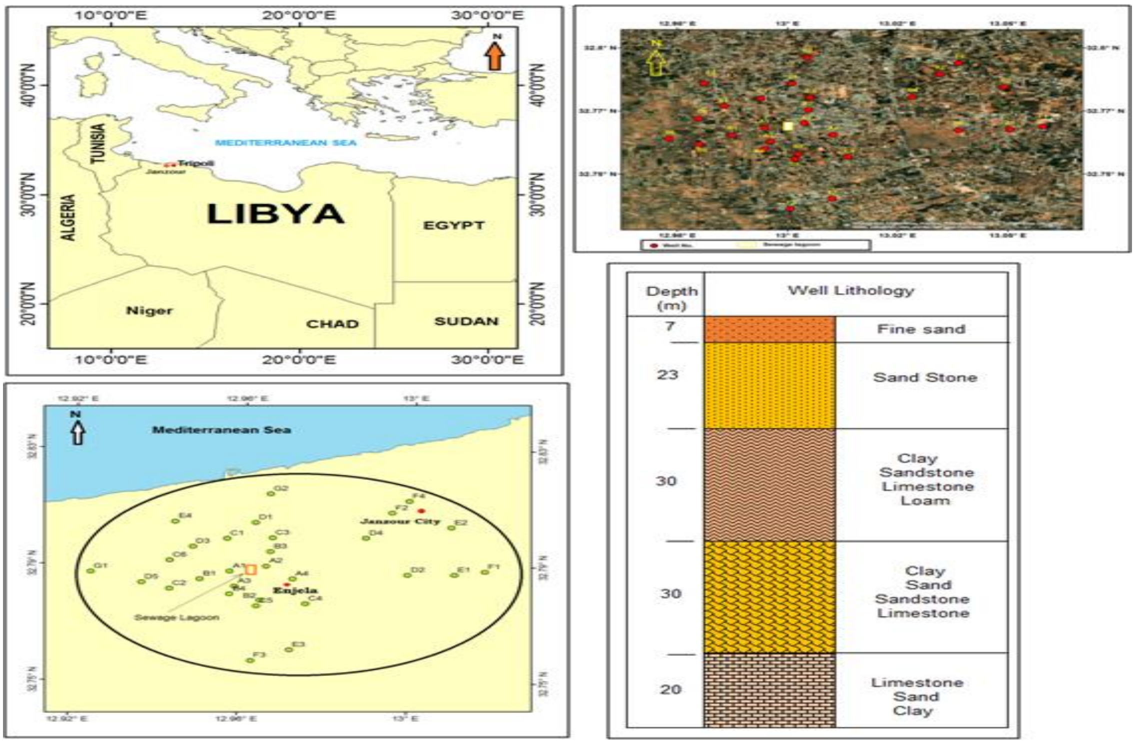

Fig. 1: Location of the study area and the lithostratigraphic of well No. A4

To investigate the groundwater contamination in the area related to the sewage lagoon, 29 wells surrounding the lagoon were selected (Figure 1). They covered around 77 km^2.These wells are used for samples collection and measuring other related field parameters. The samples of the groundwater and water lagoon were taken during summer of 2007. The geographical position of each well and their elevation was determined by mean of a Garmin GPS instrument. The distances from the well location to the nearest shoreline and to lagoon were determined via free tool of Google Earth (Google Earth, 2013). Table (1) shows the wells location and their distance to lagoon.

Direction of groundwater movement.

The direction of groundwater movement in the study area is very important. It determines the recharge zones to make sure that human activities in the area do not pose threat to the quality of the groundwater to enable a sustainable use of the resources. Given that water always flows from a region of higher head to a region of lower head (Wehrmann,2007). Basically, the locations of three wells and their elevations above sea level were determined through longitude and latitude coordinates using Garmin GPS instrument, then the groundwater level was measured in each well using a coaxial water level meter (Table 1).

Three wells were essentially needed and selected for triangulation i.e., well number C3, D5 and E4. The hydraulic head for each well (which obtained by subtracting the depth to the water table in the well from the ground elevation with respect to the mean sea level) were joined with lines representing the distances between one well and another. The lines were divided into equal increments, then connected between each two points of equal values representing water table contour by a line. A vector line was placed perpendicular to these lines to represents the flow line.

Measurements and analyses.

Laboratory analyses consist of determining the chemical and biological analyses. Chemical analyses include measuring (pH) and (EC) by pH meter and conductivity meter; measuring total dissolved solids using the gravimetric method; determining chloride and bicarbonates using Moher precipitation method; measuring sodium and potassium by flame photometer method; determining calcium and magnesium using calibration volumetric method; estimation of nitrate and phosphate by Spectrophotometer (ASTM, 1995). Biological and biochemical analyses consist of measuring coliform bacteria using multiple tube method, chemical oxygen demand (COD) and biological oxygen (BOD) by estimation of oxygen consumed by microorganisms (ASTM, 1995).

Table 1: Wells location and distance to lagoon and parameters for Determination of Groundwater Flow Direction.

