Plant Archives Vol. 20 Supplement 1, 2020 pp. 1797-1802 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

SUITABILITY OF WATER FOR IRRIGATION AND LIVESTOCK WATERING PURPOSE USING IWQI MODEL: THE CASE STUDY GROUNDWATER QUALITY OF SOME QUARTERS OF MOSUL CITY, IRAQ.

Azhar Y.R. Al-Assaf[1], Reem A. Talat[2] and Abdul-Aziz Y.T. Al-Saffawi[1*]

[1*]Department of Biology, College of Education for pure Sciences, University of Mosul. Iraq
[2]Department of Environmental Sciences, College of Environment and Technology, University of Mosul. Iraq

Abstract

The current study was carried out to evaluate the quality of the wells to irrigate the trees, the gardens and the small agricultural fields scattered in the study area. The water samples were collected from eleven wells (five replicates per well) Spread throughout the Al-Gameaa and Al-Zeraee qaurters in the left side of the city of Mosul from the month of February until April 2018 to measure the physical and chemical properties with the calculation of the irrigation criteria using the weighted mathematical model.

The results of the study indicated that the quality of the studied water was suitable for irrigation and from the category of good to excellent water quality for irrigation purposes and the WQI values ranged from 34.75 to 59.4. This relative change in the water quality of the wells 5, 8 and 9 is due to the higher values of the electrical conductivity (EC_{25}), Potential salinity (PS) and Magnesium Hazard (MH), which reached to (2.7) $dS.m^{-1}$ (11.8, 93.4) meq. l^{-1} on the sequentially.

Key words: Water quality of wells for irrigation, WQI.

Introduction

The shortage of water resources, coupled with increased demand, will lead to many critical problems for many countries in the world, especially in the arid and semi-arid zones, In recent decades, as a result of the civilizational and economic development and the rapid growth of the population, there have been clear changes in the use of land, resulting in increased water demand for various civil, industrial and agricultural activities (Al-Saffawi and Al-Shuuchi, 2018, Narany *et al.*, 2012).

There are overlapping effects between the quality of water and soil, namely Salinity problem, reports indicate that an increase of salinity problems in many parts of the world will result in the loss of approximately 10 million hectares of arable land annually due to the usage of high salinity water for irrigation, with the absence or limited scientific management of agricultural activities have led to the emergence of agricalture problems accelerated to reach the critical border (Al-Saffawi and Al-Sinjari, 2018).

***Author for correspondence :** E-mail: alsaffawia65@gmail.com

Therefore, the study of these problems must be reviewed seriously to provide all the necessary resources to confront these problems and reduce them in order to preserve suitable land for future agriculture (Saffawi, 2013), such as, the use of modern technologies in the management of agricultural processes with the using of modern technologies to determine the quality of irrigation water s, as the use of water quality index models (WQI) which is one of the most effective means of identifying water pollution and quality, which reflects the overlapping effects of water components and their suitability for different uses (Al-Saffawi and Abubakar, 2019). The quality of irrigation water depends on the following factors (Al-Saffawi, 2018a):

1. Salinity Hazards.
2. Infiltration and Permeability Hazards.
3. Specific ion toxicity.
4. Miscellaneous effects.

As for the city of Mosul in northern Iraq, the wells were spread due to the harsh conditions experienced by Iraq in general and the city in particular from the destruction of infrastructure such as water pipe networks, power transmission lines, etc. The citizens use this type of water for all uses and are still used in irrigation Gardens, trees, small agricultural fields and watering livestock and poultry. The use of WQI models of water quality has spread significantly after mathematical model was proposed by Horton in 1965 and later developed by Brown in 1970 (Kablan *et al.*, 2018). Over time, a large number of models have been proposed and developed because of the viability of the water quality model, which reflects overlaps between large numbers of data and water characteristics (Krishan *et al*., 2016, Al-Saffawi *et al*., 2019) which are understood by everyone, several studies have been conducted to evaluate groundwater quality for irrigation purposes in Nineveh Governorate using WQI, among them. The study of Al-Saffawi and Al-Shanoona (2013) for groundwater quality of some villages southeast of Mosul city. The results of the study indicated that the water of the wells are suitable for irrigation purposes for both pH, % Na and SAR, with the emergence of some problems related to salinity according to the international classification approved. Saeed *et al.*, (2018) also applied the CCMEWQI model to evaluate the well water of Al-Siddiq and Al-Hadbaa qaurters in Mosul city for irrigation purposes. The results of the study indicated that the water quality of the wells was suitable for irrigation. WQI values ranged from 66.6 to 94.0, which indicates that the water quality ranged between good to suitable categories for irrigation.

