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Health safety of drinking water: A study of the groundwater case of Wana district, northern Iraq.

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Abstract

The current study aimed to assess the quality of water for human use using the Water Pollution Index (WPI) in comparison with the limits of international standards for evaluating the quality of groundwater in the Wana region, located in the northeastern city of Mosul, Iraq, for drinking and domestic uses. Water samples were collected from 10 scattered wells. In the Wana sub-district (the villages of Deir Umm Tutha and Meshref Hobit) during the summer, autumn, and winter. 2022-2023 (ten replicates from each well) to conduct physical, chemical and bacteriological tests based on international standard methods.

The results of the water quality index. (WQI) indicated the deterioration of water quality of most studies groundwater quality, which were of the water type (10% poor water quality, 70% very poor water quality and 20% unfit water quality) for drinking and domestic uses. This deterioration is attributed to bacterial contamination. (total number of bacteria TPC), and high concentration of salts, Total hardness and sulfate ions. Thus, The study recommended using some simple techniques, such as the slow freezing and thawing method or solar radiation treatment, to improve the water quality before using it for drinking.

Key word: groundwater quality, Wana distract, logarithmic water quality index.

Introduction:

The problem of lack of safe water has increased as a result of the increased demand for it, which may lead to future issues in many countries of the world, especially in arid and semi-arid regions, due to agricultural and industrial development, as more than half of the world's population suffers from a lack of safe water, especially in third world countries, as well, approximately 95% of civilian wastewater is discharged to water resources, which leads to the spread of transmitted pathogens (Al-Saffawi 2019; Al-Hamdany, 2020a; Khattab et al, 2023; Youniand Darwesh, 2023). All this leads to an increase in the number of people suffering from water problems, which are increasingly dangerous for children, as more than a billion people in African, Asian and South American societies and 450 million people in 29 countries suffer from a lack of safe drinking water, causing large numbers of deaths. Due to the consumption of contaminated water to reach more than a million deaths, especially diarrheal diseases that kill children in poor societies (Talat et al, 2019;Jaafar and Al-Saffawi, 2020;Genter et al, 2022).

The safety of drinking water is of great importance in reducing the spread of epidemics and water-borne diseases, as nearly 60% of infections are caused by contamination of drinking water sources, as confirmed by reports and statistics of the World Health Organization that more than 80% of diseases and more than 33 % of deaths in developing countries were caused by epidemics transmitted by drinking water. For example, in Pakistan, 230,000 children under five die annually due to the contamination of drinking water with civilian wastewater (Al-Hamdany, 2018).

Contaminated water may transmit pathogens to consumers, such as polio, Hepatitis A and *Salmonella typh* and *Vibrio cholera* Cholera, in addition to protozoa such as *Lambilia Giardia*, as well as *Entamoeba histolyties* that cause amoebic dysentery, as well as *Naegleria graberi*, which may settle in the brain, causing danger to human life, in addition to the presence of types of viruses such as Rota virus and Norwalle virus, as indicated by (Al-Saffawi, 2018;Das et al, 2022; Bakari et al, 223).

On the other hand, high sulphate ions give the drinking water a bitter taste and cause diarrhea, especially when magnesium is the accompanying ion. In addition, high levels of nitrate ions harm humans, causing cyanosis, enlarged thyroid glands and cancerous diseases.

Likewise, with pregnant women, high levels of nitrates lead to an increase in the developmental delay of the nervous system and mental retardation in preterm births, in addition to the possibility of miscarriage, brain tumours, and sudden neonatal death (CIDS), as indicated by (Najic and stanic, 2017; Drozd et al. , 2018;Al-Mashhadany, 2022; Mothfer and Al-Saffawi, 2023; Al-Gadi et al, 2023), while the ions that cause hardness are of vital importance to many cellular processes and the prevention of heart disease, Thrombosis, Atherosclerosis, Hypertension, and Liver Cirrhosis. Magnesium ions also play a role in reducing the risk of developing cancerous tumours (Al-Maathidi et al., 2018; Al-Mashhadany, 2021A).

Because of the importance of the quality and safety of drinking water for humans, periodic examinations of drinking water must be conducted and evaluated with modern techniques, such as the use of mathematical models as one of the good and easy means to know the interfering effects of the studied parameters, and then find a single value that describes the quality of water instead of the huge amount of data that is understood by everyone (Al-Hamdany and Al-Saffawi, 2018; Yang et al, 2023). Therefore, this study came to evaluate the groundwater quality in the district of Wana and its villages using the logarithmic model in comparison with the international standard specifications.