Well No.	Distance from Lagoon (m)	Elevation (m)	SWL (m)	Hydraulic Head (m)	Well No.	Distance from Lagoon (m)	Elevation (m)	SWL (m)	Hydraulic Head (m)
A_1	260 NW	50	45	5	D_1	2250 N	49	45	4
A_2	240 N	50	45	5	D_2 *	3000 E	50	150	100
A_3	400 SW	50.5	44.5	6	D_3	2650 NW	49.8	45	4.8
A_4 *	380 E	50	120	70	D_4	3000 NE	49.8	44.5	5.3
B_1	1260 W	51	46	5	D_5	2550 W	50.5	44	6.5
B_2	900 S	50.5	44	6.5	E_1	4300 E	49.3	44	5.3
B_3	1000 N	50	46	4	E_2	5000 NE	50	46	4
B_4	1050 SW	51	45	6	E_3	3500 S	49.4	46	3.4
C_1	1800 NW	49.5	46	3.5	E_4	3500 NW	50.6	47	3.6
C_2	1700 W	51.2	45	5.2	F_1	5200 E	50.2	46	4.2
C_3	1850 N	49.8	47	2.8	F_2	4350 NE	50	47	3
C_4	1700 SE	51.2	45	6.2	F_3	4000 S	51.2	41	10.2
C_5	1750 S	52	44.5	6.5	F_4	3866 NE	52	50	2
C_6	1933 NW	50.9	45	5.9	G_1	4200 W	51.5	46.5	5
					G_2	5400 N	53	51	2

* Wells from deep aquifer

The obtained values of each parameter were compared with the standard values set by the World Health Organization (WHO, 2011). Table 2 shows the maximum safe limits of WHO for determining drinking water quality. The detection of seawater intrusion was performed and classified according to Simpson ratio (SR). Simpson ratio contrasts the relative abundance of the dominant seawater and freshwater anions (Ekhmaj et al., 2015). It classified the contaminated water due seawater intrusion by (Todd, 1959) into five groups: good quality (<0.5), slightly contaminated (0.5-1.3), moderately contaminated

(1.3-2.8), injuriously contaminated (2.8-6.6) and highly contaminated (6.6-15.5).

SR can be calculated using equation (1).

$$SR = \frac{Cl^-}{(HCO_3^- + CO_3^{2-})} \qquad (1)$$

where the concentrations are expressed in "mg/L" units.

Table 2: The safe limits of WHO (2011) for determining drinking water quality

Parameter	Unit	Maximum permissible limit
pH	Unit less	8.5
EC	µS/cm	no data
TDS	mg/l	1000
Cl^-	mg/l	250
HCO_3^-	mg/l	350
Na+	mg/l	200
K+	mg/l	no data
Ca^{2+}	mg/l	200
Mg^{2+}	mg/l	50
NO_3^-	mg/l	50
PO_4^{3-}	mg/l	no data
E.coli	CFU*/100ml	0
BOD	mg/l	0
COD	mg/l	0

* Colony forming units

The linear relationship among major chemical constituents of the groundwater, as measured by the simple correlation coefficient (r) is presented in table 4. Despite the complexity of the hydrochemical components of groundwater, such analysis may allow to distinguish several relevant chemical constituents' relationships (Ekhmaj *et al*., 2014).

Statistical analyses of the data including correlation analysis were carried out using software, SPSS® for windows (Ver. 16). The maps were performed by Surfer®(Golden Software, LLC).

Results and discussion:

Groundwater level and Direction movement.

The results of the field measurements which include groundwater level in the selected wells and their distance and direction from sewage lagoon are shown in Table1.

The location of the lagoon and the selected wells are shown in Figure 2. Also, Figure shows the distribution of groundwater level. It is clear from Figures 2 and 3 the main direction of the groundwater movement is in the north east even though this direction is effected by the pumping from the wells.

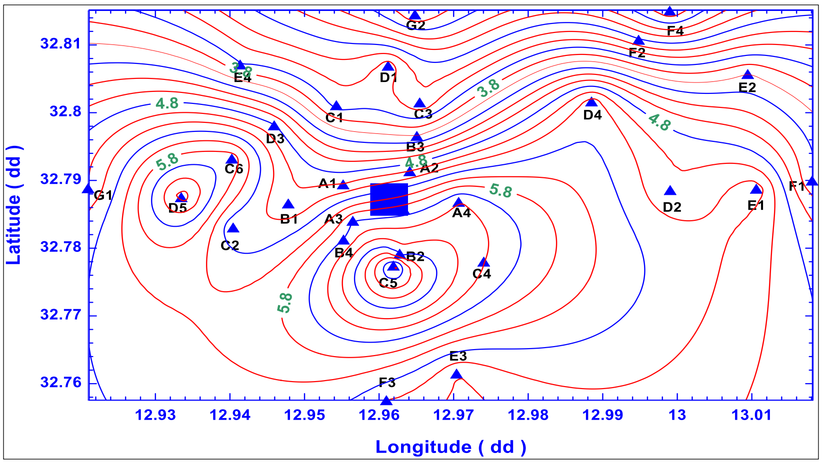

Fig. 2: Spatial distribution of groundwater level in study area.

