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Water Quality of Nimrud District Wells Southeast of Mosul City for Drinking and Civil Purpose Using the Canadian Model of Water Quality

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Abstract

The current study aims at determining the water quality of the Nimrud district wells, southwest of Mosul, for drinking and civilian purposes by using the Canadian model of water quality. The aquatic samples were collected from randomly distributed wells in the area during the dry season for chemical and physical testing to assess their quality. The results of the study indicated the high levels of most of the studied characteristics, which reflected negatively on the values of CCME WQI (Canadian Council of Ministers of the Environmental Water Quality Index), where 70% of them classified as poor quality water for drinking and domestic use. The study recommended periodic monitoring of the quality of water with water treatment processes before being used for drinking.

Keyword: CCME WQI, Groundwater quality, Nimrud district

Introduction

The provision of adequate water for human use has become one of the most difficult problems in many regions of the world, especially in the third world countries. Large numbers of human diseases are transmitted by water and cause various serious diseases, which may cause death such as cholera, typhoid, dysentery, amygdala, viral hepatitis, poliomyelitis, shigellosis, etc [1]. Studies in developing countries indicated that more than 875 million diarrhea cases occur every year, with 3 million deaths due to the use of unsafe drinking water that leads to diarrheal diseases specially in children [2]. For example, many African people suffer from lack of clean water. 18 million people in Kenya and 57 million in Nigeria do not have access to clean water. More than 3,100 children in Kenya and 45,000 children in Nigeria die every year from diarrhea caused by contaminated [3].

The truth is terrifying according to UNEP (United Nations Environment Program) predictions [4] that two-thirds of the world's population will suffer from water shortages by the year 2025, including 25 countries in Africa alone. The continued environmental deterioration may lead to a disaster that is difficult to overcome. Therefore, the international public opinion has stimulated the concerns of increasing water pollution and decreasing its amounts with increased community. Thus, awareness is recommended by all means of information. Especially, in developing countries, including Iraq with the activation of the role of environmental laws. The periodic inspection and controls of water resources are encouraged. The tracking of pollution sources to reduce deterioration of water is very important. Also, the trend towards rationalization of water consumption in all areas to maintain this wealth with the use of modern methods for estimating water quality, such as using mathematical models to assess the surface and groundwater quality should be taken into account.

The use of WQI models of water quality was widely spread after the introduction of a mathematical model by Horton in 1965, which was later developed by Brown in 1970 [5, 6]. Over time, a large number of models have been proposed and developed because of the evidence's ability to give a single value that reflects the interferences between large numbers of data and water characteristics which are understood by all [7,8]. Some models, such as CCME WQI, WAWQI, the National Sanitation Foundation (NSFWQI) and the OWQI OWQI are among the most widely used and popular models in the world [8]. The CCME WQI model is widely used worldwide by researchers to evaluate water sources and determine the degree of contamination. This model is concerned with the weight of the parameters, which is a deviation of even one test from the standard limits, but also to the weight of each measurement (test value) deviated from the standard limits, which gives high precision in the assessment of water quality studied [9-11]. Therefore, the study was conducted with the aim of assessing the groundwater of Al Nimrud district for drinking purposes using the Canadian Model.

Materials & Methods

Study site: Some physical and chemical properties of groundwater sources were studied in Al-Nimrud district, Nineveh governorate, southeaste of Mosul city, along with latitude (36 10`N) and longitude (43 20`E). Ten wells were identified randomly, as shown in Fig. 1 and most of them are unpalatable and of bitter taste because the geological formations of the study area are characterized by the formation of Al-Fatha (lower Faris) containing the evaporated salts, gypsum, anhydrite, limestone, etc., leading to deterioration of the quality of water [12, 13].

Water sampling: Forty-four water samples (during the dry season) were collected using clean polyethylene bottles for physical and chemical measurements according to internationally approved analysis methods [14].

Methodology: The acid function was measured by the pH meter after regulating the device with multiple buffer solutions having pH 9, 7 and 4. Total dissolved solids were determined by evaporating filterable water samples; the obtained residue was further dried at 105 °C. Total hardness, calcium and magnesium were measured by EDTA titration methods [14, 15]. Total alkalinity was determined by titration with sulfuric acid using methyl orange and phenolphthalein as indicators, also chloride by silver nitrate titrimetric method (Mhor M.). Amounts of sodium and potassium were evaluated with the Flame photometer. Sulfate ions were determined by Turbidimatric M. and Nitrate was measured by Ultraviolet screening M test.