Further study was conducted by Al-Saffawi (2018) on groundwater of Sinjar district, west of Mosul city to determine their suitability for irrigation. According to the results, the groundwater quality was between good to unsuitable for irrigation because of high electrical conductivity values (EC25) for 72% of the water samples, suggesting the occurrence of salinity damage to the soil and plants. Other study by Al-Saffawi (2019) to assess the groundwater quality in Nimrud area southeast of Mosul, the results indicated that high levels of most studied characteristics, which reflected negatively on WQI values, which falls within severe restriction category for irrigation, therefore, is likely to cause a problem of salinity in heavy soils as well as toxic effects on sensitive crops.

Finally, the study conducted by Talaat *et al.*, (2019) to assess the groundwater quality in some areas on the left side of the city of Mosul, which indicated that WQI values for the studied groundwater ranged from poor to unfit for use. This deterioration of quality is due to the high levels of most studied parameters. So, the current study came to evaluate the groundwater quality of Al-Gameaa and Al-Zeraee qaurters for irrigation of domestic gardens, trees and small agricultural fields scattered in the region using the water quality index.

Materials and Methods

Study site: This study was conducted on groundwater of Al-Gameaa and Al-Zeraee quarters in lift side of Mosul city, Northern part of Iraq, which that rely on groundwater as the main source of water for irrigation, washing and bathing in the last years, as a result of the great destruction that occurred in Mosul. The geological formation in the studied areas is Al-fatha (lower faris), which is largely spread in large parts of Mosul city. This formation dates back to the Middle Miocene epoch and consists of the sequence of gypsum, anhydrite and evaporation salts overlapping with limestone and Marl etc. The adjacent areas of the Tigris River cover with the newly formed sediments of flood plains formed by river deposits during floods (Al-Bachachi, 2014, Al-Sardar *et al.*, 2018). As well as, the sequence of sedimentary cycles for Upper Miocene formation consisting of claystone, sandstone, siltstone and marl (Al-Yousbakey *et al.*, 2018).

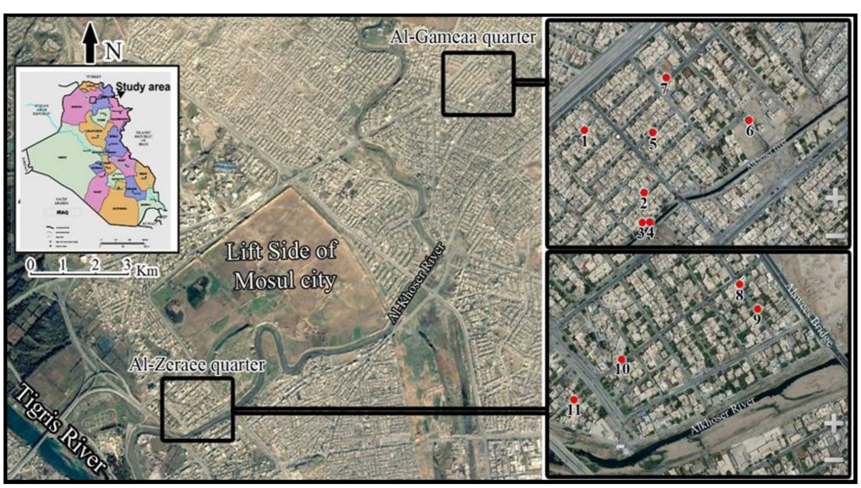

Fig. 1: Map of the left bank of Mosul city showing the study quarters.

Water sampling: In the current study, it has been identified eleven wells randomly, seven of them in the Al-Gameea quarter and four wells in the Al-Zeraee quarter, as shown in fig. 1 and table 1 water samples were collected approximately every two weeks (five replicates per well) from February to April 2018 using polyethene bottles washed with distilled water and then washed with sample water before filling (APHA, 1998).

Table 1: Coordinates and depths of the study wells on the left bank of Mosul city.

