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WATER QUALITY ASSESSMENT USING THE POLLUTION INDEX MODEL (PIJ) FOR IRRIGATION PURPOSES. A CASE STUDY: DOHUK VALLEY WATER IN NORTHERN IRAQ

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ABSTRACT

A field survey was conducted for Duhok valley, fields and orchards in northern Iraq, where water is used for irrigation. Six sites were identified for collecting water samples starting from February 2021 until January 2022 to estimate both (pH, Electrical conductivity (EC_{25}), chloride ions (Cl^-), bicarbonate (HCO_3^-) as well as irrigation parameters such as sodium adsorption ratio (SAR), residual sodium carbonate (RSC), sodium percentage (% Na), permeability index (P.I), kelly ratio (K.R), Magnesium hazard (M.H) and potential salinity (P.S). The pollution index (PIJ) model was used to assess water quality for irrigation. The results of the current study indicated that the water quality index (PIj) values ranged between (0.9691 to 1.4559) and that 66.7% of the water samples were from the Lightly polluted water category, and the rest were from the good quality category for irrigation purposes. The relative deterioration of most of the irrigation water samples is attributed to the high concentration of bicarbonate ions (HCO_3^-) and the magnesium hazard (M.H), which reached (7.80) meq. l^{-1} and (84.0), respectively.

KEYWORDS: Pollution index (Pij), surface water quality, Dohuk Valley, Iraq

INTRODUCTION

The shortage of usable water resources with the increase in demand for them will lead in the future to ignite many critical problems for many countries of the world, especially the arid and semi-arid regions. During the recent decades, as a result of the cultural and economic development and the rapid growth of the population led to clear changes in the use of land, which resulted in an increased Demand for water for various civil, industrial, and agricultural activities (Al-Saffawi and Talat, 2019).

There are overlapping effects between water quality and soil that may cause Salinity problems, as reports indicate an increase in salinity problems in many parts of the world, leading to the loss of approximately 10 million hectares of arable land annually due to the use of highly salinized water for irrigation (Al-Sinjari and Al-Saffawi, 2018).

The quality of water used for irrigation depends on some factors, including:
I. Salinity Hazard damages appear when salts begin to accumulate in the root zone of the soil, which reduces the water availability of the plant and thus reduces the amount of water ready for absorption by the roots, and the continuation of this leads to reduced growth and dehydration of the plant (Simesk and Gunduz, 2007; Al- Al-Saffawi et al., 2020a).

II. Permeability and Infiltration Hazard occurs when using water with high levels of sodium (expressed in SAR); Sodium works to break down soil aggregates and disperse fine particles, which leads to blockage of soil pores, and the most important factors affecting permeability are salinity and the sodium adsorption ratio SAR (Al-Saffawi et al, 2020B; Al-Sinjari and Al-Saffawi, 2018).

III. Miscellaneous effects: It includes the pH that affects the balance of carbonates and the water content of mineral elements. Acidic water hinders the absorption of calcium and magnesium ions by the roots, while alkaline water provides a suitable environment for the absorption of many elements and nutrients by the roots (Simesk & Gunduz, 2007). Also, the high concentrations of bicarbonate and carbonate ions work to precipitate calcium and magnesium ions, leaving sodium ions prevailing in the soil solution, which affects the soil and plants. As for nitrate ions (NO_3^-), they are considered as a nitrogen source for plants, but increasing their addition to the soil has a detrimental effect on the plant, such as reducing production and deteriorating the quality of the crop, such as late ripening of crops and fruits, as well as their accumulation in them, causing health risks to consumers, such as children's blue disease, diabetes, thyroid dysfunction and immunity (Al-Hamdany et al, 2020; Al-Bhar and Al-Saffawi, 2021).

Therefore, the current study was conducted with the aim of using the irrigation water quality index (IWQI) to assess the water quality of Duhok valley for irrigation purposes.