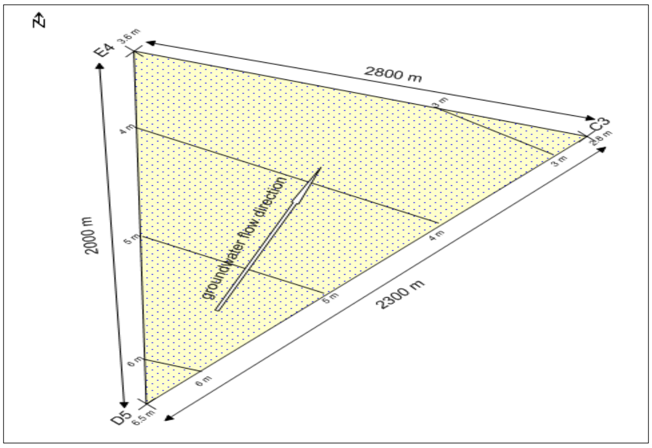

Fig. 3. Groundwater flow direction

Chemical compositions

Characteristics of hydrochemical analytical results are summarised in Table 3. This summary includes the mean, minimum, maximum and standard deviation values of hydrochemical parameters.

Table. 3: Statistical summary of Hydrochemical parameters in the study area.

Parameter	Mean	Min	Max	Std.Dev.
pH	7.3	6.8	8.1	0.237
EC	1261	938	1776	216
TDS	1609	1052	2775	406
Na^+	168	49	425	71
K^+	11.7	5.5	18	2.8
Ca^{2+}	180	127	262	37
Mg^{2+}	102	42	266	44
HCO_3^-	270	96	356	54
Cl	460	294	703	100
NO_3^-	37	12	78	19
PO_3^{2-}	0.072	0.000	0.298	0.082

Referring to the chemical measurements as mentioned in Table 3, the pH values range from (6.8 to 8.1) with an average of (7.3) and standard deviation of (0.237) which means, they are within the normal range as mentioned in WHO guidelines i.e., Table 2. Table 4 shows cross- correlations among hydrochemical groundwater parameters. The correlation coefficient matrix shows no significant correlation between pH and the other parameters at a significant level of less than 0.05.

The values of electric conductivity (EC) and total dissolved solids (TDS) in all the wells as mentioned in Table (3) are above the normal range according to WHO specifications i.e.,1000 mg/l. Table 4 indicates a positive significant correlation between EC and TDS at level of significant of less than 0.05. Such correlation leads to indicate that EC is a measure of TDS in the groundwater (Rani & Babu, 2008). The matrix correlation also shows significant positive correlation between EC and Na^+, Ca^{2+}, Mg^{2+} and Cl- at level of significant of less than 0.05. This finding gives an indication of the impact of these ions on EC values of the groundwater. Figure 3, which displays wells arrangement according to their distance from the swage lagoon, shows TDS concentrations.

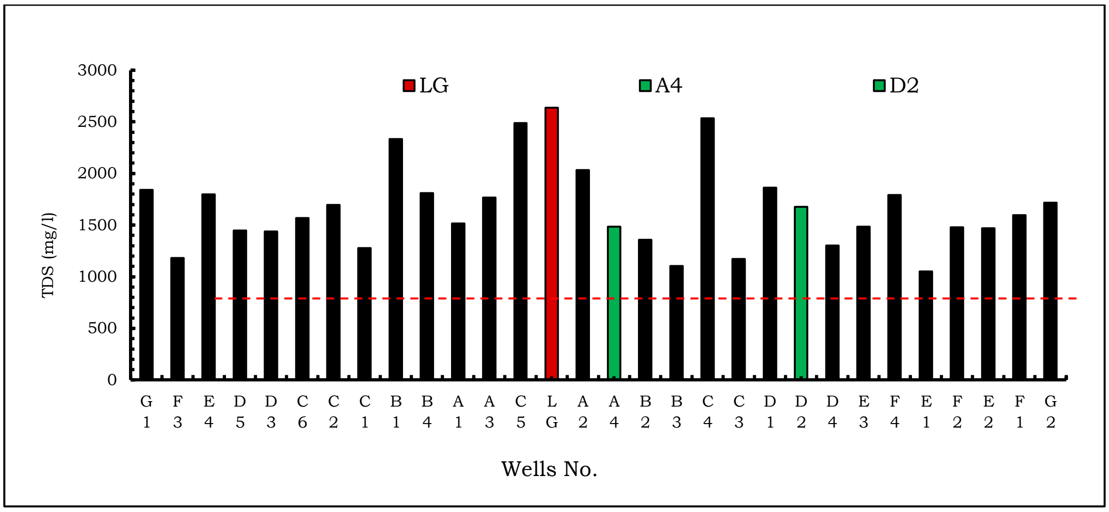

Fig. 4: TDS values in the lagoon and surrounding wells.

From the Figure 4, it reveals that the pollution is not affected by the distance from sewage lagoon which means the sewage lagoon is not the only source of the pollution according to the (TDS) criteria.

Because of the lack of recharge of the aquifer due to insufficient rainfall, the aquifer is exposed to excessive pumping. This pumping may increase the (TDS) values due to the intrusion if sea water into the aquifer. This conclusion explains the high values of (TDS) in wells (B_1 and C_4) in spite of their locations to the lagoon.

These wells are subjected to excessive pumping due to agriculture use. Such results can be drawn from the Table 4 which reveals no significant correlation between TDS of groundwater and the distance from the wells location to the lagoon. In addition, the correlation coefficients of TDS with Na^+ and Cl^- are significant and higher as compared with the other ions. It can be deduced to modern seawater mixing and not attributed to formation salinity. Such result coincides with (El-Trriki, 2006; Rani & Babu, 2008).

