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USING THE ORGAN MODEL (OWQI) TO EVALUATE AL-DANDAN WATER SUPPLY STATION AND ITS RESIDENTIAL QUARTERS, MOSUL, IRAQ.

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ABSTRACT

The current study was conducted to assess the quality of treated water in the Dandan water treatment plant for drinking water and its related residential neighborhoods on the right side of Mosul city. Water samples were collected from ten sites (before and after treatment and the rest from the residential areas included in the study) to estimate the physical, chemical and bacteriological properties, the Organ Model (OWQI) was also applied to assess the quality of the studied water. The results of the study indicated the efficiency of the Dandan water treatment plant for drinking, where the water was of the type of excellent water after treatment, while the rest of the studied sites were of the category of excellent water quality to very good quality, as a result of the quality index values ranged between (88.74 to 91.7) This relative decline in water quality in some residential neighborhoods is due to the presence of fecal coliform bacteria in some periods. The study recommends educating the population about the harms of connecting water pumps directly to the distribution network pipes and applying deterrent laws to violators.

KEYWORDS: OWQI model, Al-Dandan water supply station, Mosul city.

INTRODUCTION

One of the most important pillars of national security is securing water resources and managing them properly, especially in arid and semi-arid areas such as countries whose water sources are from outside their territories, such as Iraq, Egypt and Sudan, because upstream countries are trying to exploit them politically and economically to achieve their strategic goals (Al-Saffawi et al. al, 2021a). Global reports indicate a shortage of water resources by the year 2025, especially in the Middle East, including Iraq, despite being rich in water resources until a few decades ago, but as a result of climatic changes, an increase in water consumption and the construction of dams on the Tigris and Euphrates rivers by neighboring countries, which led exacerbating the problem of water shortage and deteriorating its quality (Al-Ansari, 2018). The report of the International Organization for Migration for the period between (1998 to 2018) AD indicates that Iraq is facing a complex water crisis that is expected to continue for long periods, which may result in economic, security and social repercussions, although the priority of public water supplies is compared to other uses. However, there is a slight and frequent shortage of public water supplies, especially during drought years in some periods in many governorates such as Najaf, Babil, Qadisiyah, Dhi Qar, Muthanna, etc. (IOM, 2020).

Therefore, efforts must be made to build and develop scientific and service institutions to solve the problems of pollution of water resources, build dams on rivers, and construct water harvesting dams, while rationalizing water consumption for all purposes (Bortolini et al., 2018; Al-Saffawi et al, 2018; Ewaid et al., 2019), because neglect and tampering with water resources can lead to the destruction of health, wealth and all forms of life, so providing water suitable for human use has become one of the problems that the world suffers from, especially the third world countries.

Where Iraq suffers from the problem of the deterioration of the water quality of the Tigris and Euphrates rivers during their flow as a result of the discharge of the huge amount of wastewater resulting from human activities (civil, industrial and agricultural) through many estuaries, so that the quality has become very poor in southern Iraq due to the presence of organic materials consuming dissolved oxygen and compounds of nitrogen and phosphorous leading to the occurrence the phenomenon of Eutrophication in an aquatic ecosystem (Ehab et al.,2020; Fadhel, 2020; Al-Ridah et al, 2020).

Which affects the quality of water for the water supply station in Iraq, as they are the main source of raw water. Therefore, the quality of water sources must be maintained through wastewater treatment before it is discharged into rivers, because this threatens the health and development of society. Therefore, strict and accurate programs must be developed for periodic follow-up of the quality of water sources and conducting periodic studies with the application of modern methods in determining its quality, such as the use of weighted sports models. To stand in emergency situations as an effective way to determine changes in water quality instead of large numbers of data to be understood by professionals and non-professionals (Al-Sadani, 2021; Patil et al.,2020; Verma et al, 2020; Salman et al, 2015). Therefore, the study came to evaluate the quality of Al- Dandan water supply station and residential quarters, which are covered by the distribution pipeline network, with giving recommendations and solutions necessary to reduce the problems of water pollution in residential quarters.