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Materials and Methods:

i. General description of the current study area: The study included conducting a field survey to evaluate some physico-chemical properties of water for the Dohuk valley, which passes from the city center, where urban wastewater (houses, restaurants, hospitals, hotels, etc.) are dumped to be transported through its course that ranges from 25 km to the Mosul Dam lake on the Tigris River. Agricultural fields and orchards are spread on both sides of the valley to use this water for irrigation, especially during the dry season. Through field observations, we noticed a decrease in the transparency of the water with the emission of fetid odors. Figure (1) and table (1) show some of the characteristics and characteristics of the studied sites of the valley. Which was determined using the Global Positioning System (GPS) of Google Earth.

ii. Methodology: Water samples were collected monthly from six sites starting from Dohuk Dam Lake until its exit from the city of Dohuk and for a long distance (from February 2021 until January 2022) using clean polyethylene containers and then keeping them in a cold box and away from light until reaching the laboratory at the University of Dohuk. International standard methods for the analysis of water samples were used (APHA, 1998; 2017) where the pH was determined by (PH meter) after regulation with (PH: 4, 7, 9), electrical conductivity using EC-meter with values adjusted to 25 °C, bicarbonate ions (HCO3-) titrated with H2SO4 sulfuric acid (0.02 N), the concentration of chloride ions titrated by Mohr's method with standard AgNO3 solution (0.0141 N), calcium and magnesium ions titrated with Na2EDTA solution (0.02N). Sodium and potassium ions using a flame-Photometer (APHA 1998, 2017).

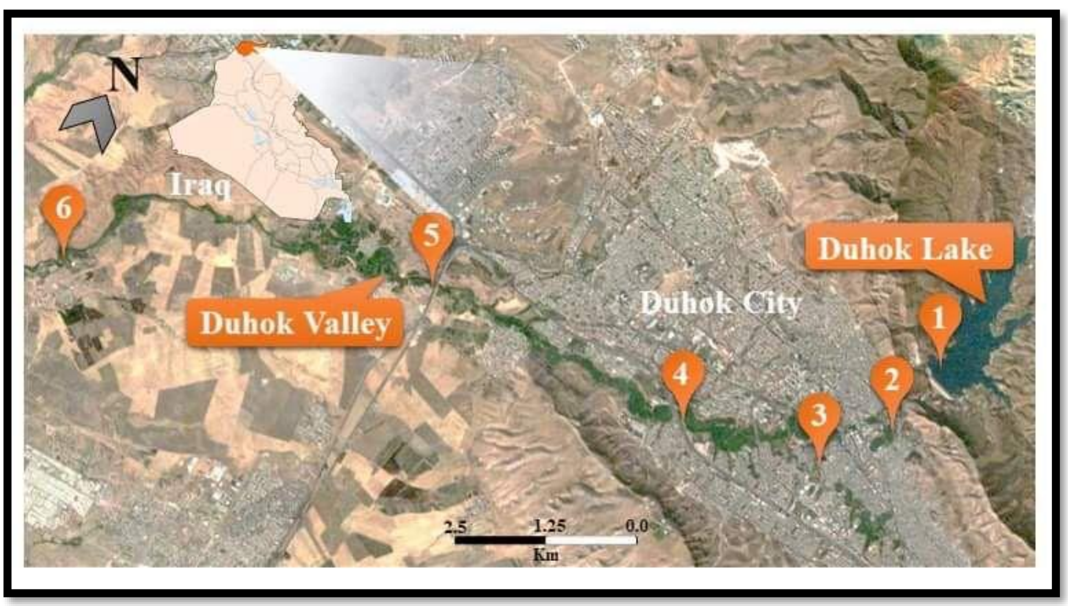

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Figure (1): A satellite image showing the study area and water sampling sites.

Table (1): Characteristics of the studied sites for the waters of Duhok valley, northern Iraq.

Sites		Altitude	Latitudes-N	Longitudes-E	Notes
S1	Duhok dam	607 m	36°87'74"	40°00'09"	
S2	Near D.P.C.[1]	551 m	36°86'78"	43°00'23"	
S3	Khashman Spring[2]	523 m	36.85'39"	42°99'38"	
S4	Shindokha Bridge	499 m	36°85'19"	42°96'79"	
S5	Aloka bridge	434 m	36°84'05"	42°91'08"	
S6	Bakhotmy	364 m	36°80'86"	42°85'38"	

[1]Near the Duhok Provincial Council., [2]Near Duhok Stadium

The irrigation parameters were also calculated using the following equations (Xu et al., 2019; Chegbeleh et al., 2020; Al-Saffawi, et al, 2020ab):

