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Comprehensive study on groundwater quality for domestic and agricultural purposes at al khassah area, kirkuk province, Iraq

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Abstract: The present study offered comprehensive groundwater quality information in Al Khassah area at Kirkuk province. The state of water quality collected from 10 well sites is compiled and compared with the obtained data with some international quality criteria of surface fresh waters intended for irrigation and domestic water supply. In order to monitor the groundwater quality and determine its suitability for different purposes; hydrochemical parameters (pH, EC, TDS, DO, BOD_5, COD, TN, TP, NH_3) and heavy metals concentrations (Pb, Mn, Cr, Cd, Ni, Cu, Zn, Fe) were measured and exhibited local variations. Groundwater quality information was emphasized from comparison of the present current concentrations in the well sites with international quality criteria for drinking water. It was found that most averages of hydrochemical parameters and heavy metals for all well sites are lesser than the maximum admissible and desirable limit except for Cd. In general, it was found that the underground water quality studied from Al Khassah area is suitable for irrigation and domestic purposes

Keywords: Wells water, Pollution, Hydrochemical parameters, Heavy metals, Standard International limits

1.Introduction

Al-Khassah area in Kirkuk has recently witnessed an increase in population compared to previous years, as well as urbanization, which requires increasing the supply of energy sources including water and food. Local residents in this area were depend on the groundwater for drinking purposes in order to meet their daily needs due to lack of surface water, as a result of increasing population in this region. The chemical characteristics of natural water are a reflection of the contact with the soils and rocks. In addition, agricultural and urban runoff, municipal and industrial treated wastewater all has impact onthe water quality.

Water pollutants include contamination due to domestic wastes, insecticides and herbicides, pollutants from heavy metals livestock action, chemical waste, volatile organic compounds, and others.

Many ecological changes that occur in water result from human activities include agricultural, industrial and municipal wastes (1). Some of these substances are harmless, although many of them add disagreeable odors or taste to the water; others are significantly upset the ecosystem without being direct hazardous to humans and plants.

(2) and (3) carried out a groundwater regional study on Al Adhaim basin on order to determine the hydrogeological characteristics of the aquifers in the study area. They evaluated the advantages and disadvantages of Kirkuk Irrigation Canal, the hydrological circumstances, the groundwater levels and the effects of the canal on the groundwater quality. A rise of the water table due to the good irrigation project where Kirkuk was addressed using wells pumping (4). A hydrogeological study of the upper Al Adhaim basin made by (5), and indicated the existence of two hydrogeological systems; confined (Bai Hassan) and unconfined (Quaternary). The recharge is achieved by rain and the branches of the Al Adhaim River.

Study area

AL-Khassah area is located north of Iraq at northeastern part of Kirkuk province (Fig. 1). It forms the north side of Al Adhaim basin with an area of 420 km^2. The area is formed of a series of long, sinuous fold mountains trending northeast and separated by valleys in the middle and eastern parts. It represents deep valley contains ephemeral stream coming down from the high areas where

soil is formed as a result of intensive erosion processes on formation rocks; Bai-Hassan and Mukdadiyah. The study area contains a number of villages inhabited by thousands of peoples; and most lands are occupied by farms where the population depends on the groundwater.

Water samples were collected from 10 well sites at Al Khassah area (Table 1, Fig. 1). The objective of the present study is to evaluate the groundwater quality in the studied well sites of Al Khassah area for irrigation and domestic purposes.

2. Materials and methods

The hydrochemical parameters of water samples were measured using portable digital meters at the laboratory of Environmental Research Unit, University of Kirkuk (Iraq). **pH** was measured with pH meter (Model : WTW inolab pH 720). **EC** and TDS were measured using portable digital meters. **TN** was determined by using Kjeldahl method according to (6). **DO** was measured by using DO meter. **BOD_5** was determined by using the 5 days method at 20 C°. **TP**, **COD** and **NH_3** were determined by using Spectrophotometer. Concentrations of heavy metals; Fe, Zn, Mn, Cu, Ni, Co, Pb and Cd were measured after filtering process by the Atomic Absorption Spectrophotometer (Model AA-7000, SHIMADZU, Japan).