Materials and Methods:

1.Study area:

The study area is located south and southeast of Mosul Dam in northern Iraq between longitudes 42◦45'- 03◦43' and latitudes 30◦36- 36◦36' at a distance of about (35) km northwest of the city of Mosul. The region is bounded from the west and south by the Tigris River, while from the east, it is bordered by the hills and heights of the village of Al-Mistah, which are an extension of the mountains and heights of the village of Al-Dawasa, but it is more rugged. The area rises about 450 meters above sea level in the highlands, while the lowest elevation is about 245 meters in the west and south of the area near the riverbed. The area is interspersed with shallow valleys that descend to the Tigris River. Table (1) and Figure (1) show some characteristics of the wells and the studied area. The study area is also characterized by its agricultural nature, where most of the local population id engaged in agriculture and raising livestock and poultry.

2. Geology of the study area:

The study area is characterized by the spread of the Plaspi Formation (upper middle. Eiocene), which contains limestone, and the Fatah Formation (middle Miocene), which contains salty rocks. (halite), gypsum ($CaSO_4$.$2H_2O$), . anhydrite ($CaSO_4$), in addition to the Anjana Formation (Upper Miocene), consists of a succession of clays, sandy rocks, and marl, which is reflected in the quality of the water passing through it (Al-Youzbaky and Eclimes, 2018; Al-Youzbaky et al., 2018).

Table (1): Characteristics and specifications of the studied area and wells.

Wells No	Coordinates N	E	Depth(m)	Uses
1	36.31’30.821	42.45’34.182	45	ng ute nsi ls an d
2	36.31’7.585	42.46.8.757	100	

3	36.5150938	42.7704600	27
4	36.30’50.20	42.46.14.6	20
5	36.30.50.182	42.46.27.904	50
6	36.30.31.410	42.46.33.801	17
7	36.30.46.305	42.47.51.052	40
8	36.30.52.686	42.49.5.575	41
9	36.30.56.819	42.49.5.067	117
10	36.30.53.091	42.49.21.773	50