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MATERIALS AND METHODS:

1. General description of the study area:

The study area is located on the right side south of the city of Mosul. The station was established in the middle of the last century to supply the following quarters with drinking water: Dandan, Jawsaq, Al-Dawasah, Al-Nabi Sheet, Al-Sijn, Bab Al-Jadid, Bab Al-Beidh, Al-Akeedat, etc. The production capacity is 45 thousand m3 per day. This station is distinguished by the fact that its network of pipelines is old, as well as the military operations during the past years that have led to the destruction of the city's infrastructure. In addition to this are the geological formations of the city of Mosul and the spread of the Al-Fatha (lower Faris) formation containing gypsum $CaSO_4.2H_2O$, anhydrite $CaSO_4$ and water-soluble evaporate salts (Al-Hamadany et al, 2021; Mohtfer and Al-Saffawi, 2022)), which leads to the occurrence of erosion in the surface layer that may lead to a fracture in the connection areas of the water transport pipes, and one of the common negatives among the residents of the city are the connection of water pumps directly to the network, which leads to the possibility of waste water entering the pipes and polluting the drinking water. Table (1) and Figure (1) show the characteristics of the study area.

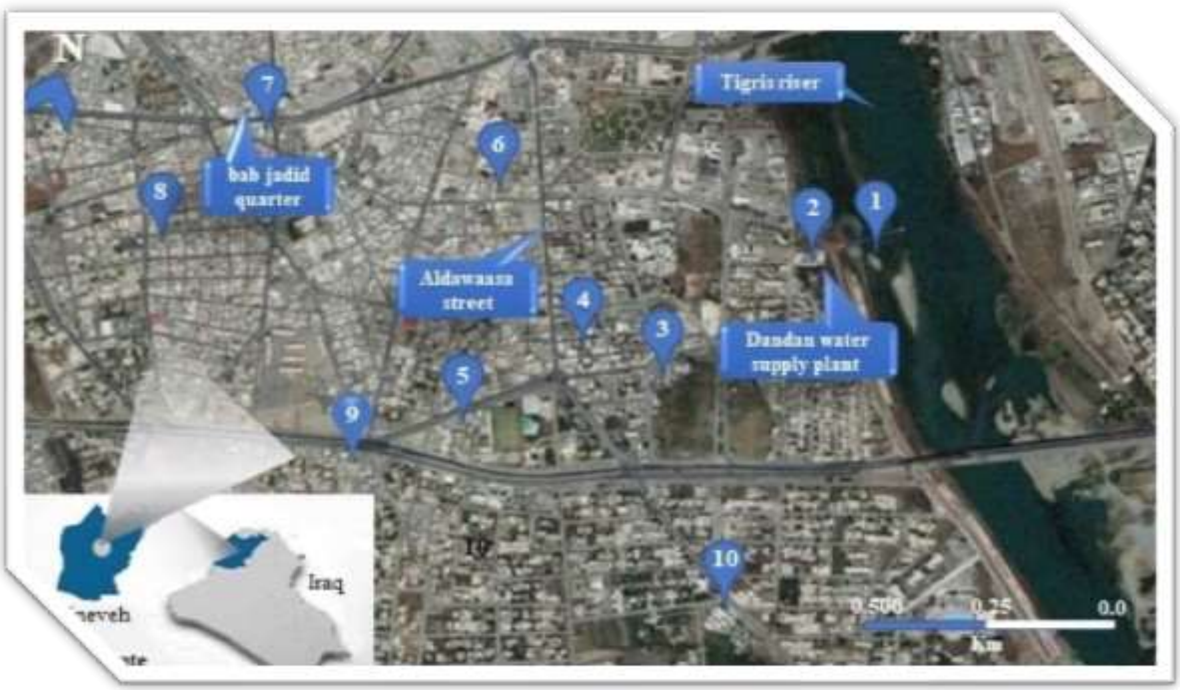

Figure 1: Satellite image of the Dandan water plant and residential quarters on the right side of the Tigris River, south of Mosul city.

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Table (1): Characteristics of Dnadan water supply plant and the residential quarters on the right side of Mosul city.