Sites	Well No.	E	N	Depth (m)
Al-Gamea quarter	1	43°18'56"	36°38'92"	42
	2	43°18'71"	36°38'93"	36
	3	43°18'70"	36°38'73"	5.0
	4	43°18'72"	36°38'74"	14
	5	43°18'29"	36°38'91"	48
	5	43°18'97"	36°38'93"	33
	7	43°18'76"	36°39'02"	45
Al-Zeraee quarter	8	43°14'87"	36°35'63"	13
	9	43°14'91"	36°35'58"	13
	10	43°14'56"	36°35'48"	23
	11	43°14'44"	36°35'39"	9.0

Methodology: Each sample of groundwater was analyzed to estimate the following characteristics: pH, chlorides, sulphates, nitrates, based on universal standard methods and irrigation indices such as sodium percentage (Na%), sodium absorption ratio (SAR), Magnesium Hazard (MH), residual sodium carbonate (RCS), Kelley ratio (KR), potential salinity (P.S) and permeability index (PI) were calculated from the following equations (Bhat *et al.*, 2016, Ramadhan *et al.*, 2018, Ememu and Nwankwoala, 2018, Yasmin *et al.*, 2019, Xu *et al.*, 2019):

$$\% Na = Na \times 100 / Na + K + Ca + Mg$$

$$SAR = \frac{Na}{\frac{\sqrt{Ca + Mg}}{2}}$$

$$M.H = Mg / Ca + Mg \times 100$$

$$KR = Na / Ca + Mg$$

$$PI = \frac{Na + \sqrt[2]{HCO3}}{Na + Ca + Mg} \times 100$$

$$RSC = (Ca + Mg) - (CO_3 + HCO_3)$$

$$P.S = ½SO_4 + Cl$$

Estimation of Water Quality Index (WQI):

The weighted mathematical model was used Referred to by many researchers (Boateng *et al.*, 2016, Howladar *et al.*, 2017, Dawood *et al.*, 2018). The model is applied to twelve criteria to calculate the water quality index (WQI) according to the following four phases:

Phase I: The weight of wi is given to each property according to its relative importance and ranges from 5-1. The electric conductivity (EC_{25}), sodium absorption ratio (SAR) and permeability index (PI) are given a weight of five for their importance and their effect on the soil and developing plants, while the residual sodium carbonate (RSC) was given weight 1 for its low values in Iraqi water as given in table 2.

Table 2: Standard limits (Si), parameter weight (wi) and relative weight (Wi) used to calculate IWQI. (*meq.l*$^{-1}$).

Parameters	Si*	Weight (wi)	Wi
pH	6.5-8.5	4	0.088888888
EC25 dS.m^{-1}	2.00	5	0.111111111
Cl	10	3	0.066666666
NO_3	2.18	3	0.066666666
HCO_3	8.5	3	0.066666666
RSC	2.25	2	0.044444444
PI	75	5	0.111111111
KR	1.0	3	0.066666666
%Na	60	4	0.088888888
SAR	10	5	0.111111111
M.H	50	4	0.088888888
P.S	10	4	0.088888888
Σ		45	0.999999993

* Moghimi, 2016.

Phase II: Relative weigh is calculated according to the following equation:

$$Wiw\ i = \frac{\square}{\Sigma(_i = i(\square^n)_{wi}}$$

As: Wi: relative weight, wi: property weight.

Phase III: Find the rate of values of Quality rating (qi) as in the following equation:

$$qi = Ci / Si \times 100$$

As: Ci: the measured value of the property,Si: the standard limit.

Phase IV: The Subindex (Sli) and water quality index (WQI) values are calculated from the following equations:

$$SLi = Wi \times qi$$

$$WQI = \Sigma Sli$$

Water quality is then classified as compared to table 3.

Results and Discussions

The weighted mathematical model was applied for the evaluation of well water for irrigation purposes using 12 criteria such as (pH, electrical conductivity (EC_{25}), Chloride (Cl), Bicarbonate (HCO_3), Nitrate (NO_3), Sodium adsorption ratio (SAR), residual sodium carbonate values RSC, PI permeability index, Kelly percentage, Sodium percentage (% Na), Magnesium Hazard (MH)

Table 3: Classification of water quality by the water quality index values.

WQI Values	< 50	50-100	100-200	200-300	> 300
Class	I	II	II	IV	V
Water status	Ecellent quality	Good quality	Poor quality	Very poor quality	Unfit quality

and Potential salinity (PS) and comparing them with the internationally approved standard limits for irrigation referred to (Nag and Das, 2014, Moghimi, 2016).