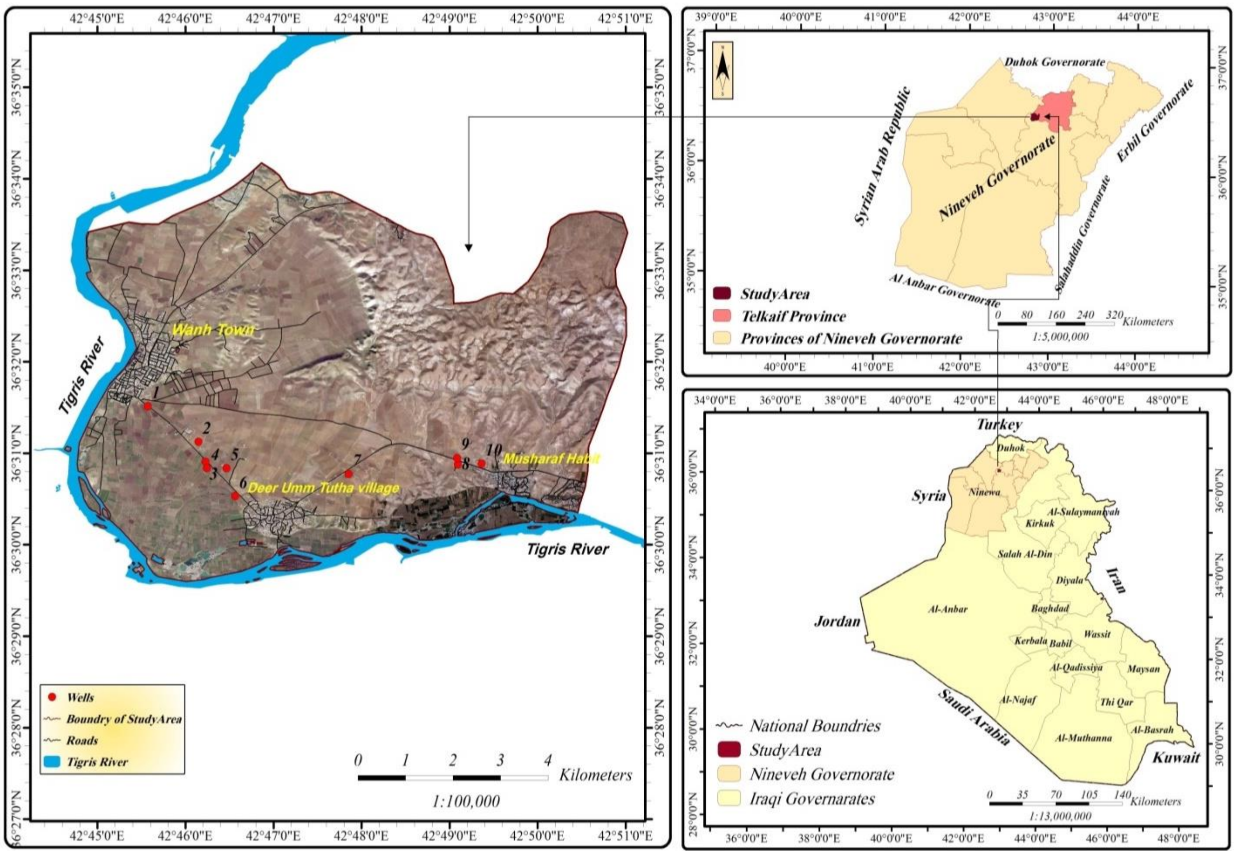

Figure 1: A satellite map of the location of the wells of the town of Wana and its affiliated villages, showing the wells studied.

3. Methodology:

The current study included [collecting one hundred water samples from ten wells scattered in the Wana district and the villages of Deir-Um Tutha and Musharraf Ahbeet during the summer, fall and winter of 2022-2023 using clean polyethene bottles, which were washed with the sample water before filling it. As for the samples for dissolved oxygen, Glass bottles with a capacity of 100 ml were used, with a tight seal, filled with the least possible ventilation, and fixed in the field by adding 1 ml of manganese sulfate reagent (Winkler A), then 1 ml of Akali-Iodied-Azid reagent (Winkler B) . In addition to the samples for the bacterial examinations, sterilized autoclaved glass bottles were used. The samples were placed in a refrigerated box and away from light until reaching the environment laboratory at the College of Education for Pure Sciences to conduct the required analyses (APHA, 1998; 2017). Tests were also performed for each of the following characteristics: Temperature, pH , electrical conductivity (EC_{25}), total alkalinity (T. alk.), Total hardness (TH), chloride, sulfate , phosphate, nitrate, total number of bacteria$_1$ (TPC) and Fecal coliform based on global methods of measurement (APHA, 1998, 2017).

4. Estimation of the water quality index:

The weighted logarithmic water quality index (WQI) was applied to twelve important characteristics in comparison with the global standard limits of drinking water (WHO, 2017) using the following equations (Hossen et al, 2019; Khan and Tahsin, 2020; Khan et al, 2021; Pantha et al, 2022).

$$WQI = \text{Anti log} \sum \{Wi \times \text{Log10}\ Qi\}$$

$$K = \sum_{i=0}^{n} 1 \ / \ Vs$$

$$Wi = \frac{K}{Vs}$$

$$Qi = \left(\frac{Va - Vi}{Vs - Vi}\right)$$

Where: Wi = unit weight ofthe ithparameter.,K = proportion constants., i : sub index corresponding to the ith parameterVa : actual value of each parameter. Vi = the deal value of each parameter (for pH = 7.0., DO = 14.6 mg.l^{-1}, while other parameters are equal to zero. Vs = the internationally recommended standard value, as shown in (table 2).

Table 2: Standard limits (Vs), and weight (Wi) for each parameter for drinking and household uses.

Parametrs		Vs	Wi
T.∘C		25	0.06530100
P H		6.5-8.5	0.21766660
EC_{25}	*uS. Cm*	1400	0.00116607
DO	*mg. l^{-1}*	5.0	0.32650000
T.A	*mg. l^{-1}*	200	0.00816250
T.H	*mg. l^{-1}*	500	0.00326500
Na^{+}	*mg. l^{-1}*	200	0.00816250
Cl^{-}	*mg. l^{-1}*	250	0.00653000
SO_4^{-2}	*mg. l^{-1}*	400	0.00408130
PO_4^{-3}	*mg. l^{-1}*	10.0	0.16325000
$NO3^{-}$	*mg. l^{-1}*	50.0	0.03265000
TPC	*Cell. ml^{-1}*	10.0	0.16325000
∑			1.00325000

After finding the values of the quality index (WQI), the water quality is determined by referring to Table (3) (Jaafar and Al-Saffawi, 2020).