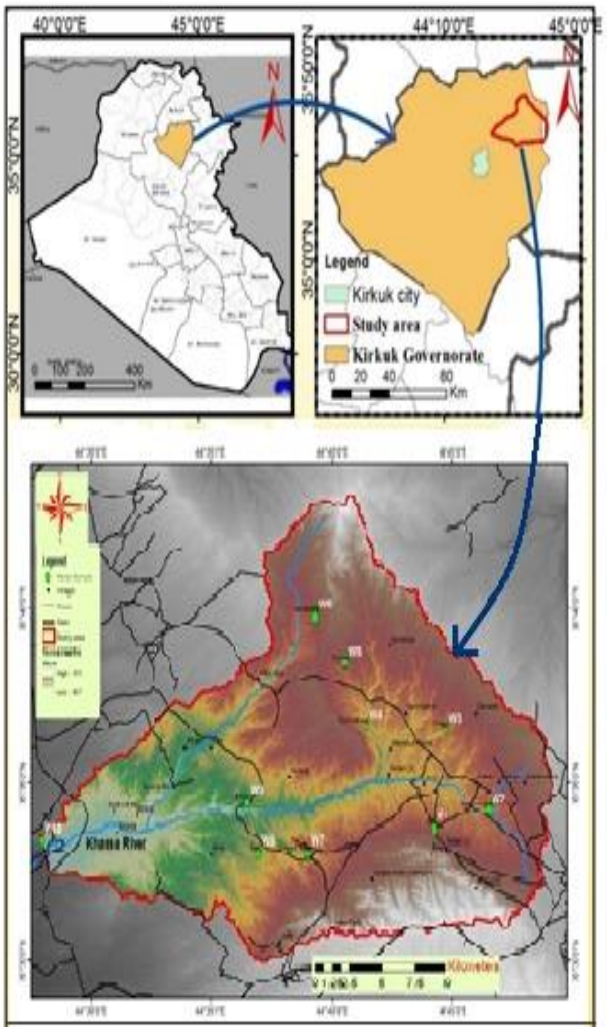

Fig.1 Key map showing distribution of groundwater well sites at Al Khassah area

Table 1. Local names and depths of the Wells water sites

Well no	1	2	3	4	5	6	7	8	9	10
Depth (m)	55	150	170	60	100	155	100	180	100	180
Locality	Bina	Ibrahim Agha	Chalaw	Gulam Kawa	Daesala	Dar Basara	Gurgagi Khan	Sarti	Goran	Kuchak

3.Results and discussion

Hydrochemical characteristics

Data of hydrochemical parameters are summarized in Table 2 and represented graphically in bar graph distributions shown in Figs (2 to 9).

pH values ranged between 7.33 and 7.92 with an average of 7.6. Small local differences were observed (Fig.2) where the pH values of all locations can be described as slightly alkaline to alkaline. Average of pH values lies within the range of permissible limits of (7**)** for drinking water and irrigation water (6.5 - 8.5). The presence of $CaCO_3$ in high amounts raises the pH value of water and thus switching it to alkaline.

EC measures total soluble salts, their values fluctuated between 306 and 840 µs/cm with an average of 492 µs/cm, lower than the permissible limits of (7) (1500 µS/cm). Variation of EC values is depending on the nature and distance from pollution source. The lowest EC value is noticed in well site 4 (Fig.3).

TDS values varied from 152 to 420 mg/l with an average 273 mg/l, lower than the permissible limits of (7) (1000 ppm). According to the classification of water salinity Al Khassah groundwater is considered fresh water, which means that the groundwater in Al Khassah area is suitable for irrigation and domestic purposes. For good quality water, the total dissolved salts (TDS) should not exceeds 500 ppm. For irrigation purposes and agricultural expansion, water quality is considered satisfactory when it contains TDS less than 1000 ppm and considered inferior if it contains more than 2000 ppm of salts.

DO values ranged between 3.43 and 5.32 mg/l with an average of 4.65 mg/l, lower than the permissible limits of (7) for drinking water (9.26 mg/l) indicating fragile water quality. This means that the consumption of high rate of oxygen in the decomposition of organic matter discharged in this area is considered the major cause of diminishing the oxygen. All groundwater samples analyzed from Al Khassah wells are classified as moderately polluted water according to (8).

Table 2 Results of hydro-chemical parameters determined in groundwater samples collected from well sites at Al Khassah area.