Sodium Adsorption Ratio (SAR) = $\frac{Na}{\sqrt{Ca+Mg/2}}$

Potential salinity (P.S) meq/L = $Cl + \frac{1}{2} SO_4$

RSC (meq. l^{-1}) = $[HCO_3^{-1} + CO_3^{=}] - (Ca^{+2} + Mg^{+2})]$

Sodium Percentage $\%Na = \frac{Na}{Na+K+Mg+Ca} \times 100$

Magnesium Hazard $(M.H) = \frac{Mg \times 100}{Ca+Mg}$

Kelly Ratio (K.R) $= \frac{Na}{Ca+Mg}$

Permeability Index (P.I) $= \frac{Na+\sqrt{HCO3}}{Ca+Mg+Na} \times 100$

Note: *All units used in laws are in (meq. l^{-1}).*

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As for calculating the water quality index (WQI), the pollution index model (PIJ) was used to evaluate the valley water for irrigation purposes using the most important parameters affecting the quality of irrigation water such as (pH, EC_{25}, SAR, Cl^-, HCO_3^-, RSC, PI, KR, % Na, M.H and P.S). To apply the pollution index model (PIJ) using the following formula indicated by Nemerow and Sumitomo (Tanjung et al, 2019; Hoya et al, 2020):

$$\text{Pij} = \sqrt[2]{\frac{\left[\frac{\text{Ci}}{\text{Lij}}\right]A^2 + \left[\frac{\text{Ci}}{\text{Lij}}\right]M^2}{2}}$$

If the value of [Ci/ LIJ] more than (1.0), then a new Ci/Lij will be calculated from the following formula:

$$\text{New Ci/Lij} = 1.0 + \text{P. log [Ci/ Lij]}$$

P: It is a constant whose value is usually equal 5.

For the Ci/Lij pH value is calculated:

5. If Ci < average Lij

$$\text{Ci/Li New} = \frac{\text{Ci} - \text{Lij average}}{\text{Lij min.} - \text{Lij average}}$$

ii. If Ci > average Lij :

$$\text{Ci/Lij New} = \frac{\text{Ci} - \text{Lij average}}{\text{Lij max.} - \text{Lij average}}$$

where: *Lij: standard Limit of water quality parameter at specified purpose (j).*
Ci: measured value of i^{th} parameter.
Pij: Pollution index for a specified water quality purpose (j)
[Ci /Lij] M: maximum value of Ci / Lij.
[Ci /Lij] A: average value of Ci/ Li

After calculating the value of the pollution index (IP), the water is classified into the appropriate category according to Table (2) (Al-Hamdani and Al-Saffawi, 2021).

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Table (2): Classification of water quality according to Pij value.

Class	Pij Value	Pij Category
1	0.0 to 1.0	Good water quality
2	1.1 to 5.0	Lightly polluted
3	5.1 to 10	Moderately polluted
4	➢ 10.0	Extremely polluted

RESULTS AND DISCUSSIONS:

The results are shown in Table 3 indicate that the pollution index values ranged from (0.9691 to 1.4559). When compared with Table 2 to assess water quality for irrigation purposes, most of the studied water samples (66.7%) were from the Lightly polluted water category (Class 2). Except for the waters of Dohuk Dam Lake (S_1 and the first site of the valley (S_2), which were of good quality water for irrigation.

This relative deterioration of the waters of Duhok valley (S_3 to S_6) is a result of the increase in most of the values of [Ci/lij] Max. and values of [Ci/lij] average reaching (1.9545 and 1.6565) compared to those of the waters of the site (S_1 and S_2) which

Table (3): Results of (IWQI) values and water quality classification of Duhok valley for irrigation purposes.

Sites No	[Ci/Lij]		IWQI (Pij)	
	Max.	Average	Values	Category
S1	1.4318	0.5513	1.0849	Good water quality
S2	1.2845	0.4779	0.9691	Good water quality
S3	1.7918	0.6654	1.3515	Medium polluted water
S4	1.6883	0.6728	1.2851	Medium polluted water
S5	1.9545	0.6478	1.4559	Medium polluted water
S6	1.2535	1.6565	1.2535	Medium polluted water

Amounted to (1.4318 and 0.5513) and (1.2845 and 0.4779), consecutively, which was negatively reflected in the (Pij) values, these effects can be clarified for the parameters used in calculating the IWQI values shown in Table 4, 5.