Table (3): Water quality index values, class and condition of drinking water *

WQI	Values	0.0 to 25	26 to 50	51 to 75	76 to100	>100
	Statue	Excellent	Good	Poor	Very Poor	Unfit
	Class	A	B	C	D	E

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Results and discussion:

The results of the logarithmic model shown in Table (4) for assessing the suitability of groundwater for drinking and domestic uses indicate that the WQI values ranged between (55.53 to 107.4); To classify the water quality according to Table (3) from the category of poor-quality water to Unfit, and the highest value of the studied samples was in well 10 and the lowest values in well 4. This deterioration in groundwater quality is mainly due to the low concentrations of dissolved oxygen in the water and bacterial contamination. Then the hydrogen ace, although the values are within limits, the reason is due to the high relative weight (Wi). As for the relative increase in the value of the water quality index for well 10, it is mainly due to the rise in the total number of bacteria, the TPC value, which was reflected negatively on the values of (Wi × log Qi), and this confirms the results of the characteristics shown in Table (5), Where the relative decrease of the dissolved oxygen concentration is observed to fluctuate between (2.40 to 7.60) $mg.l^{-1}$, at a rate of (2.90 ± 0.20 to 5.70 ± 0.70) mg. l^{-1}.

Table (4): Results of (Wi*logQi) values, drinking water quality index (WQI), and water status for the study area.

Pararamet. \ Sites		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
T.◦C	Wi*logQi	0.124	0.124	0.124	0.125	0.125	0.125	0.126	0.126	0.126	0.126
P H	Wi*logQi	0.283	0.322	0.390	0.283	0.283	0.322	0.322	0.353	0.333	0.339
EC_{25}	Wi*logQi	0.002	0.002	0.002	0.003	0.003	0.003	0.002	0.002	0.003	0.002
DO	Wi*logQi	0.648	0.647	0.647	0.659	0.662	0.644	0.642	0.645	0.681	0.713
T.A	Wi*logQi	0.017	0.017	0.017	0.017	0.018	0.017	0.016	0.015	0.015	0.014
T.H	Wi*logQi	0.007	0.007	0.007	0.007	0.008	0.007	0.007	0.006	0.008	0.008
Na^+	Wi*logQi	0.012	0.014	0.015	0.015	0.015	0.015	0.012	0.011	0.013	0.011
Cl^-	Wi*logQi	0.008	0.010	0.009	0.011	0.011	0.010	0.010	0.009	0.010	0.008
SO_4^{-2}	Wi*logQi	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.008	0.009	0.009
PO_4^{-3}	Wi*logQi	-0.05	-0.05	-0.05	-0.04	-0.145	-0.048	-0.045	-0.05	-0.04	-0.03
$NO3^-$	Wi*logQi	0.042	0.045	0.045	0.045	-0.036	0.044	0.045	0.045	0.025	0.038

TPC	Wi*logQi	0.807	0.804	0.799	0.800	0.789	0.814	0.778	0.795	0.809	0.794
	∑Wi*logQ	1.913	1.952	2.018	1.932	1.742	1.963	1.924	1.971	1.991	2.031
	WQI value	81.94	89.57	104.2	.8590	55.20	.9162	83.95	92.25	98.17	107.7
	WQI status	V. P.	V. P.	Unfit	V. P.	Poor	V. P.	V. P.	V. P.	V. P.	Unfit

*V.P. :Very Poor

.

Table 5: Range, average and standard deviation of groundwater analysis results for wana town, North West of Mosul city (ppm),