The results indicated that water quality index values (IWQI) for irrigation ranged between (59.40-34.75), after comparing it with table 2 to classify the water that all samples of well water studied were from Excellent quality water (class I) except for the wells water 5, 8, 9, it was of good water quality (class II) as shown in table 3 and the above equations.

The subindex values (Sli) used to calculate the water quality index (IWQI) are relatively low, leading to lower values of the IWQI. while the wells water 5, 8 and 9, the Sli values were slightly higher for some studied characteristics, especially the pH values, electrical conductivity (EC_{25}), Potential salinity (P.S), and HCO_3 ions, as well as the impact of relative weight (Wi), which reflected on the values of (IWQI).

The pH has a great effect on the irrigation water quality because of its effect on the balance of carbonates and the water content of the mineral elements. Acidic water hinders the absorption of calcium and magnesium ions by roots, while alkaline water provides a suitable environment for absorbing many nutrients by roots but is responsible for the accumulation of calcium carbonate (Al-Saffawi, 2018b).

The results are shown in table 4 indicate that the values ranged between 6.73 to 8.29 and 24% of the water samples within the acidic range (natural acidic). The lower values will increase the solubility of toxic metal elements from the rocks in the geological formations that water passes through it, such as aluminium and thus increase the negative effects on plants. The slightly alkaline values are due to the presence of bicarbonate ions (Al-Saffawi, 2018b).

The relative decline of values was due to the high concentration of salts and Sovereignty phase of chloride and sulfate compared to the bicarbonates phase, leading to a reduction of the pH values slightly towards the acidic (Al-Saffawi and Al-Shanoona, 2013). In addition to the possible formation of H_2S from oxidation and reduction processes in the anaerobic conditions of sulphate ions, which oxidizes when exposed to oxygen to form sulfuric acid, as shown in equations (Al-Saffawi and Maathidi, 2017).

$$H_2S + 3O_2 \longrightarrow 2SO_2 + 2H_2O$$

$$H_2SO_3 + O_2 \longrightarrow 2H_2SO_4$$

In general, all studied water samples are within the appropriate limits for irrigation.

Electrical conductivity (EC_{25}) is an indicator that represents the concentration of water-soluble salts such

Table 4: The quality rating (Qi), Subindex (Sli) and water quality index (WQI) of studied groundwater for irrigation purpose.

Wells		pH	EC_{25}	HCO_3	Cl	NO_3	P.S	%Na	SAR	M.H	PI	KR	RSC	Values	Water Status
1	Qi	94.8	105.5	64.94	27.40	8.618	53.2	4.00	1.71	80.0	11.4	4.60	0.0	40.85	Excellent quality
	Sli	8.43	11.72	4.329	1.830	0.575	4.73	0.36	0.19	7.111	1.27	0.31	0.0		
2	Qi	98.7	124.0	78.35	41.00	8.710	72.6	6.20	3.10	72.64	10.37	3.60	0.0	46.28	Excellent quality
	Sli	8.77	13.80	5.224	2.733	0.581	6.45	0.55	0.34	6.457	1.153	0.24	0.0		
3	Qi	94.4	70.50	74.82	14.3	1.106	28.3	4.27	1.11	61.62	34.53	2.60	0.0	34.75	Excellent quality
	Sli	8.39	7.830	4.988	0.950	0.074	2.52	0.39	0.12	5.477	3.837	0.17	0.0		
4	Qi	99.2	72.00	68.82	18.80	1.060	31.8	5.67	1.56	115.3	27.47	3.30	0.0	39.07	Excellent quality
	Sli	8.18	7.999	4.588	1.253	0.071	2.83	0.48	0.17	10.25	3.052	0.22	0.0		
5	Qi	9.52	115.0	102.8	50.80	1.106	83.2	11.6	5.21	82.74	16.80	7.70	0.0	50.29	Good quality
	Sli	8.46	12.78	6.845	3.387	0.074	7.40	1.03	0.58	7.355	1.867	0.51	0.0		
6	Qi	94.4	115.5	80.47	28.90	3.548	60.8	11.8	18.1	105.0	14.67	7.60	0.0	48.67	Excellent quality
	Sli	8.39	12.83	5.347	1.927	0.237	5.40	1.05	2.02	9.332	1.630	0.507	0.0		
7	Qi	98.1	92.50	64.00	22.60	6.636	46.4	6.37	2.20	143.9	15.07	3.90	0.0	44.88	Excellent quality
	Sli	8.72	10.28	4.267	1.507	0.443	4.12	0.57	0.24	12.79	1.674	0.26	0.0		
8	Qi	96.4	106.0	106.4	35.90	2.533	60.1	12.5	5.55	150.3	21.33	8.00	0.0	53.33	Good quality
	Sli	8.57	11.78	7.089	2.393	0.169	5.34	1.11	0.62	13.36	2.370	0.53	0.0		
9	Qi	97.6	135.0	87.53	53.00	2.304	96.8	10.0	5.60	160.8	12.73	4.10	0.0	59.40	Good quality
	Sli	8.68	15.00	5.835	3.533	0.154	8.60	0.89	0.62	14.29	1.526	0.27	0.0		
10	Qi	100	93.50	88.47	24.50	2.535	46.7	6.00	2.10	116.2	18.27	2.70	0.0	44.47	Excellent quality
	Sli	8.92	10.39	5.898	1.633	0.169	4.15	0.53	0.23	10.33	2.030	0.18	0.0		
11	Qi	99.6	66.00	66.82	11.40	2.119	21.2	5.38	1.37	132.3	24.27	2.10	0.0	38.64	Excellent quality
	Sli	8.85	7.333	4.455	0.759	0.141	1.88	0.48	0.15	11.76	2.696	0.14	0.0		