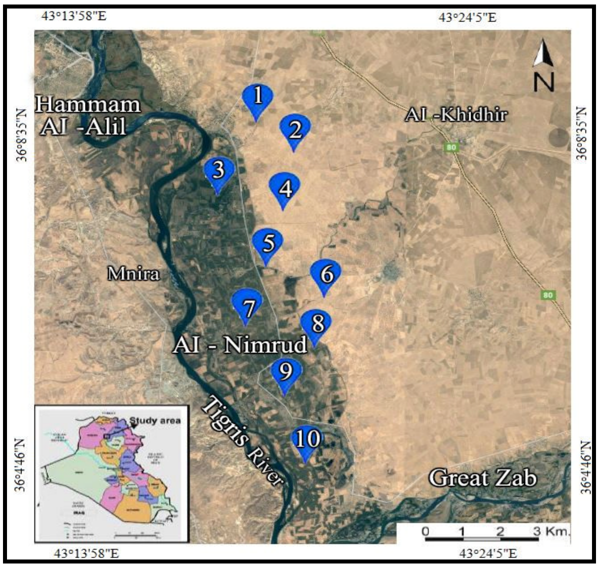

Figure 1. **Map of the southern part of Iraq (Nineveh governorate) showing the studied stations.**

Calculation of the Canadian Water Quality Index

The Canadian Mathematical Model of Water Quality is characterized by high accuracy and the values of the index are calculated by three factors as follows [16-18].

1. (Scope) K_1: represents the percentage of variables exceeding standard limits compared to the total number of variables (even once during the study period.

$$K_1 = \left[\frac{\text{Number of failed variables}}{\text{Total number of variable}}\right] \times 100$$

2. (Frequency) K_2: Percentage of individual tests exceeding standard limits on the total number of tests.

$$K_2 = \left[\frac{\text{Number of failed variables}}{\text{Total number of tests}}\right] \times 100$$

3. (Amplitude) K_3: The number of exceeded tests were calculated in three stage:

The first stage: the number of times the individual concentrations of the standard limits exceeded (called the excursion) was calculated as follows:

a. When the test value must not exceed the objective:

$$\text{Excursion} = \left[\frac{\text{Failed test calue i}}{\text{Objective j}}\right] - 1$$

b. When the test value must not fall below the objective:

$$\text{Excursion} = \left[\frac{\text{Objective j}}{\text{Failed test calue i}}\right] - 1$$

The second stage: the quantity of the group of individual exceeded tests calculated by divided the sum of individual deviations and divided on the total number of tests and called Normalization of Excursion:

$$\text{nse} = \frac{\sum_{i}^{n} = 1 \text{ excusion}}{\text{Number of Test}}$$

The third stage: calculation of F_3 by the following equation:

$$K_3 = \left[\frac{\text{nse}}{0.01 \text{ nse} + 0.01}\right] - 1$$

Finally the CCME WQI is calculated as:

$$CWQ_1 = 100 - \left[\frac{\sqrt{K_1^2 + K_2^2 + K_3^2}}{1}.732\right]$$

Constant 1.732 is to modify the result of the index value and makes it limited between 0.0 - 100. Then water quality index values are classified into five categories as shown in (Table 1).

Table 1. **Classification of water quality based on values of CCME WQI [19].**

WQI value	95 - 100	80 - 94	65 – 79	45 - 64	0 - 44
Categories	Excellent	Good	Fair	Marginal	Poor
Class	1	2	3	4	5

Results and Discussion

In the present study, the physiochemical analysis results of groundwater, which was collected from ten wells of Al-Nimrud district are presented. The guideline values (objectives), recommended by Iraqi standards [19, 20] are listed in (Table 2).

The values of the various scopes (K_1), frequencies (K_2), and amplitudes (K_3), with their respective WQI, are presented in (Table 3). During the study period, the CCME WQI values of the groundwater at the wells showed that the water can be ranked from 21 to 62. The WQI values were relatively lower; however, these values revealed that the groundwater quality could be ranked as marginal at the wells 3, 5, 9 for drinking and domestic uses. However, the values obtained for remaining wells were lower than 38 making the water to be ranked as poor quality water.