Referring to contamination by nitrate, the concentration level the wells is changed from 78 mg/l in well C_1 to 13 mg/l in well F_2.As shown in Figure 5, it is clear that the nitrate concentration level is above the safe limits set by WHO (50 mg/l) in all the wells except (F_3, A_4, D_2, E_3, F_4, F_2).

Table 4: Cross correlation matrix of groundwater quality parameters.

Parameter	pH	EC	TDS	Na^+	K+	Ca^{2+}	Mg^{2+}	HCO_3^-	Cl^-	NO_3^-
pH	1.00	0.23	0.04	0.20	0.12	0.01	0.07	-0.22	0.05	0.18
EC		1.00	0.72*	0.68*	0.30	0.52*	0.52*	0.16	0.50*	0.29
TDS			1.00	0.63*	0.25	0.48*	0.11	0.09	0.61*	0.34
Na^+				1.00	0.41*	0.24	0.34	0.08	0.42*	0.42*
K^+					1.00	0.16	0.07	-0.35	0.14	0.71*
Ca^{2+}						1.00	-0.13	0.13	0.51*	0.51*
Mg^{2+}							1.00	0.10	0.09	-0.10
HCO_3^-								1.00	-0.26	-0.17
Cl									1.00	0.24
NO_3^-										1.00
PO_3^{2-}										

Parameter	PO_3^{2-}	E.Coli	COD	BOD	Simpson Ratio	Distance to lagoon	Distance to shoreline
pH	0.18	0.04	0.20	0.09	0.04	-0.14	0.13
EC	0.24	0.24	0.09	0.20	0.18	-0.24	0.05
TDS	0.21	0.27	0.21	0.33	0.17	-0.18	0.01
Na^+	0.34	0.43*	0.34	0.42*	0.22	-0.35	0.33
K^+	0.79*	0.68*	0.58*	0.52*	0.37*	-0.72*	-0.09
Ca^{2+}	0.33	0.51*	0.44*	0.48*	0.12	-0.29	0.05
Mg^{2+}	0.03	-0.11	-0.13	-0.08	0.07	-0.14	0.26
HCO_3^-	-0.46 *	-0.20	-0.25	-0.16	-0.79*	0.18	0.28
Cl	0.34	0.31	0.22	0.32	0.65*	-0.18	0.08
NO_3^-	0.74*	0.87*	0.78*	0.75*	0.25	-0.64*	0.12
PO_3^{2-}	1.00	0.85*	0.70*	0.63*	0.60*	-0.79*	0.13
E.Coli		1.00	0.83*	0.82*	0.34	-0.65*	0.21
COD			1.00	0.97*	0.29	-0.56*	0.09
BOD				1.00	0.26	-0.51*	0.15
Simpson Ratio					1.00	-0.31	-0.05
Distance to lagoon						1.00	-0.21
Distance to shoreline							1

* Correlation is significant at the 0.05 level (2-tailed).

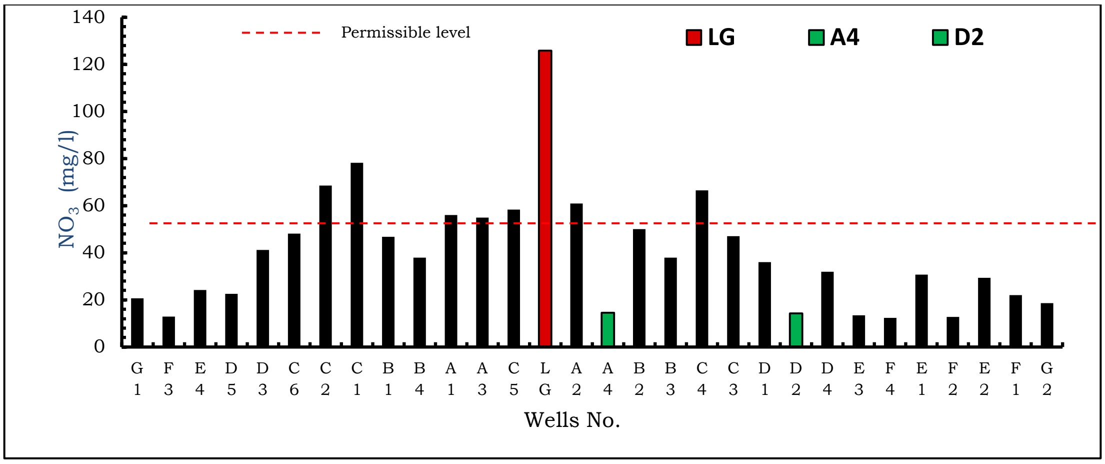

Fig. 5: Nitrate levels in the lagoon and surrounding wells.

The concentration level in the sewage lagoon, is 126 mg/l. Therefore, the lagoon represents the main source of pollution. The high level of nitrate in wells (C_1, C_2, C_3, C_4), even though they are not closed to the sewage lagoon, it may due to the existence of individual sewage sink holes closed to them. In general, the nitrate concentration is decreasing as getting far from the lagoon. Such result is obvious through examining the table 4 where a moderate significant negative correlation (-0.64) at significant level less than 0.05 between NO_3^- and the distance from the wells location to the lagoon.