as calcium, magnesium, sodium, sulfate and chloride ions etc. (Karroum *et al.*, 2019). The electrical conductivity of the groundwater sample values varied from (1.10 to 3.61) $dS.m^{-1}$ (Table 4), which showed that 44% of the aqueous samples exceeded the limit, these high values due to the nature of the geological formations of study areas rich in evaporative salts. (Al-Saffawi *et al.*, 2018a, Al-Sardar *et al.*, 2019). Therefore, salt-tolerant plants should be selected and the washing processes should be considered to prevent salt accumulation.

In this study, the minimum mean concentration of recorded bicarbonate ions was 5.44 $meq.l^{-1}$ and the maximum recorded was 9.04 $meq.l^{-1}$ during the study period, about 14% of these values are well above the appropriate limit for irrigation, the main reason for the presence of bicarbonate ions in groundwater may be due to the reaction of calcite and magnesium calcite with carbonic acid as described below (Al-Saffawi and Al-Sardar, 2018a, Kablan *et al.*, 2018). Eqs.:

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

$$CaCO_3 + H_2CO_3 \longrightarrow Ca^{+2} + 2HCO_3^{-1}$$

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

As well as the high average concentration of sulfate and chloride ions reaches to (3.0, 5.08) $meq.l^{-1}$ consecutively, which contributes to the high concentration of Potential salinity which reach to (8.32) $meq.l^{-1}$ and the relative rise in values is due to the nature of the geological rocks of the formation of Al-fatha in the study area which water passes through it, as well as the biodegradation processes of proteins by sulfur bacteria Thiobacillus denitrificatis, which aerobic oxidizes to sulfate ions as in the following equations (Al-Hamdany and Al-Saffawi, 2018):

$$CaSO_4 + 3[CH_2O] + \xrightarrow{Bacteria} 2CaCO_3 + 2S + CO_2 + 3H_2O$$

$$S^{=} + 2H^{+} \longrightarrow H_2S$$

$$H_2S + 2O_2 \xrightarrow{Bacteria} H_2SO_4$$

As for irrigation water indicators such as (%Na, SAR, KR. PI and RSC), the values are within the appropriate limits for irrigation due to the high concentrations of calcium and magnesium ions compared with the concentration of sodium and bicarbonate, thus, there are no problems of sodicity and harm permeability hazard (Ramadhan *et al.*, 2018), except the values of Magnesium Hazard (MH) for some wells water because of the high concentration of magnesium ions, which is due to the nature of the geological formations of the study area (Al-Sardar *et al.*, 2018).

Conclusions and Recommendations

Well water was characterized by the fact that most of the results of the analysis and indicators of irrigation water were within the appropriate limits for irrigation, with some minor exceptions such as high salinity and magnesium hazard values, which affected the quality of irrigation water (ranged from excellent to good quality).