P.L.*= Permissible limit of WHO (2017).

Well Site no.	EC µs/cm	TDS mg/l	pH	DO mg/l	BOD mg/l	COD mg/l	TN mg/l	TP mg/l	NH_3 mg/l
1	438	219	7.38	4.67	0.39	1	6.182	0.066	0.081
2	519	258	7.92	4.21	1.37	1	12.130	0.036	0.090
3	707	352	7.40	3.43	1.39	2	4.045	0.012	0.051
4	166	334	7.75	5.29	0.50	3	4.630	0.046	0.071
5	840	420	7.75	5.19	1.10	2	6.395	0.030	0.085
6	592	295	7.36	5.23	1.20	1	1.743	0.028	0.042
7	310	154	7.33	4.21	1.10	2	4.968	0.023	0.081
8	612	306	7.54	4.93	1.00	2	4.075	0.023	0.072
9	306	152	7.62	4.58	2.31	3	4.669	0.011	0.077
10	432	241	7.82	4.81	1.20	2	2.510	0.042	0.060
Ave.	492	273	7.60	4.65	1.16	1.9	5.13	0.030	0.07
P.L.*	1500	1000	<8.5	9.26	1.1	3.42	-	-	0.2

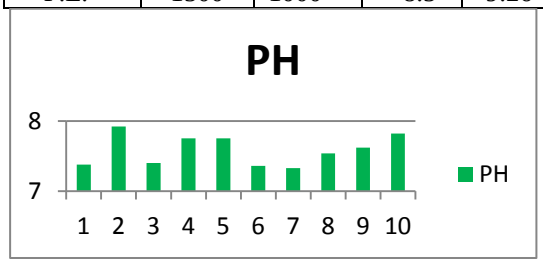

Fig. 2 Distribution of pH concentrations in the collected groundwater samples

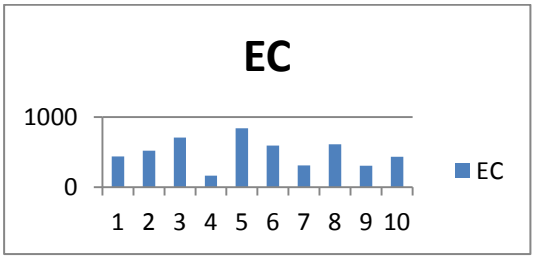

Fig. 3 Distribution of EC µs/cm concentrations in the collected groundwater samples.

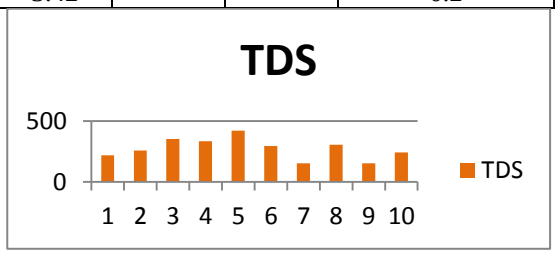

Fig. 4 Distribution of TDS mg/l concentrations in the collected groundwater samples

Table 3 Classification of water based on DO (ppm) values (8).

DO (ppm)	Water Quality
>8	Good
6.5 – 8	Slightly polluted
4.5 – 6.5	Moderately polluted
4 – 4.5	Heavily polluted
<4	Severely polluted

BOD_5 is defined as the amount of dissolved oxygen that consumed by

microorganisms for decomposing organic matter also is an indirect indicator for the amounts of microorganisms such as bacteria in the water. The high level of BOD_5 refers to a decrease of dissolved oxygen levels and high amounts of microorganisms in the water (8 and 9). BOD_5 values showed distinct variability (Fig.6) ranging between 0.39 and 2.31 mg/l with an average of 1.16 mg/l, generally equal to the permissible limit of (7) (1.1 mg/l); could be considered suitable for irrigation and/or domestic purposes. According to (10) classification all groundwater samples analyzed from Al Khassah wells are clean water (BOD_5 <2).