Sites	Latitude	Longitude	Altitude	Uses
S1	36˚33′54″ N	43˚14′65″ E	231 m	for drinking and domestic uses
S2	36˚33′50″ N	43˚14′47″ E	213 m	
S3	36˚33′12″ N	43˚14′25″ E	240 m	
S4	36˚33′13″ N	43˚14′02″ E	240 m	
S5	36˚32′87″ N	43˚13′75″ E	235 m	
S6	36˚33′40″ N	43˚13′66″ E	246 m	
S7	36˚33′35″ N	43˚13′05″ E	246 m	
S8	36˚33′06″ N	43˚12′90″ E	232 m	
S9	36˚32′75″ N	43˚13′57″ E	235 m	
S10	36˚32′71″ N	43˚14′65″ E	213 m	

ii. Methodology: Ten sample collection sites were identified to include both raw water (Tigris River) before and after treatment, and the rest of the station's residential quarters for the period from September 2021 until February 2022 (Ten replications for each site).

As for the samples related to the determination of dissolved oxygen in water, they were collected using glass bottles with a tight stopper and fixed in the field by adding a solution of manganese sulfate and azide alkaline iodide reagent respectively with shaking up and down [11]. As for the samples for bacterial tests, they were collected using sterile glass vials at a pressure of 1.5 pounds and a temperature of 121 ̊C for 15 minutes, The samples were kept in a refrigerated container away from light until they reached the Environment and Pollution Laboratory at the College of Education for Pure Sciences to measure each of the dissolved oxygen in water, total alkalinity, total hardness, fluoride ions, nitrates, phosphates, chlorides, sulfates and fecal coliform bacteria based on international standard methods.(APHA, 1998, 2017).

iii. Calculating the values of the Organ index (OWQI): viz أي

The Organ Water Quality Index (OWQI) was used to assess the quality of water for drinking purposes, which represents the square root of the harmonic mean function, where the most important parameters affecting the quality of drinking water are selected depending on the opinions of specialists, research and the experience of researchers in the studied environments (Galal Uddin et al, 2021), this index was applied ten Parameters : (TC, pH, DO, TDS, TH, SO_4^{-2}, Cl^{-1}, NO_3^{-1}, PO_4^{-3} and F. coliform Bacteria) to evaluate the water quality of the Dandan water supply plant and the residential quarters included within the network. This model is distinguished by the fact that each of the parameters used has the same effect on the final value of the indicator, where the value of the sub-index is found from two curves or mathematical equations to calculate the value of OWQI from the following equation indicated by (Cude, 2001; Darvishi et al, 2016; Al-Gadi, 2022):

$$OWQI = \sqrt[2]{\frac{N}{\sum_{i=1}^{n} \frac{1}{Sli^2}}}$$

where: N: Sub-indices number used in the model. Sli: represents the sub-index value for each parameter, Water quality is rated according to the OWQI values from Table No. (2).

Table (2) Classification of Water Quality by OWQI Values (Akhtar et al, 2021).

OWQI range	Class	Status
91 to 100	I	Excellent
80 to 90	II	Very Good
70 to 79	III	Good
61 to 69	IV	Fair
50 to 60	V	Poor
≤ 45	VI	Very Poor

RESULTS AND DISCUSSION: -

The purpose of raw water treatment processes in water treatment plants is to produce potable water that is free of pathogens, palatable taste, colorless and odorless etc. for the health of consumers (APHA, 2017; Al-Hamadany et al, 2021). The results of the Organ Water Quality Index (OWQI) indicate that it is a good tool for assessing the quality of drinking water because it takes the interactions between all studied properties to give a single value to indicate the quality of drinking water. Instead of a large number of data that confuses the reader, bearing in mind not to use a large number of parameters to avoid confusion in the results of the index values (Al-Saffawi et al, 2020).

The results shown in Table 3. indicate that the average values of the water quality index for site S1 (raw water from the Tigris River) amounted to (29.97), this relative deterioration in the quality of raw water is due to the effect of the inverted squares values of the sub-index ($1/Sli^2$) for each of the Total dissolved solids, nitrate ions and fecal coliform bacteria, which reached (16E-4, 16E-4, 10E-3) respectively, which was reflected in the lower values of the raw water quality index.

Table (3): Results of the inverted sub-index square ($1/Sli^2$), OWQI values and status for water samples of the sites under study.