Therefore, we recommend using the studied water to irrigate plants and trees growing in sandy and mixing soils, taking into account the washing processes to prevent the accumulation of salts in the soil. Solar water treatment is also required to improve its quality by activating photochemical reactions (Al-Saffawi and Talaat, 2018).

References

Al-Bachachi, O.M.S. (2014). Hydrogeochemistery of selected wellson both banks of Tigris river in Mosul area, Northern Iraq. *Iraqi J. of Earth Sci.*, **14(1):** 1-18.

Al-Hamdany, A.S. and A.Y.T. Al-Saffawi (2018a). Evaluation of the groundwater quality of the right side of Mosul city for drinking purposes using the water quality index (WQI). Accepted for publ. in the Proceed. of the First Int. Conf. and the third scientific of the Faculty of Science, Univ. of Tikrit, 17-18 December 2018. Iraq.

Al-Saffawi, A.Y.T. (2019). Water qualityindex assessment of ground water in Al- Nimrud district of Southeastern Mosul City. Iraq. *Pak. J. Anal. Environ. Chem.*, **20(1):** 75-81. http://doi.org/10.21743/pjaec/2018.06.01

Al-Saffawi, A.Y.T. and Y.A.M. Al-Shuuchi (2018). Assessment of groundwater quality for irrigation by using water quality index(IWQ index) in Al- Kasik district Northeastern of Mosul City. *Iraq. Int. J. of Enhanced Res. in Sci., Techn. and Engin.,* **7(1):** 76-81. http://www.erpublications.com.

Al-Saffawi, A.Y.T. (2018a). Assessment of groundwater for irrigation and domestic suitability byusing (WQI) in Singiar district eastern of Mosul city. Iraq. Mesopo. *Environ. j., Special Issue F.*, 75-84. http: www.bumej.com.

Al-Saffawi, A.Y.T. (2018b). Assessment of groundwater for irrigation and domestic suitability byusing (WQI) in Singiar district eastern of Mosul city. Iraq**.** *Mesopo. Environ. j., Special Issue F.*, 75-84. www.bumej.com.

Al-Saffawi, A.Y.T. and W.E. Al-Sinjari (2018). Assessment of water quality for irrigation by using water quality index (IWQ index) in Al- Kharrazi Valley at Mosul city. *Iraq (In Arabic) Alutroha for Env. Sci.*, **5:** 57-71.

Al-Saffawi, A.Y.T. and A.H. Al-Maathidi (2017). The quality evaluation of Wady Eqab wastewater in north of Mosul city for Irrigation Tikrit. *J. of Pure Sci.*, **22(12):** 14-20.

Al-Saffawi, A.Y.T. and R.A.A. Al-Shanoona (2012). Ecological and bacteriological study of the quality of groundwater Eastern of Mosul city. Proceedings of the 8th Envir. Sci. Confe. of the Faculty of Environmental Sci. and Techno. University of Mosul, 137-153.

Al-Saffawi, A.Y.T. and B.S.U. Abubakar (2019). Assessment of groundwater quality for irrigation using water quality index (IWQ index) in Al- Kasik subdistrict Northwestern of Mosul city. Iraq. (in publication).

Al-saffawi, A.Y., W.E. Al Sinjari and Y.A. Al-Taee (2019a). Application of WQI model to assessment of water dor irrigation and livestock drinking purpose: The case study, ground water quality of Gleewkhan village southeastern of Mosul city, Iraq. *Accepted for publication in j. Engineering and Applied Sci*., **14:** 23-24.

Al-Saffawi, A.Y.T. and R.A. Talat (2018). Sewage water purification through direct exposure to solar radiation. *Al-Rafidain J. of Sci*., **27(1):** 64-75.

Al-Sardar, N.M., A.Y.T. Al-Saffawi and R.A.A. Al-Shanona (2018). Water quality assessment in Abu Maria village/ district of Tall-Afar for irrigation and livestock drinking. *Educat. J. for Pure Sci*., **27(3):** 81-98.

Al-Yousbakey, K.T., A.M. Sulaiman and D.A. Ismaeel (2018). The evalution of chemical characterization for selected wells water in Mosul-Bahshiqa-Shalalat areas, Ninivah governorate, Northern Iraq. The 9th periodical Sci. Confer. of dam and water resources Res. Center. Mosul Univer. Iraq. 28-29 Nov. 2018, 201-216.