COD values fluctuated between 1 and 3 mg/l with an average of 1.9 mg/l, lower than the permissible limit of (7) (COD not exceeds 3 mg/l). Thus these underground waters are suitable for irrigation and domestic purposes. Distribution of COD values is shown in Fig. (7). High COD content recognized at well sites 4 and 9 (Gulawa and Goran) is probably due to the high decomposition rate of organic matter as a result of low DO content. Low COD content exhibited in well sites 1, 2, and 6 (Bina, Ibrahim Agha and Dar Basara) is probably due to phytoplankton abundance (11). Estimation of BOD/COD ratio indicates that waters at well sites; Ibrahim Agha and Dar Basara are the most polluted sites (1.37 ppm and 1.2 mg/l, respectively)

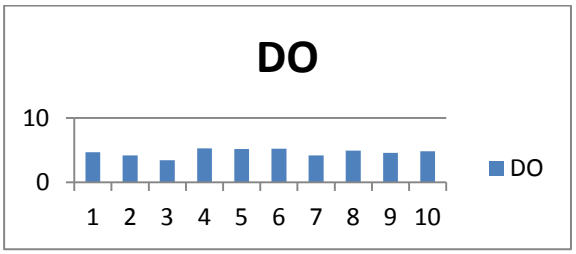

Fig. 5 Distribution of DO mg/l concentrations in the collected groundwater samples

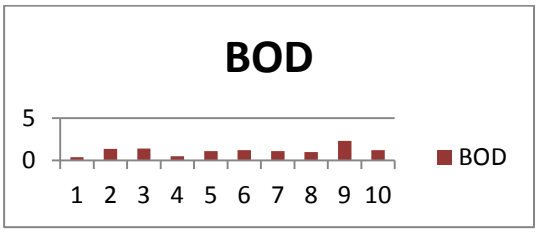

Fig. 6 Distribution of BOD mg/l concentrations in the collected groundwater samples

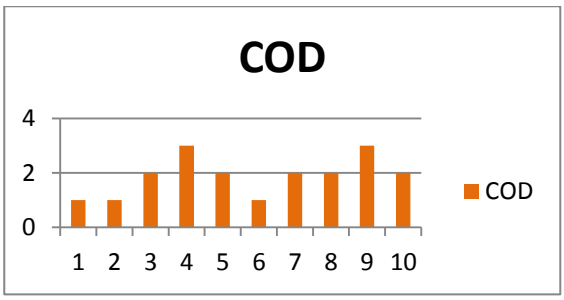

Fig. 7 Distribution of COD mg/l concentrations in the collected groundwater samples

TN values exhibit remarkable local variation (Table 3, Fig. 7) ranging between 1.74 and 12.13 mg/l with an average of 5.13 mg/l. The highest (TN) value (12.13 mg/l) was recorded at well site 2 (Ibrahim Agha), this is probably due to high nitrate concentrations in the drainage water. The lowest concentration of TN values (1.74 mg/l) is recorded at well site 5 (Dar Dasara). Contamination of N and P comes from septic tanks because of the effluent discharge by means of tile drains and seepage pits (12).

Phosphorus is an essential nutrient for living organisms and appears exclusively as phosphate (PO_4^{-3}) in aquatic environment. Phosphate is a constituent of soils and is used extensively in fertilizer. Run off from agricultural areas is a major contributor of phosphates in surface and underground waters. **TP** values ranged between 0.011 to 0.066 mg/l with an average of 0.03 mg/l. The highest TP value (0.66 ppm) was found at well site 1 (Bina) due to agricultural drainage water rich with fertilizers, and the lowest TP value (0.011 ppm) was recorded at well site 9 (Goran).

The bacterial decomposition of organic matter containing nitrogen in the aquatic system may have led to the presence of ammonia (13). Ammonia is considered as the major proportion of total soluble inorganic nitrogen. Ammonia concentrations. **NH_3** measured in the groundwater of Al Khassah area ranged from 0.042 to 0.090 mg/l with an average of 0.07 mg/l, lower than the permissible limit of (7) (0.2 mg/l). The highest NH_3 value is recorded at well site no. 12 (Ibrahim Agha) where the rate of ammonification process increases and converts the organic matter to ammonia at high temperature

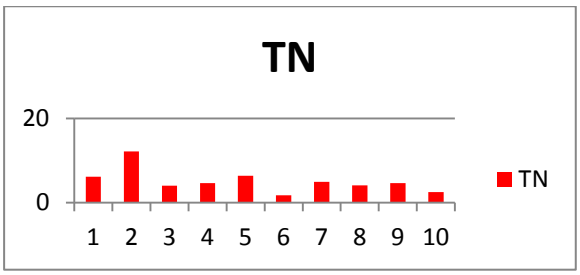

Fig. 7 Distribution of TN mg/l concentrations in the collected groundwater samples.