Sites / Param	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
T ˚C	11E-5	11E-5	11E-5	11E-5	11E-5	11E-5	11E-5	12E-5	12E-5	11E-5
PH	10E-5	10E-5	10E-5	10E-5	10E-5	10E-5	10E-5	10E-5	10E-5	10E-5
DO	14E-5	12E-5	16E-5	16E-5	19E-5	13E-5	18E-5	17E-5	18E-5	19E-5
TDS	16E-4	10E-5	16E-5	15E-5	14E-5	14E-5	14E-5	16E-5	15E-5	15E-5
T.H	12E-5	10E-5	10E-5	12E-5	10E-5	12E-5	12E-5	12E-5	12E-5	12E-5
SO_4^{-2}	13E-5	10E-5	12E-5	10E-5	10E-5	11E-5	12E-5	11E-5	12E-5	12E-5
Cl^{-1}	10E-5	10E-5	10E-5	10E-5	10E-5	10E-5	10E-5	10E-5	10E-5	10E-5
NO_3^{-1}	16E-4	16E-5	10E-5	15E-5	16E-5	18E-5	16E-5	16E-5	15E-5	16E-5
PO_4^{-3}	11E-5	11E-5	14E-5	11E-5	10E-5	11E-5	11E-5	10E-5	11E-5	12E-5
F. C.	10E-3	11E-5	10E-5	10E-5	10E-5	11E-5	10E-5	11E-5	10E-5	10E-5
Σ	**111E-4**	**111E-5**	**119E-5**	**120E-5**	**120E-5**	**121E-5**	**123E-5**	**125E-5**	**125E-5**	**127E-5**
Value	29.97	95.78	91.7	91.29	91.29	91.00	90.17	89.44	89.44	88.74
Status	V.P	Excel.	Excel.	Excel.	Excel.	Excel.	V.G	V.G	V.G	V.G

Where the table (4) indicate that the values ranged between (269 to 335), (0.696 to 3.601) mg. l^{-1}, with average of (298 ± 22.8), (2.72 ± 0.887) mg. l^{-1} and (0.3 to 110) x 10^3 $cells^{-1}$ with average of (45.5 ± 52.5) x 10^3 $cells^{-1}$. 100 ml^{-1} consecutively. As for the water after treatment (site S2), it is noted that there is a significant improvement in the water quality to reach the value of (OWQI) to 95.78 due to sterilization operations, and the value of (1/Sli2) for F. coliform decreases as a result of a decrease in its numbers by

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99.9 % compared to raw water, an indication of the relative efficiency for the treatment processes at the plant, despite the fact that the rest of the studied parameters are within the permissible levels for drinking according to the (WHO, 2017), as shown in the two tables (3, 4).

As for the residential quarters (sites 1 to 6), there is a relative deterioration in the water quality due to a decrease in the values of (OWQI) ranging between (90.0 to 91.29) despite the quality of the water being Excellent. The reason is primarily due to microbial

`Table (4): range, mean and standard deviation of the results of drinking water analysis for the studied sites with unit (ppm).

Parameters \ Sites		1	2	3	4	5	6	7	8	9	10
T ˚C	*Min.*	11.3	11.5	12.1	12.4	12.1	12.3	12.2	12.3	12.4	11.9
	Max.	20.0	20.1	20.0	20.0	19.9	20.0	20.0	20.2	20.0	20.0
	Mean	15.8	15.8	15.8	16.1	16.0	16.0	16.1	16.6	16.2	15.9
	± Sd	3.73	3.82	3.36	3.39	3.26	3.34	3.31	3.01	3.18	3.37
pH	*Min.*	6.82	7.10	7.31	7.37	7.34	7.48	7.30	7.44	7.41	7.46
	Max.	8.03	7.88	7.75	7.75	7.90	7.90	7.80	7.94	7.85	7.84
	Mean	7.36	7.48	7.53	7.58	7.61	7.65	7.58	7.71	7.69	7.73
	± Sd	0.30	0.25	0.16	0.15	0.16	0.14	0.21	0.15	0.12	0.11
DO	*Min.*	7.06	7.02	7.02	6.08	6.00	6.08	6.08	6.08	6.04	6.04
	Max.	8.04	8.04	8.04	8.02	8.00	8.00	8.04	8.01	8.04	8.02
	Mean	7.64	7.77	7.47	7.33	7.13	7.24	7.19	7.04	7.23	6.93
	± Sd	0.47	0.39	0.42	0.62	0.91	0.82	0.69	0.61	0.74	0.82
TDS	*Min.*	269	257	268	257	252	260	249	249	248	246
	Max.	335	319	301	318	327	304	317	309	325	320
	Mean	298	279	292	297	290	282	283	289	289	291
	± Sd	22.8	25.7	20.1	24.7	20.3	20.3	22.8	20.5	21.5	22.1
T. H	*Min.*	176	160	172	160	160	176	172	180	164	160
	Max.	188	200	200	200	204	212	200	200	200	188
	Mean	183	184	191	186	192	197	187	190	188	176
	± Sd	6.35	14.3	13.9	17.3	12.4	12.9	9.06	9.85	14.4	9.28
$SO_4^=$	*Min.*	0.44	42.0	45.0	39.0	46.2	43.0	49.0	39.1	46.7	43.0
	Max.	72.6	69.5	65.4	84.3	70.7	66.8	63.9	70.0	60.0	68.5
	Mean	58.9	56.1	55.5	57.6	54.9	54.4	55.0	54.4	53.6	55.6
	± Sd	8.77	8.24	6.28	12.3	6.91	7.14	5.45	8.07	3.98	6.82