Figure 5 shows the chloride level and the recommended limit in the surrounding wells. The concentration level of Cl^- is changed from 703 mg/l in well C_4 to 294 mg/l in well E_1. In all the wells the concentration level exceeds the permissible limit (250 mg/l). The concentration level in lagoon is reached 800 mg/l. Although this highest level of chloride in the sewage lagoon that may lead to pollute the groundwater, the correlation analysis indicate non-significant correlation between Cl^- and the distance from the wells location to the sewage lagoon as revealed by Table 4. The excessive pumping appears the main source of pollution. Since the study area is not far from the sea, the excessive pumping leads the sea water to intrude the aquifer causing groundwater pollution with chloride and sodium. This explains the fluctuations of chloride level in the wells as indicated in Table 3. However, due to their relatively high abundance in seawater, Cl^- and Na^+ are widely used to detect seawater intrusion in the coastal area (Ekhmaj et al., 2014).

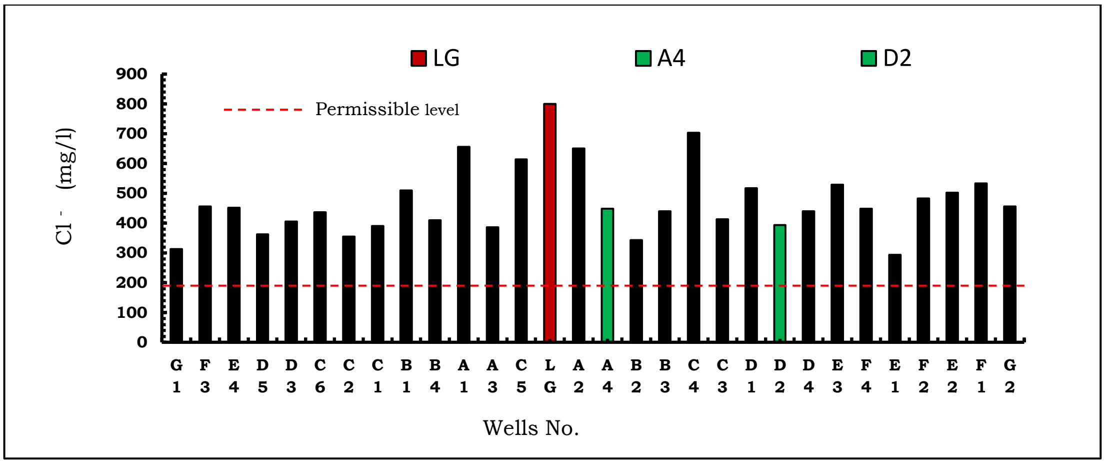

Fig. 6: Chloride level in the lagoon and surrounding wells.

Table 3 indicated that the average concentration of Na^+ is 168 mg/l and it ranges from 49 mg/l in well F3 to 425 mg/l in well C4 with standard deviation of 71 mg/l while it is 245 mg/l in the sewage lagoon. Figure 7 shows sodium concentration level in the sewage lagoon and surrounding wells. The sodium concentration in some wells is higher than that in the lagoon which means the lagoon is not the main source for Na^+. The positive significant correlation between concentrations of Na^+ in the groundwater and the distance from the wells location to the sewage lagoon may indicate to a minor mixing of the fresh groundwater with sewage lagoon. However, usually in coastal areas, the excessive pumping increases the pollution by chloride and sodium as in wells B1 and C2. In most of the wells the concentration level of Na^+ is below the permissible limits set by WHO (200 mg/l).

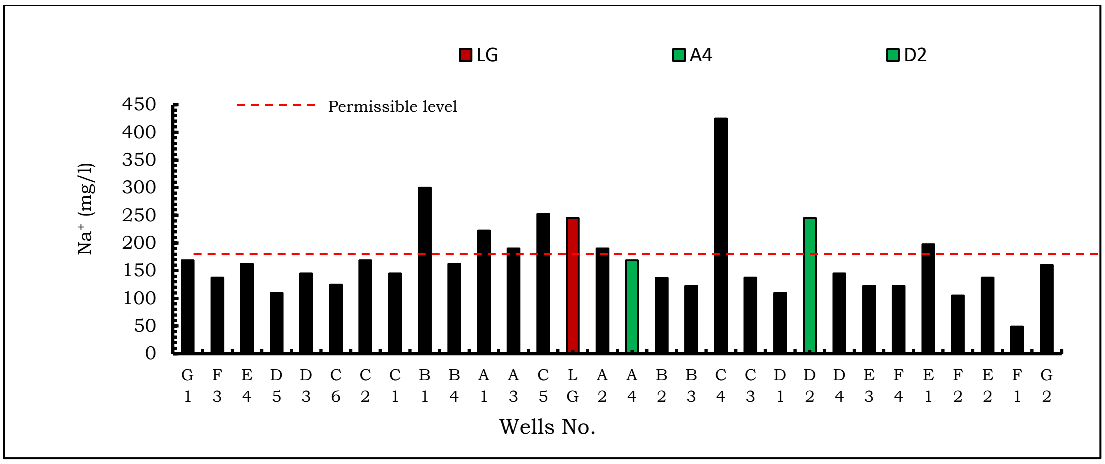

Fig. 7: Sodium levels in the lagoon and surrounding wells.