APHA, A.W.W.A. and W.C.P.E. (2017). Standard Method for Examination of water and wastewater American public Health Association, 23th ed., Washington, DC, USA.

Bhat, M.A., M.S. Grewal, Rajpaul, S.A. Wani and E.A. Dar (2016). Assessment of Groundwater Quality for Irrigation Purposes using Chemical Indices *Indian J. of Ecology*., **43(2):** 574-579. www.researchgate.net/publication/ 316063170.

Boateng, T.K., F. Opoku, S.O. Acquaah and O. Akoto (2016). Groundwater quality assessment using statistical approach and water quality index in Ejisu-Juaben Municipality, *Ghana Environ Earth Sci*., **75(489):** 1-14.

Dawood, A.S., A.N. Hamdan and A.S. Khudier (2018). Assessment of water quality index with analysis of physico-clemical parameters. Case study: The Shatt Al-Arab river, Iraq. *Int. Energy and Environ. Foundation*., 93-106. www.IEEFoundation.org.

Ememu, A.J. and H.O. Nwankwoala (2018). Application of water quality index (WQI) for agricultural and irrigational use around Okpoko, southastern Nigeria. Engin. *Heritage J. (GWK)*., **2(1):** 14-18.

Howladar, M.F., M.A. Al Numanbakth and M.O. Faruque (2017). An application of water quality index (WQI) and multivariate statistics to evaluate the water quality around Maddhapara granite mining industrial area, Dinajpur, Bangladesh. *Environ. Syst. Res*., **6(13):** 1-18. https:// www.researchgate.net/publication/323228536.

Karroum, L.A., M. El Baghdadi, A. Barakat, R. Meddah, M. Aadraoui and W. Ennaji (2019). Assessment of surface water quality using multivariate statistical techniques: El Abid River, Middle Atlas, *Morocco as a case study. Desalin. and Water Treat.,* **143:** 118-125. https:// www.researchgate.net/publication/331105832.

Nag, S.K. and S. Das (2014). Quality assessment of groundwater with special emphasis on irrigation and domestic suitability in Suri I&II block, Birbhum district, west Bengal, India. *Amer. J. Wat. Reso*., **2(4):** 81-98.

Narany, T.S., M.F. Ramli, A. Aris, W.N.A. Sulaiman and F.K. Kazem (2012). Assessment of groundwater quality for irrigation purpose in Amol Plain, Iran. 6th Int. Symposium on advances in Sci.and Techn. Malaysia, kuala lumpur, 24-25 March, 2012.

Ramadhan, O.M., A.Y.T. Al-Saffawi and M.H.S. Al-Mashhdany (2018). Assessment of Surface Water Quality for Irrigation using WQI model, A Case Study of Khosar and Tigris Rivers. *Int. J. of Enhanced Res. in Sci., Techn. and Engin.* **7(3):** 63-69. http://www.erpublications.com

Saeed, I.O., A.Y.T. Al-Saffawi and A.Y.H. Kaplan (2018). Application of the Canadian model for evaluating groundwater for irrigation and livestock watering: Case study: well water of Al-Sideq and Al-Hadba sectors in Mosul City. Proceedings of the 1st Inter. Conf. and the 3rd scientific of the Faculty of Sci. - Univ. of Tikrit, Iraq / 17 - 18 December 2018., 109-117.

Talat, R.A., A.Y.R. Al-Assaf and A.Y.T. Al-Saffawi (2019). Valuation of water quality for drinking and domestic purposes using WQI: Acase study for groundwater of Al-Gameaa and Al-Zeraee qaurters in Mosul city/Iraq. IOP Conf. Series, *Journal of Physics: Conf. Series*., 1-10. doi:10.1088/1742-6596/1294/7/072011.

Xu, P., W. Feng, H. Qian and Q. Zhang (2019). Hydrogeochemical characterization andiIrrigation quality assessment of shallow groundwater in the central-western Guanzhong Basin, China. *Int. J. Environ. Res. Public Health.,* **16:** 1-18. www.mdpi.com/journal/ijerph.

Yasmin, G., D. Islam, M.D.T. Islam, M.D. Shariot-Ullah and A.K.M. Adham (2019). Evaluation of groundwater quality for irrigation and drinking purposes in Barishal district of Bangladesh. *Fundamental and Applied Agriculture*., **4(1):** 632-641. https://www.researchgate.net/publication/ 333092092.