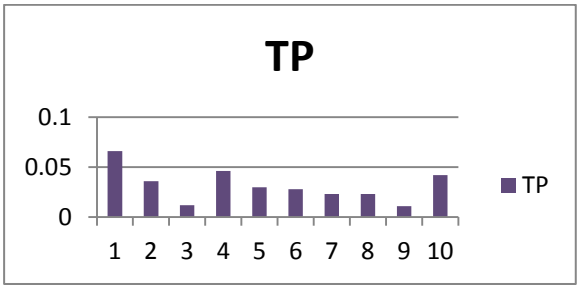

Fig. 8 Distribution of TP mg/l concentrations in the collected groundwater samples.

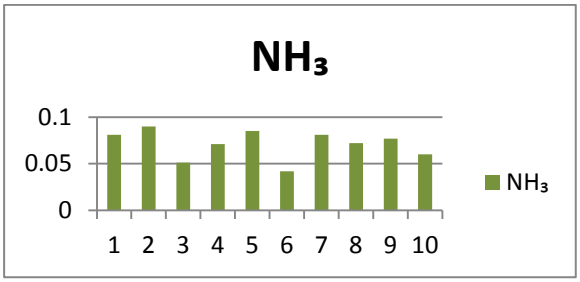

Fig. 9 Distribution of NH_3 mg/l concentrations in the collected groundwater samples

2-Heavy metal concentrations in the underground water.

The dangerous heavy metals related to anthropogenic origin are toxic pollutants and able to transfer into human through the food-chain (14). Metals are non-degradable and can accumulate in human body, causing damage to the nervous system and internal organs (15 and 16). Results and data of heavy metals measured in the ten well water samples are summarized in Tables (4&5) and shown in (Figs.10&11). In general, it was found that concentrations of heavy metals in the groundwater of Al Khassah area follow the order; Fe > Cu > Cd > Ni > Pb > Mn > Cr. Their behavior and distribution are discussed and interpreted in the following:

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Pb concentration has a distinct variable distribution (Fig.12), fluctuating

between 0.0027 and 0.0148 mg/l with an average of 0.0084 mg/l, lower than the permissible limits of (7) (not exceed 0.01 mg/l). Pb content exhibits positive correlation with Cd (r = 0.512).

Mn values occurred between 0.0010 and 0.0113 mg/l with an average of 0.0064 mg/l, lower than the permissible limits of (7) (not exceed 0.1 mg/l). The maximum Mn content is recorded at well site 1 (Bina) while the minimum content recorded at site 3 (Chalaw) (Fig.13). (17) reported that the burning discharge of diesel fuel in the motor cars is the major sources for manganese in air and water. Mn has a strong positive correlation (significant) with Cu and Ni (r = 0.717, r = 0.500 respectively, Table 5).

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Table 4 Soluble heavy metal concentrations in Al Khassah groundwater

Well Site no.	Pb mg/l	Mn mg/l	Cr mg/l	Cd mg/l	Ni mg/l	Zn mg/l	Cu mg/l	Fe mg/l
1	0.0136	0.0113	0.0005	0.0162	0.0300	0.0792	0.1304	0.1884
2	0.0068	0.0067	0.0028	0.0089	0.0113	0.0502	0.0398	0.1742
3	0.0027	0.0010	0.0015	0.0083	0.0144	0.0386	0.0385	0.2025
4	0.0056	0.0041	0.0079	0.0096	0.0072	0.0405	0.0371	0.2096
5	0.0138	0.0016	0.0005	0.0221	0.0025	0.0280	0.0302	0.1949
6	0.0025	0.0061	0.0108	0.0102	0.0028	0.0097	0.0336	0.1914
7	0.0128	0.0064	0.0012	0.0143	0.0033	0.0032	0.0306	0.1855
8	0.0067	0.0042	0.0017	0.0083	0.0066	0.0021	0.0342	0.1914
9	0.0047	0.0069	0.0014	0.0160	0.0032	0.0031	0.0360	0.1814
10	0.0148	0.0056	0.0005	0.0092	0.0031	0.0029	0.0499	0.1963
Ave.	0.0084	0.0064	0.0029	0.0123	0.0084	0.0257	0.0460	0.1916
P.L.*	0.01	0.1	0.05	0.003	0.07	3	2	0.3

P.L.* = Permissible limit of WHO (2017).