Param. / Wells		T ◦C	pH	EC_{25}	T.alk	T.H	SO_4	Cl	Na	DO	NO_3	TPC *	PO4
1	*min*	19.0	6.98	800	200	580	265	33.3	60	4.80	8.00	3.50	0.035
	max	21.0	7.22	896	232	620	386	52.4	70	6.40	11.0	19.1	0.078
	mean	19.9	7.10	846	220	599	332	44.0	66	5.30	9.70	8.81	0.053
	± sd	0.60	0.09	35.0	11.0	13.0	45.0	5.40	3.3	0.50	0.85	4.84	0.016
2	*min*	19.0	6.98	1257	240	540	349	71.4	95	4.80	12.0	2.75	0.033
	max	21.0	7.30	1621	272	720	415	90.4	112	6.80	12.0	17.9	0.069
	mean	19.9	7.15	1419	249	641	377	79.0	102	5.40	12.3	8.39	0.051
	± sd	0.60	0.11	108.0	9.00	71.0	26.0	6.40	4.9	0.60	0.05	4.73	0.01
3	*min*	19.0	6.99	1223	224	540	344	80.9	95	4.40	11.0	2.90	0.032
	max	21.0	7.31	1341	268	600	425	119	146	7.20	15.0	13.4	0.085
	mean	19.9	7.17	1303	245	571	390	99.0	122	5.40	11.9	7.82	0.053
	± sd	0.60	0.10	40.00	14.0	15.0	28.0	12.7	20	0.80	1.24	3.51	0.017
4	*min*	19.0	6.91	1952	260	800	543	85.7	135	4.00	11.3	3.56	0.035
	max	22.0	7.21	2184	288	1000	652	119	161	5.60	12.4	17.1	0.075
	mean	20.2	7.09	2053	271	924	597	105	145	4.60	12.3	7.98	0.055
	± sd	0.80	0.10	70.00	10.0	88.0	36.0	11.3	9.0	0.50	0.03	4.39	0.013
5	*min*	19.0	6.95	2000	280	880	617	95.2	128	3.60	12.1	2.28	0.029
	max	22.0	7.29	2171	290	1100	705	129	162	5.60	12.3	13.2	0.069
	mean	20.7	7.10	2089	283	1011	654	116	146	4.40	12.2	6.84	0.050
	± sd	1.10	0.12	64.00	4.00	43.0	33.0	11.0	9.3	0.50	0.04	3.58	0.013
6	*min*	19.0	7.02	1845	256	800	522	71.4	125	4.00	11.0	3.34	0.035
	max	22.0	7.25	2596	292	920	646	119	136	7.60	12.0	17.7	0.069
	mean	20.8	7.15	2067	272	876	594	96.0	131	5.60	11.3	9.70	0.051
	± sd	1.00	0.08	264.0	14.0	11.0	37.0	17.1	4.3	1.00	0.57	4.27	0.013
7	*min*	20.0	7.06	1177	184	700	482	76.2	50	4.80	11.0	3.44	0.025
	max	22.0	7.26	1485	212	780	583	114	64	7.20	12.0	9.36	0.082
	mean	21.0	7.15	1353	198	735	527	93.0	58	5.70	11.8	5.81	0.053
	± sd	0.80	0.07	117.0	9.00	25.0	31.0	12.9	4.7	0.70	0.18	2.10	0.016
8	*min*	20.0	7.15	825.0	128	320	262	52.4	33	4.00	12.0	3.39	0.023
	max	21.2	7.3	1015	156	390	354	76.2	50	7.20	13.0	16.0	0.086
	mean	21.2	7.21	930.0	146	361	298	62.0	40	5.50	12.3	7.39	0.053
	± sd	0.80	0.05	56.00	9.00	8.00	29.0	7.30	6.1	0.90	0.22	4.21	0.018

9	*min*	20.0	6.96	1236	128	1000	631	66.6	75	2.40	3.00	4.80	0.033
	max	22.0	7.29	2416	164	1140	717	100	93	3.00	4.00	18.8	0.079
	mean	21.0	7.17	2196	146	1071	683	85.0	83	2.90	3.00	9.00	0.056
	± *sd*	0.80	0.09	351.0	10.0	50.0	29.0	10.1	5.7	0.20	0.26	4.49	0.014
10	*min*	20.0	6.96	1813	104	970	629	33.3	37	2.80	7.00	2.20	0.031
	max	22.0	7.32	2276	130	1020	755	64.9	43	5.60	8.00	16.5	0.096
	mean	21.3	7.18	2138	118	996	697	48.0	40	4.10	7.30	7.32	0.064
	± *sd*	0.80	0.08	126.0	9.00	11.0	39.0	10.9	2.6	0.80	0.25	5.28	0.020

*$\times 10^3$ cell. ml^{-1} .

This decrease may lead to the creation of anaerobic conditions and a change in the paths of reactions to the formation of harmful products, as in the neutrophils that he referred to (Qaseem et al, 2020a ;Sousa-Silva et al, 2020; Omer, 2023):

$2(CH_2O) + H_2O + SO_4^{-2} \longrightarrow H_2S + CO_2 + 3H_2O$

$4C_3H_7O_2NS + 8H_2O \longrightarrow 4CH_3COOH + 4NH_3 + 4H_2S + 4CO_2 + 8H^+$

$4CH_3COOH + 8H^+ \longrightarrow 5CH_4 + 3CO_2 + 2H_2O$

Organic Compound $\longrightarrow PH_3\uparrow + CO_2 + 2H_2O$

$HPO_4^{-2} + 4H_2 \longrightarrow PH_3\uparrow + 2H_2O + 2OH^{-1}$

$HPO_4^{-2} + CH_4 \longrightarrow PH_3\uparrow + CO_2 + 2OH^{-1}$

Whereas 44% of the studied samples exceeded the international standard limits (WHO, 2017). Fortunately, the exposure of groundwater to oxygen when collected in ponds may improve the quality and some of the products are oxidized into harmless forms (Omer, 2023).