Sodium contamination has almost the same trend as total dissolved solids and chloride contamination which means they are caused by the same source (i.e., seawater intrusion).

Referring to Table 3, the concentrations of potassium range between 5.5 mg/l in F1 to 18 mg/l in C1 with mean and standard deviation of 11.7 mg/l and 2.8 mg/l, respectively. The potassium concentration in sewage lagoon is 21 mg/l. Since there is no evidence that potassium levels in municipally treated drinking-water, even water treated with potassium permanganate, are likely to pose any risk for the health of consumers, it is not considered necessary to establish a health-based guideline value for potassium in drinking-water (WHO, 2011). The fluctuation level of K^+ in wells indicates that the sewage lagoon is not the main source of pollution even though it might be a part of it. However, the significant negative correlation between the concentrations of K^+ in groundwater samples and the distance from the wells location to the sewage lagoon probably gives an evidence of the impact of sewage lagoon on groundwater.

The concentration level of calcium is changed from 145.6 mg/l in well B_2 to 262.4 mg/l in well A_2 whereas it is 112.8 mg/l in the sewage lagoon. The concentration level in all the wells is higher than that in the sewage lagoon which means the lagoon is not the source of pollution. This result is assured as there is no a significant correlation between the concentrations of Ca^{2+} in groundwater samples and the distance from the wells location to the sewage lagoon. Another important aspect is the positive significant correlation between the concentrations of Ca^{2+} and Cl^-, NO_3^- and PO_3^{2-} in groundwater samples. Due to their relatively abundant as compared with NO_3^- and PO_3^{2-}, Ca^{2+} is highly associated with Cl^-. The $CaCl_2$ type water may be a leading edge of the seawater plume in the region (Appelo & Postma, 1993; Jeen *et al*., 2001).

For magnesium contamination, the concentration level changes from 41.6 mg/l in well C_3 to 266.5 mg/l in the well $D_{2,}$ whereas in the sewage lagoon is 144.6 mg/l. Even though the lagoon could be a source for magnesium contamination but it is not the main source for it. It can be noted from Table 4 that the correlation between the concentrations of magnesium in the ground water and the distance from the wells location to the sewage lagoon is not significant.

Referring to contamination by bicarbonates, the concentration level in wells is changed from 96.4 mg/l in well A_1 to 355.4 mg/l in well D_2 whereas it is 768 mg/l in the lagoon. However, table (4) indicated no significant correlation between the concentrations of bicarbonates in the groundwater and the distance from the wells location to the sewage lagoon. Figure 8 shows bicarbonates concentration level in sewage lagoon and surrounding wells. It is clear from the figure that the bicarbonates concentration is exceeding the permissible limit in most of the wells.

For phosphate contamination, the concentration level in wells is changed from 0.0001 mg/l in well F1 to 0.298 mg/l in well A1. The World Health Organization (WHO), in 1980 concluded that there is no nutritional basis for the regulation of phosphorus levels in the US drinking water supplies. However, Europe Community issues a guide level of 0.5 mg/L for drinking water (Fadiran et al., 2008). The concentration in sewage lagoon is 8.2 mg/l.

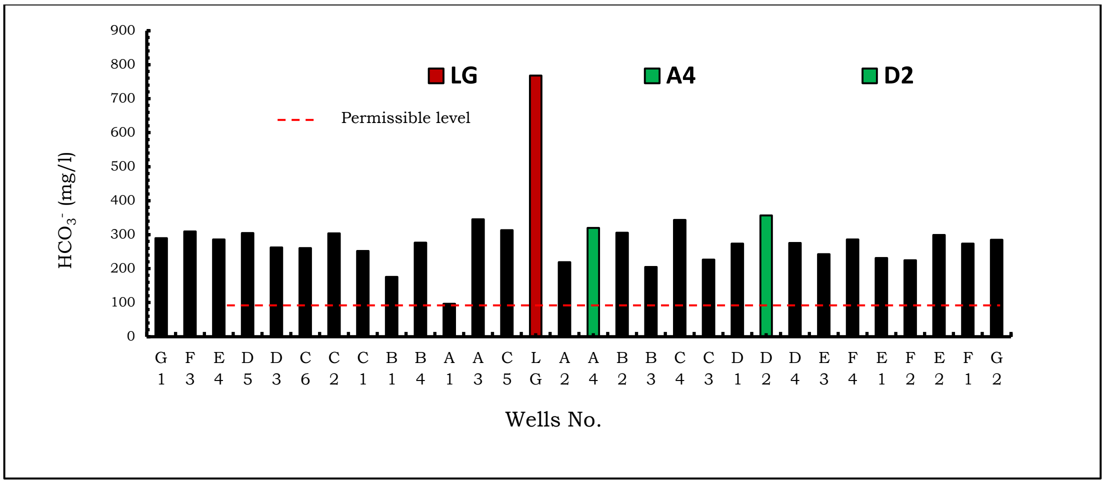

Fig. 8: Bicarbonate levels in the lagoon and surrounding wells.