Table 5 Correlation coefficients matrix for the groundwater samples

	Pb	Mn	Cr	Cd	Ni	Zn	Cu	Fe	EC	TDS	pH	DO	BOD	COD
Pb	1													
Mn	0.273	1												
Cr	-0.603	-0.032	1											
Cd	0.51*	0.104	-0.363	1										
Ni	0.118	0.500*	-0.238	0.005	1									
Zn	0.096	0.316	-0.062	0.115	0.867*	1								
Cu	0.405	0.71*	-0.260	0.193	0.886*	0.71*	1							
Fe	-0.093	-0.544	0.275	-0.180	-0.044	0.036	-0.086	1						
EC	-0.005	-0.499	-0.194	0.185	-0.001	0.037	-0.130	0.000	1					
TDS	-0.148	-0.73*	0.207	0.010	0-.068	0.198	-0.244	0.596*	0.65*	1				
pH	0.164	-0.187	-0.111	-0.054	-0.272	0.038	-0.244	-0.067	-0.046	0.228	1			
DO	0.172	0.104	0.450	0.250	-0.315	-0.166	-0.019	0.218	-0.114	0.235	0.243	1		
BOD	-0.365	-0.166	-0.171	0.051	-0.476	-0.527	-0.492	-0.456	0.073	-0.321	0.128	-0.333	1	
COD	-0.131	-0.396	-0.082	0.085	-0.443	-0.400	-0.423	0.423	-0.433	-0.023	0.208	0.108	0.288	1

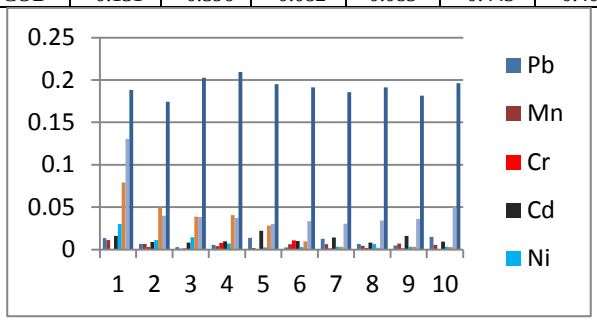

Fig. 10 Distribution of heavy metal concentrations in Al Khassah groundwater samples.

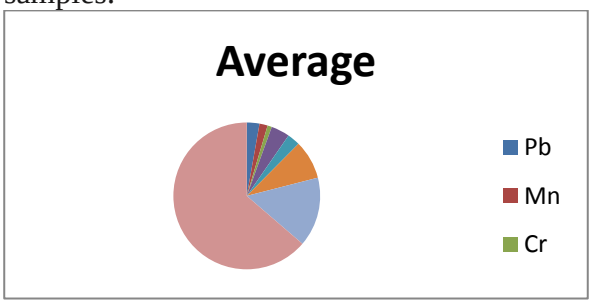

Fig. 11 Pie average concentrations of heavy metals in Al Khassah groundwater samples

Cr values exhibit considerable variable distribution (Fig. 14) with maximum value (0.0108 mg/l) at site no. 6 (Dar Basara) while the lowest content (0.0005 mg/l) occurred at sites no. 1, 5, 10. Cr has average concentration equals 0.0029 mg/l, lower than the limit given by (7) (not exceed 0.05 mg/l)

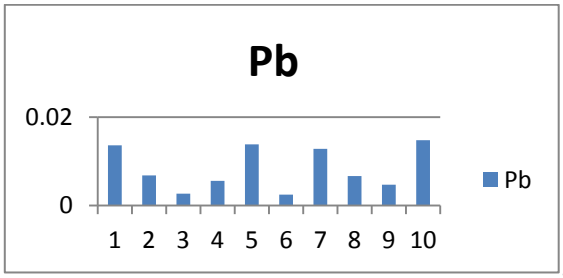

Fig. 12 Distribution of Pb concentrations in the collected groundwater samples

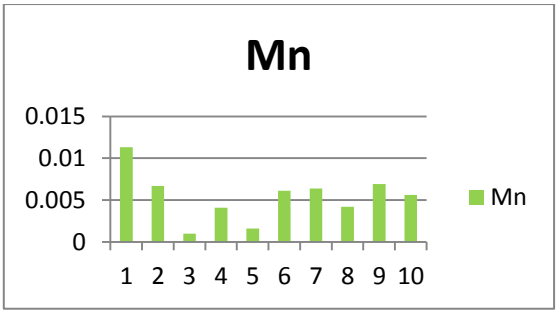

Fig. 13 Distribution of Mn concentrations in the collected groundwater samples.