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Cl^-	*Min.*	14.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	Max.	30.0	30.0	30.0	30.0	32.0	30.0	30.0	32.0	30.0	30.0
	Mean	21.6	24.4	24.3	25.2	24.8	23.0	24.6	23.2	22.6	23.6
	± *Sd*	4.78	3.62	2.98	4.54	3.91	3.30	3.77	3.79	3.89	2.79
NO_3^-	*Min.*	0.696	0.901	0.95	1.623	1.000	1.000	1.505	1.458	1.065	0.885
	Max.	3.601	5.641	3.000	2.905	3.548	12.765	2.482	2.517	2.552	6.196
	Mean	2.072	2.550	1.923	2.305	2.281	3.447	2.082	2.054	1.954	2.402
	± *Sd*	0.887	1.272	0.645	0.386	0.841	3.372	0.270	0.270	0.376	0.481
PO_4^{-3}	*Min.*	0.007	0.001	0.011	0.004	0.005	0.009	0.010	0.007	0.010	0.007
	Max.	0.072	0.077	0.078	0.066	0.079	0.083	0.090	0.090	0.070	0.103
	Mean	0.029	0.025	0.026	0.030	0.026	0.031	0.031	0.025	0.029	0.038
	± *Sd*	0.020	0.022	0.020	0.018	0.024	0.024	0.025	0.023	0.021	0.035
FC**	*Min.*	0.30	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Max.	110*	16.0	16.0	16.0	9.20	9.20	16.0	16.0	5.20	16.0
	Mean	45.5	2.90	2.74	3.42	2.06	2.06	2.33	2.84	0.95	3.52
	± *Sd*	52.0	6.20	5.20	6.32	3.63	3.63	4.82	4.82	1.63	6.32

**Cell × 10^3. $100ml^{-1}$ for raw water only .

contamination resulting from the possibility of fractures in the water. The areas of connecting pipes and connecting water pumps directly to the network pipes, which leads to the entry of waste water into the pipes, so that the values of the reciprocal of the sub-indicator squares range between (11E-5 to 10E-5) Also, the table (4) shows that the number of fecal bacteria reached (16) cells. 100 ml^{-1}. This relative deterioration of the water supply has been observed in the distribution pipes of the residential quarters (Al-Hamadany et al, 2021a, Al-Hamadany et al, 2021b) in their study of the water supply in Mosul city

For sites (S7 to S10), it is noted from Table (3) the relative decrease in the values of (OWQI) index to range between (88.44 to 90.17) to make the quality of the water category very good. This decrease is mainly due to water contamination with fecal coliform bacteria at times during the study period, which led to a relative increase in the values of the reciprocal of the sub-indicator squares to reach (11 E-5) at sites 6 and 8, as well as for the values of TDS to range between (14E-5 to 16E-5). These values are negatively reflected on the decrease in the values of the water quality index. This problem was noticed by Al-Maadidi et al, (2018), when they studied the water quality of some schools in Mosul city, and in some periods it reached a very poor quality. As a result of contamination of the water supply with wastewater as a result of connecting water pumps directly to the pipes of the water supply network.