It is also noted that the total number of bacteria increased to range from (2.20 to 19.1) x 103 cells. mL-1 at a rate between (5.81 ± 2.1 to 9.70 ± 4.27) x 103 cells. ML-1 This increase in numbers is attributed to the possibility of agricultural and animal waste leaking into the water through the cracks in the ground layers (Al-Saffawi et al, 2020b). The same applies to salinity levels, as the electrical conductivity ranges between (800 to 2596) to exceed 62% of The samples were studied for the recommended standard limits for drinking (WHO, 2017), this fluctuation in the peak may be due to the difference in the geological layers that the groundwater passes through, and this is confirmed by the studies carried out by each of (Al-Saffawi and Al-Shuuchi, 2018)

The results of Peterson's statistical analysis shown in Table (6) also indicate that there is a strong correlation ($P \geq 0.01$) between electrical conductivity, total hardness, and sulfate ions, which indicates the dissolution and dissolution processes of gypsum and anhydrite spread in the aquifer rocks (Khattab et al, 2023). Also, the strong correlation between alkalinity and sodium ions (0.883), indicates reactions that lead to the formation of sodium bicarbonate (Saha et al., 2019).

It is also noted from Table (5) that 67% of sulfate ions are higher than the standard upper limits allowed by WHO. It is also noted that there is a strong correlation () between sodium ions and chlorides, which indicates the passage of water with halite deposits.

As for nitrate ions, a relatively high concentration was observed, reaching rates (3.0 ± 0.26 to 12.3 ± 0.03) mg. This rise in concentrations may be due to fertilization operations in the area, while the phosphate levels in the studied water did not exceed (0.064 ± 0.02) mg. This decrease is due to the ability of phosphate ions to precipitate in the form of calcium phosphate, as well as the ability of clay minerals to adsorb on the surfaces of the particles (Al-Hamdany et al, 2020; Asuma et al, 2020).

Conclusions and recommendations:

Most groundwater was characterized by high electrical conductivity, total hardness, and sulfate ions. This is confirmed by the strong correlation coefficient of Peterson at the level ($P \geq 0.01$), as well as microbial pollution with a low concentration of dissolved oxygen to exceed the recommended limits for drinking, to be reflected negatively on the values of (WQI) to It indicated that the studied water was not suitable for drinking and human uses, especially bacterial contamination, despite the temperature, pH, phosphate ions and nitrates being within the recommended limits. Therefore, the study recommends not using water in its current state, but rather carrying out treatment to improve its quality, such as using the technique of exposure to solar radiation or the technique of slow freezing and thawing (Al-Saffawi and Al-Hamadani, 2018; Al-Saffawi and Tallaat, 2018).

Table (6) Pearson correlation coefficient for the studied groundwater parameters

Para.	DO	Cl^{-1}	T.A.	T.H.	pH	EC	SO_4^{-2}	NO_3^{-2}	PO_4	Na^+	K^{+1}	TPC	F.C
DO	1												
Cl^{-1}	-.005-	1											
T.A.	.404	.681*	1										
T.H.	-.722*	.347	.048	1									
pH	-.004-	-.348-	-.702*	-.344	1								
EC	-.651*	.449	.084	.933**	-.166	1							
$SO4^{-2}$	-.677*	.353	-.063-	.966**	-.175	.946**	1						
$NO3^{-1}$	.831**	.337	.634*	-.525-	-.248	-.404	-.490	1					
PO4	-.509-	-.516-	-.719*	.352	.318	.330	.434	-.582	1				
Na^+	.006	.822**	.882**	.345	-.596	.439	.251	.345	-.515	1			
K^{+1}	.188	-.081-	.525	-.055-	-.764*	-.281	-.259	.125	-.404	.296	1		
TPC	-.154-	-.145-	.170	.095	-.061	.150	-.037	-.329	-.107	.271	.367	1	
F.c.	-.478-	.058	-.398-	.271	.395	.444	.417	-.331	.583	-.019	-.574	-.001	1

*Correlation coefficient at the level of ($p \geq 0.05$), **at the level ($p \geq 0.01$).

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