The decrease in WQI values is an evident that different pollutants are present in the groundwater due to the their geological formation; that is Al-Fatha (Lower Fars) that consists mainly of gypsum, anhydrite, evaporated salts limestone. Moreover, various agricultural activities may be accountable for the poor water quality [21].

Table 2. **The physiochemical analysis results parameters of the groundwater (mg/L).**

Well No.		pH	TDS	T.alk.	T.H	Ca	Mg	Na	K	Cl	SO_4	NO_3
1	*Min.*	6.55	4198	244	2280	389	256	365	4.0	356	1166	1.3
	Max.	7.24	5144	496	2720	569	321	495	9.0	465	1523	10.6
	mean	6.89	4818	326	2473	514	293	440	7.0	406	1328	5.2
2	*Min.*	6.89	4898	247	2330	409	246	418	50	296	1253	2.1
	Max.	7.10	5144	566	2440	545	340	510	115	328	1309	19.0
	mean	----	4997	348	2390	505	275	459	63	315	1371	9.3
3	*Min.*	7.5	1488	130	850	96	78	96	3.6	170	393	1.1
	Max.	7.6	1536	286	980	224	156	141	4.0	196	544	6.2
	mean	----	1507	187	903	152	119	123	3.9	181	467	4.5
4	*Min.*	6.73	3954	216	980	152	146	249	28	260	889	1.7
	Max.	7.28	4064	644	1900	409	285	475	50	318	1438	12.9
	mean	----	4001	384	1600	87	222	333	39.0	289	1147	7.7
5	*Min.*	7.30	1392	165	1070	44	83	229	4.0	140	636	1.3
	Max.	7.53	2444	314	740	514	153	613	23.0	325	1049	5.4
	mean	----	2073	225	2720	87	123	378	11.3	273	916	3.4
6	*Min.*	7.53	3314	139	1060	128	156	547	6.4	445	1370	1.2
	Max.	7.68	3572	262	1250	200	226	820	9.1	543	1645	5.9
	mean	----	3441	179	1178	173	181	664	7.8	498	1470	3.3
7	*Min.*	6.71	2322	188	1100	80	146	415	5.3	286	786	1.1
	Max.	7.52	2472	370	1780	385	204	487	9.1	330	1297	6.3
	mean	----	2439	283	1255	208	179	461	7.5	311	1098	4.0
8	*Min.*	6.7	1738	355	2280	241	353	113	9.0	378	1355	2.7
	Max.	7.32	5782	644	2340	357	423	820	13.0	420	1865	9.5
	mean	----	4243	454	2320	302	381	553	11.0	396	1688	6.8
9	*Min.*	7.20	1340	120	1060	152	102	104	1.2	120	527	10.3
	Max.	7.32	1806	126	1080	265	165	113	1.7	128	578	11.3
	mean	----	1573	123	1070	159	134	109	1.3	124	553	10.8
10	*Min.*	7.30	1496	143	780	92	138	182	3.0	165	875	6.8
	Max.	7.72	3395	482	2600	469	348	510	5.0	438	1225	8.9
	mean	----	2446	313	1690	281	243	346	4.0	303	1049	7.9
Standard limit		6.5-9	1000	150	500	200	150	200	12	250	400	45

Table 3. **Water quality index at each well.**

Well	K_1	K_2	K_3	WQI	Ranking	Well	K1	K2	K3	WQI	Ranking
1.	90	82	6.0	21	Poor	6.	70	65	51	38	Poor
2.	90	83	61	21	Poor	7.	80	70	43	34	Poor
3.	60	37	15	59	Marginal	8.	80	77	63	27	Poor
4.	80	75	51	30	Poor	9.	50	40	19	62	Marginal
5.	70	60	33	44	Marginal	10.	80	55	48	38	Poor

Thus, the results of the current study of water quality index clearly indicate that the state of most of the groundwater in the study area is not suitable for human use.

The value of pH has an impact on the quality of irrigation and drinking water because of its effect on the balance of carbonates and water content of mineral elements [22]. The results shown in Table 3 indicate the relative fluctuation of pH values ranging between 6.55-7.72 and 77% of the water samples were within slightly alkaline range due to the presence of bicarbonate ions [14]. The low values of pH were may be due to the high concentration of salts, chloride and sulphurous phase at the expense of the bicarbonate phase, resulting in slightly acidic pH values [23]. This resulted in increased solubility of toxic mineral elements in rocks when the water passed through the geological formation and thus increased the negative effects on the consumer of this water [23].