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In general, all the studied symptoms, despite the presence of a relative height for most of them, were within the permissible limits for drinking, with the appearance of some fecal coliform bacteria cells in some periods. It is noted from Table (4) that the temperatures rise in some periods to reach (20) ˚C, which stimulates the activity of bacteria when present in the water (Oleiwi and Al-Dabbas, 2022).

It also notes the relative fluctuation of the pH values within the limits of neutralization due to the high buffering ability of the Iraqi water to prevent the large fluctuation in the pH (Al-Saffawi et al, 2018a; Al-Saffawi et al, 2020b; Al-Saffawi et al, 2020b), where the values ranged between 7.1 to 7.94). These results are relatively close to the results obtained by (Al-Maathidi et al, 2018) when they studied the quality of water supply in some schools in Mosul city.

The same is true with the concentration of oxygen dissolved in water, as it is noted from Table (4) that there is a relative decrease in the concentration in some periods to reach (6.0) mg. l^{-1}, that is due to its low concentration in raw water (Tigris river) for reasons related to the pollution of the Tigris river water resulting from the discharge of wastewater from the city of Mosul, which is rich in organic materials, through many estuaries spread on both sides of the river, which leads to the consumption of oxygen by microorganisms to carry out oxidation processes (Talat, and Al-Saffawi, 2018; Al-Saffawi, 2018c).

Also, the average concentration of the total hardness in the studied water ranged between (176 ± 9.28 to 197 ±12.9) mg. l^{-1}, which is attributed to its rise in the raw water resulting from the nature of the soil and rocks through which the river water passes, as well as the interactions that challenged the calcite and dolomite compounds present in the bottom sediments of the river as in the following equations (Al-Hamdany and Al-Saffawi, 2018; Jaafer and Al-Saffawi, 2020):

$CO_2 + H_2O \longrightarrow H_2CO_3$
$CaCO_3 + 2H_2CO_3 \longrightarrow Ca^{+2}+2H_2CO_3$
$CaMg(CO_3)_2 + 2H_2CO_3 \longrightarrow Ca^{+2} + Mg^{+2} + 4HCO_3\text{-}^{1}$

Hardness plays an important role in the prevention of cardiovascular diseases as well as the vital role of magnesium in more than 600 enzymatic reactions, neuromuscular activity, bone formation, and the efficiency of the immune system, and it is related to the development of the fetus during pregnancy and the growth of newborns after the birth period, and prevention from Sudden Infant Death Syndrome (SIDS) (Fanni et al, 2021).

As for the sulfate and chloride ions, their rates ranged between (53.6 ± 3.98 to 58.9 ±8.77) and (21.6 ±4.78 to 25.2 ±4.54) mg. l^{-1}, respectively. The relative rise in the levels of sulfate ions is due to the nature of the geological formations of the region and is important for the prevention of autism in children (Jaafer and Al-Saffawi, 2020; Al-Gadi et al, 2022).

Also, the concentrations of plant nutrients (PO_4^{-3}, NO_3^{-1}) were low in the studied water and did not exceed (0.103 and 2.402) mg. l^{-1},

The low concentration of nitrates has health benefits for humans, such as the prevention of diseases and death from heart disease, because it increases the elasticity of the walls of blood vessels, while high concentrations cause many diseases for humans, such as stomach, colon and rectal cancer, thyroid enlargement and miscarriage in pregnant women (Al-saffawi and Awad, 2020).

Conclusions and recommendations:

1. The current study is one of the very necessary studies in relation to the health of consumers. It was noted that the concentrations of parameters in the drinking water of the Dandan supply station were within the internationally permissible levels, except for the frequent appearance of *F. coliform* bacteria in some periods for all the studied sites.
2. The results of calculating the (OWQI), indicated that the quality of the treated water in the Dandan water supply station was efficient, as it was of the excellent water category as well as for sites (3, 4, 5 and 6), while the quality deteriorated relatively in the rest of the sites, so that the water became of the very good category.

Therefore, the study recommends periodic follow-up to conduct checks on the water supply for users in order to preserve their health, with awareness of the serious damages when connecting water pumps to network pipes and the application of deterrent laws against violators.

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