This means the sewage water is highly contaminated by phosphate. The level concentration in the wells is very low compared with that in the lagoon which means the sewage lagoon represents the main source of phosphate contamination. The correlation matrix revealed that concentration of phosphate in groundwater decreases significantly with increasing distance from the sewage lagoon as shown in Table 4.

Referring to the biological contamination, Table 5 shows the statistical analysis of biological contamination indicators. Figure. 9 depicts the pollution caused by coliform bacteria in the sewage lagoon and surrounding wells. From the figure, it is clear that the number of colonies is very high in the lagoon whereas it is changed from more than 1100 colonies /100 ml in adjusting wells to nil in wells that are far from lagoon. This explains the sewage lagoon represents the main source of pollution by coliform bacteria. Such finding is assured by the negative significant correlation between colonies/100 ml and the distance from the wells location to the sewage lagoon as indicated in Table 4. The high values in wells that far from lagoon such as wells C_1, C_2, B_3, and C_4 may due to existing individual sink holes for sewage waste near to those wells. Also, the deep wells A_4 and D_2 are not contaminated which means the contamination is decreased by the depth.

For chemical oxygen demand (COD), the concentration level in the wells is changed from 0.01 mg/l in well G_1 to 9.1 mg/l in well A_2 (Table 5) whereas it is 16 mg/l in sewage lagoon. As it can be seen from Figure 10, the concentration level decreases as getting far from the lagoon. According to the significant negative correlation between COD level and the distance from the wells location to the sewage lagoon, it is clear that the lagoon is the main source for chemical oxygen demand.

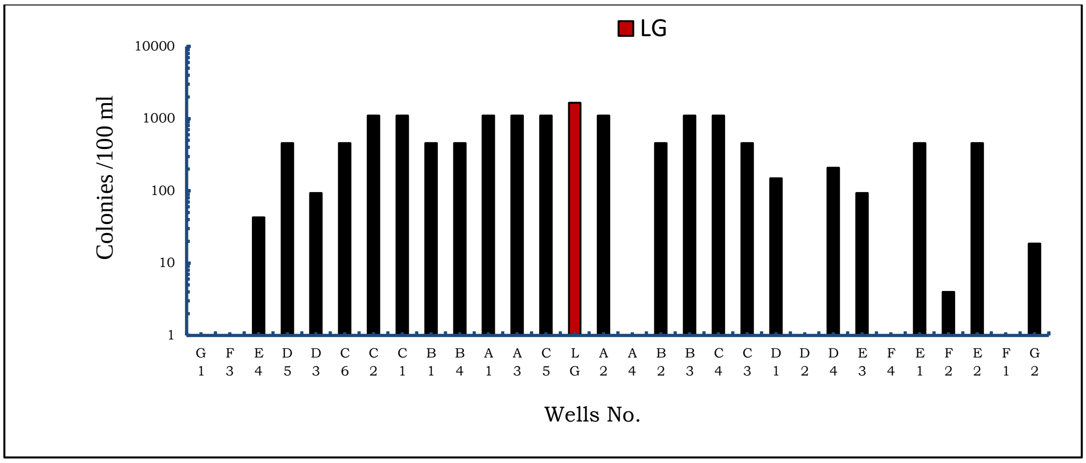

Fig. 9: Coliform bacteria levels in the lagoon and surrounding wells.

Table. 5: Biological Contamination Indicators

Parameter	Mean	Min	Max	Std.Dev.
E.Coli	451	0.000	1100	445
COD	5.1	0.01	9.1	3.4
BOD	3.632	0.001	8.0	2.7

In case of biological oxygen demand (BOD), the concentration level in the wells is changed from 0.002 mg/l in well C_5 to 6.2 mg/l in well B_2 whereas it is reached 9 mg/l in sewage lagoon. The concentration level fluctuation in the well is similar to that of chemical oxygen demand. However the significant negative correlation between BOD level and the distance from the wells location to the sewage lagoon showed the direct impact of sewage lagoon on BOD in the groundwater within the study area.

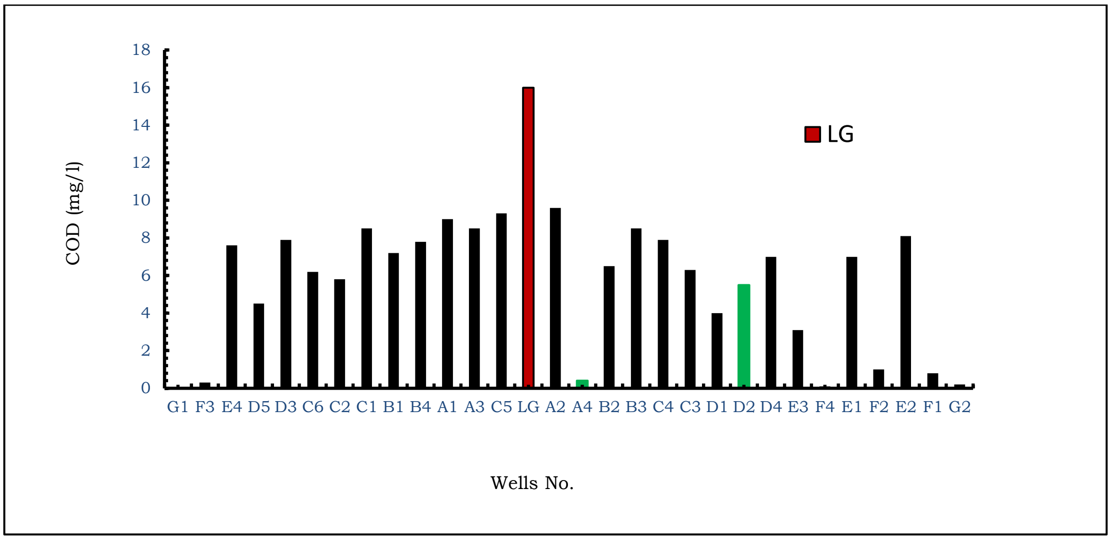

Fig. 10: Chemical Oxygen Demand level in the lagoon and surrounding wells

Seawater contamination.