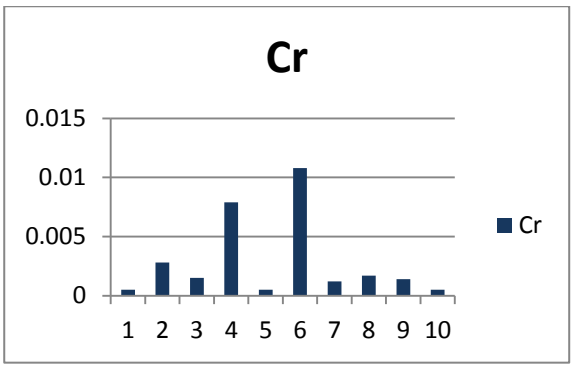

Fig. 14 Distribution of Cr concentrations in the collected well water samples

Cd is extremely toxic to biota and living organisms, even at low concentration and has a long biological life of 20-30 years in the kidney (18). The main source of Cd is the phosphatic fertilizers used in crop farms (19). The measured Cd content ranged between 0.0083 and 0.0221 mg/l (Table 4) with an average of 0.0123 mg/l, higher than the permissible limits of (7&22) (values not exceed 0.003 mg/l). Maximum Cd concentration recorded at well site 5 (Daesala, Fig. 15) was probably related to hazardous waste discharged from point source. Cd has a positive correlation with Pb (r = 0.512, Table 5).

Ni displays variable distribution (Fig.16) with values varied from 0.0024 to 0.0300 mg/l and average 0.0084 mg/l less than the permissible limit of (7) not exceed 0.07 mg/l). The highest Ni value seen in well site 1 (Bina) is probably related to fuel exhaust and abrasion of tires rubber (20). Ni has a significant strong positive correlation coefficient with Cu, Zn and Mn (r = 0.886, r = 0.867, r = 0.500, respectively, Table 5).

Zn is an essential trace metal for the growth of aquatic organisms. Zn concentration in Al Khassah well water samples fluctuated between 0.0021 and 0.0792 mg/l with an average of 0.0257 mg/l less than the permissible limits of (7) (not exceed 3.0 mg/l). The maximum concentration of Zn is recorded at well site1 (Bina, Fig.17). Zn has a strong positive correlation with Cu (r = 0.710) indicating the same source of pollution.

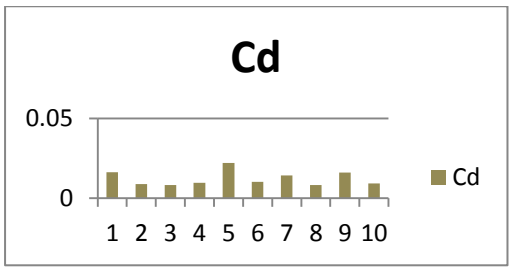

Fig. 15 Distribution of Cd concentrations in the collected groundwater samples

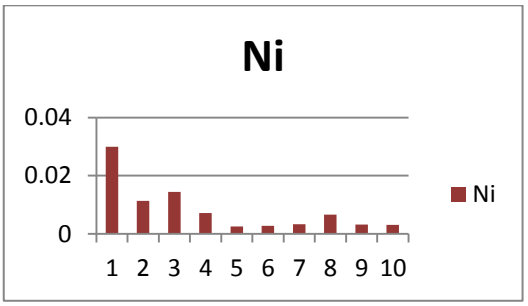

Fig. 16 Distribution of Ni concentrations in the collected groundwater samples 16