All values are generally within the permissible drinking limits of WHO [20].

Total dissolved solids are important components of water and are a measure of water salinity [24]. The obtained results of TDS (Table 3) indicate that the concentrations of TDS for the studied water ranged between 1340 - 5782 mgL^{-1}, these high concentrations are the indicator of excessive dissolution of rock minerals and salts [16]. These results are similar to the results obtained by Al-Saffawi [25] when he studied the groundwater of Al-Conseya village, Hamidat subdistrict, which had TDS value of to 2944 mgL^{-1} and relatively larger than the results obtained for the groundwater of Al-Kubah and Al-Sherkhan areas north-west of Mosul city, which had TDS value of 2112 mgL^{-1}. In general, all studied samples exceeded the upper limits set for drinking water [20, 26].

The total alkalinity plays an important role in acid neutralization (ANC) as it minimizes the negative effects of acidic water on aquatic ecosystem [27]. In general, total alkalinity ranged between 126 – 644 mgL^{-1} and 79 % of the tested sample were found to have higher values than the permissible limit (Table 3). This relatively high concentration is due to the reactions occurring in the water when it passes through the geological formations as shown in the equations below [28]:

$$CO_2 + H_2O \rightarrow H_2CO_3$$
$$CaCO_3 + 2H_2CO_3 \rightarrow Ca(HCO_3)_2$$

The total hardness of water plays a protective role to reduce the toxic effects of some toxic substances such as heavy metals. This effect increases by increasing its concentration, as toxic elements compete on absorption sites [9].

The results obtained by groundwater surveys conducted in this investigation revealed that average of total hardness is varied between 690-2720 mgL^{-1}. The values obtained were beyond the maximum permissible level recommended by the WHO for drinking water [20]. This increase in concentration is due to the dissolution of minerals from the rocks in the geological formations [16]. The mean concentrations of calcium and magnesium were ranged between 87-514 and 119-381 mgL^{-1}, respectively.

It is useful to mention that, in all parts of Iraq Na^{+1} ions concentration is greater than K^{+1} ions. In these groundwater samples sodium and potassium concentrations reached to 820 and 115 mgL^{-1}, respectively. These variations are due to the high solubility if sodium ions in water and potassium ions adsorption ability on the soil via ion exchange mechanism. However, 77 % of tested samples often contained higher concentration of Na^{+1} may not be suitable for domestic and livestock purposes [29]. Determination of total chlorides is an important parameter in assessing the water quality. Chlorides have high affinity towards sodium and hence their concentration is high in groundwater due to the geothermal gradient. Soil porosity and permeability plays a key role in building up the chloride concentration. High concentration of chloride makes water unpalatable and unsuitable for drinking and livestock watering [21]. However, the mean concentration of total chlorides in the samples is varied from 124-498 mgL^{-1}. Also, it was found that 79 % of tested samples exceeded from the permissible limit of chlorides that is 250 mgL^{-1}.

High concentrations of sulfate ions give water a bitter taste and causes diarrhea, especially in the presence of magnesium ions. They are naturally occurring anion present in all kinds of natural water bodies [30]. The sulfate ions concentrations in the present study were varied from 393-1865 mgL^{-1} and the results indicated that 97 % of studies samples were exceeding from the acceptable limit of sulfate ions concentration (400 mgL^{-1}) recommended by the WHO for drinking water. The high concentration of nitrates is a serious threat to human health. The high amounts of nitrates in drinking water cause Blue baby syndrome especially in rural areas that use groundwater as a major source of drinking water. In addition, studies indicated their relationship with the occurrence of tumors such as cancers of the stomach, rectum, colon, and liver. Also, they cause abortiont and sudden death at the time of births [31]. Fortunately, the concentration of nitrates in the studied samples did not exceed the permissible drinking limits (50 mgL^{-1}), which ranged between 1.1 and 19.0 mgL^{-1}.

Conclusion

This study suggests that the groundwater quality of the Al- Nimrud district is affected by high salinity, total hardness, sulfates, chlorides etc. due to the geological formation of the studied area. Their values exceeded greatly from the standard limits set by WHO. Also 70 % of WQI values of the studied area revealed that under study samples were poor for drinking purpose. So, there is great need to control and conduct periodic tests of water quality in order to determine emergency cases. Moreover, an extensive treatment of this water is required before using it for drinking purpose [32].

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