Contamination by seawater into wells according to SR was detected and classified as depicted by (Todd, 1959). The Simpson ratio of the lagoon water was 1.04 which is less than those for the groundwater in the study area. The results revealed that Simpson ratio values fluctuated between 1.08 and 6.8 with mean and standard deviation equal to 1.86 and 1.06, respectively. Well No A1 had a ratio of 6.80 which indicating highly seawater contaminated. Few wells which are G1, D5, C2, A3, B2, D2, E1 revealed values less than 1.30 and classified as slightly contaminated. The rest of wells were classified as injuriously and highly contaminated. Fig. 11 shows the spatial distribution of SR. It can be noted a point source contaminated region originated from well A1. Such source revealed a seawater upcoming which can be expected due to the excessive pumping in the regions close to the sea (Ekhmaj *et al*., 2014, El-Trriki, 2006). Such phenomena induced non-significant correlation between SR in the groundwater and the distance from the wells location to the nearest distance to the coast line. In addition, the insignificant negative correlation between SR in the groundwater and the distance from the wells location to the sewage lagoon indicated no impact of the sewage lagoon on SR in the groundwater, as well (Table 4).

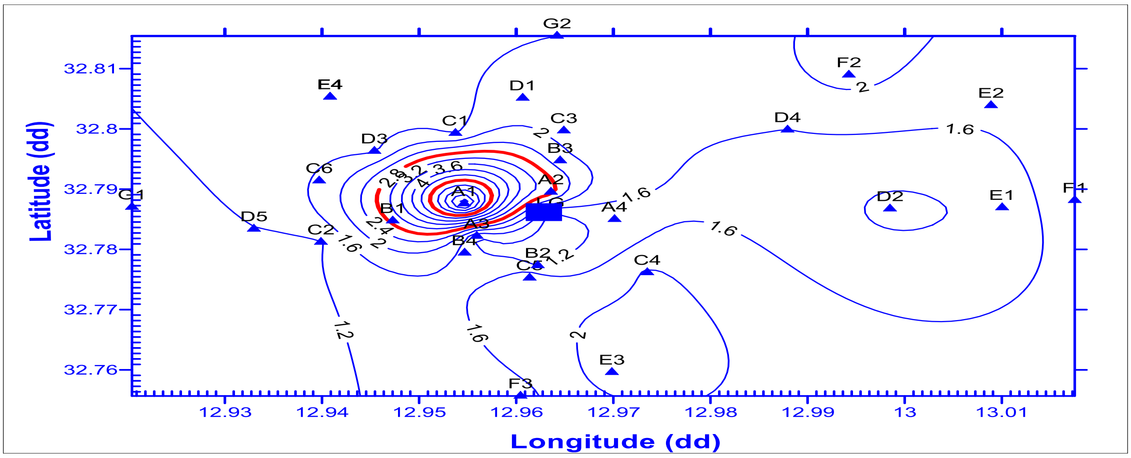

Fig.11: The spatial distribution of the values of Simpson ratio in the study area.

Conclusion:

From the conducted measurements and the above discussion, the following conclusions can be extracted. The study area is consisted of rock formations with high permeability that facilitates the movement of pollutants. Sewage waste contains chemical and biological pollutants that can be harmful for health. In case of chemical pollution, the sewage lagoon represents the source for nitrate and phosphate contamination. Also, it contributes in contamination with potassium. Other pollutants such as sodium, calcium, magnesium, chloride and bicarbonate are not related to the sewage lagoon. Beside the pollutants mentioned here, the sewage lagoon could be a source of other pollutants such as heavy metals. For biological pollution, the sewage lagoon represents the main source of pollution for coliform bacteria, chemical oxygen demand, and biological oxygen demand.

The level fluctuation of pollutant in wells is due to many factors such as distance from the pond, well depth and casing, and amount of pumping from the well. From the results of Simpson ratio, the groundwater in the area is affected by seawater intrusion.

To minimize the dangerous of sewage waste pollution, the following recommendations should be taken into account. The well location should be far enough from the sewage lake and any individual sink hole. The disposal area should be subjected to engineering design that fits the international specification to minimize the infiltration from the lake. Before discharged to the lake, the waste water should be going through waste treatment plant which highly minimizes the pollution. The community should be aware about the use of water that is extracted from these wells. Depends on the stage of treatment process, the treated water can be applicable for different uses.

Although this study is not relatively recent, the results obtained shows the negative effects of sewage water which diverted into collecting lagoon on the groundwater. It also confirms the continuation of conducting many studies to track the distribution of groundwater pollution spatially and temporally.

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