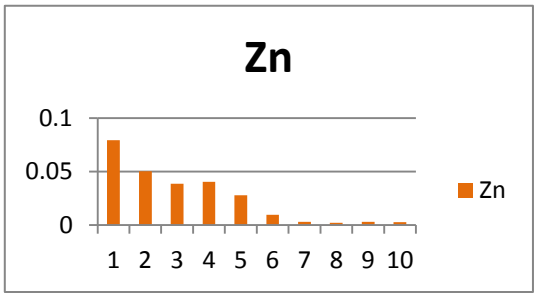

Fig. 17 Distribution of Zn concentrations in the collected groundwater samples

Cu contents varied between 0.0302 and 0.1304 mg/l with average 0.0460 mg/l less than the permissible limits of (7) for drinking water (not exceed 2 mg/l). The highest Cu concentration is recorded at well site 1 (Bina, Fig. 18), this may be due to polluted water area. The main contributors of Cu in the environment are the domestic sources (21). Cu has a significant strong positive correlation with Ni, Mn, Zn, Pb (r = 0.867, r = 0.717, r = 0.710, respectively, Table 5).

Fe concentration exhibits no distinct variation (Fig. 19). Fe values varied from 0.1742 to 0.2096 mg/l with an average of 0.1916 mg/l, lower than the permissible limit given by (7) where Fe not exceed 0.3 mg/l. Iron compounds are most probably related in the aquatic environments to the precipitation of Fe in alkaline and oxidizing conditions. Fe content in all samples has positive correlation with TDS (r = 0.596, Table 5)

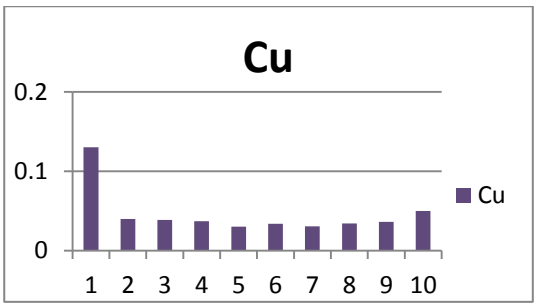

Fig. 18 Distribution of Cu concentrations in the collected groundwater samples

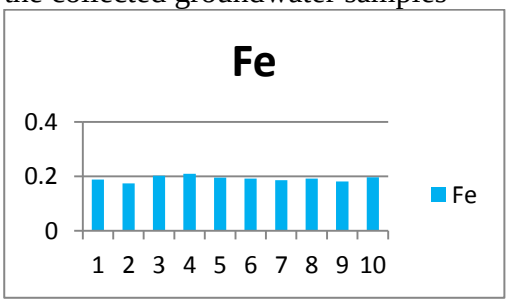

Fig. 19 Distribution of Fer concentrations in the collected groundwater samples

Water quality information for Al Khassah groundwater can be emphasized from comparison of the present current concentrations in the well sites with international quality criteria for drinking water (22 and 7, Table 5). It was found that most of the average concentrations of heavy metals for all well sites are lesser than those suggested by European Communities Directives except for Cd metal. In general, concentrations of the other heavy metals are characterized by remarkable local variations. Water of well site 1 displays the highest concentration probably due to point source pollution. Thus the groundwater quality in Al Khassah area is suitable for irrigation and domestic purposes

Table 5 Standards specifications for heavy metals in natural water

Well Site no.	Element	IQS (2009) ppm	WHO (2017) ppm	Present study averages ppm
1	Pb	0.01	0.01	0.0084
2	Mn	0.1	0.1	0.0064
3	Cr	0.05	0.05	0.0029
4	Cd	0.003	0.003	0.0123
5	Ni	0.02	0.07	0.0084
6	Zn	3	3	0.0257
7	Cu	1	2	0.0460
8	Fe	0.3	0.3	0.1916

Conclusion

Most average values of hydrochemical parameters and trace metals determined in ten groundwater samples from Al Khassah area were less than the maximum admissible and desirable limit when compared with the National and International organizations except for Cd which exceeds the permissible limit due to combination of several factors; domestic waste, industrial discharge and return flow of agricultural drainage waters. Therefore it was not surprise to find inferior water quality at well site 1. Concentrations of TP, TN, TDS, BOD, Cu, Pb, Zn, Fe increase significantly as we proceed from up to downstream sites where the multipurpose uses of water and human activities are intense. For domestic and irrigation purposes water quality is considered satisfactory

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