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Table 4: Lower, upper limits, mean and standard deviation (± Sd) for irrigation parameters*

Sites \ Parameter		pH	EC_{25}	Na^+	K^+	HCO_3^-	$SO_4^=$	Cl^-
S1	Min.	7.65	0.671	1.400	0.130	3.200	1.500	1.500
	Max..	8.16	0.794	2.700	0.230	7.400	4.100	2.200
	mean	7.79	0.727	2.200	0.186	4.617	2.950	1.867
	± Sd	0.14	0.043	0.363	0.032	1.894	0.664	0.193
S2	Min.	7.32	0.812	0.900	0.130	4.300	1.900	2.000
	Max..	7.88	1.045	1.700	0.230	6.400	5.700	2.600
	mean	7.64	0.918	1.408	0.175	5.175	4.008	2.283
	± Sd	0.18	0.061	0.263	0.034	0.597	1.204	0.207
S3	Min.	7.24	0.795	1.800	0.310	6.600	2.100	2.100
	Max..	7.61	1.016	2.400	0.380	8.100	4.000	3.500
	mean	7.38	0.877	2.083	0.332	7.200	3.067	2.867
	± Sd	0.09	0.072	0,223	0.025	0.430	0.548	0.429
S4	Min.	7.21	0.825	1.900	0.380	5.700	3.500	1.700
	Max..	7.86	0.981	3.000	0.460	7.800	5.000	3.700
	mean	7.32	0.877	2.508	0.418	6.867	4.250	2.583
	± Sd	0.17	0.048	0.415	0.031	0.677	0.454	0.479
S5	Min.	7.25	0.856	1.500	0.310	6.600	1.500	2.000
	Max..	7.58	0.943	2.500	0.360	9.800	2.200	3.000
	mean	7.45	0.894	2.142	0.332	7.760	1.833	2.475
	± Sd	0.11	0.024	0.225	0.022	0.734	0.228	0.344
S6	Min.	7.18	0.897	1.600	0.230	4.300	2.000	1.700
	Max..	7.85	1.135	2.800	0.280	9.500	2.700	2.400
	mean	7.66	1.016	2,342	0.265	6.765	2.425	2.067
	± Sd	0.17	0.098	0.293	0.018	0.938	0.213	0.213

* *Unites in meq.* l^{-1} *, except electrical conductivity in dS.* m^{-1}

As for the salinity damage represented by electrical conductivity (EC_{25}) and potential salinity (P.S), they are relatively high in the study, where (EC_{25}) values fluctuated between (0.671 to 1.136) dS. m^{-1}, as it is classified from a type of Doubtful

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Table (5): Lower, upper limits, mean and standard deviation (± Sd) for irrigation parameters.

Sites \ Parameters		RSC	P.S	SAR	% Na	PI	M.H	KR
S1	Min.	-1.400	2.800	0.600	12.00	31.50	45.00	0.140
	Max.	-5.500	4.300	1.400	25.20	53.00	76.00	0.340
	mean	-3.600	3.358	1.100	21.38	42.73	61.21	0.274
	± Sd	1.260	0.368	0.216	3.961	6.771	10.13	0.070
S2	Min.	-2.200	3.300	0.400	8.400	30.40	49.00	0.090
	Max.	-4.800	5.000	0.800	18.10	43.90	61.00	0.220
	mean	-3.442	3.400	0.667	14.00	36.99	56.50	0.165
	± Sd	0.906	0.508	0.137	3.009	4.770	3.937	0.045
S3	Min.	-0.800	3.400	0.900	17.70	47.00	61.00	0.220
	Max.	0.100	5.100	1.300	24.90	53.60	74.00	0.350
	mean	-0.283	4.408	1.067	21.03	49.88	67.07	0.280
	± Sd	0.302	0.585	0.149	2.374	2.278	3.964	0.046
S4	Min.	1.000	3.800	1.000	19.00	48.40	57.00	0.250
	Max.	-1.700	5.500	1.600	28.80	59.00	73.00	0.430
	mean	-2.442	4.700	1.308	24.15	51.90	66.00	0.339
	± Sd	0.793	0.410	0.236	3.285	3.311	5.071	0.065
S5	Min.	1.300	2.700	0.700	14.70	42.60	48.00	0.180
	Max.	-0.900	3.900	1.400	27.20	59.90	74.00	0.390
	mean	-0.050	3.400	1.083	20.68	49.79	59.93	0.276
	± Sd	1.037	0.363	0.207	3.628	5.096	7.950	0.069
S6	Min.	0.200	3.000	0.700	13.90	36.90	45.80	0.170
	Max.	-2.800	3.700	1.400	25.50	50.30	80.00	0.350
	mean	-2.200	3.292	1.117	20.28	43.72	64,43	0.264
	± Sd	1.290	0.206	0.191	3.543	4.684	14.06	0.063

and high salinity water (C_3) according to the classification of the USSL (Patel and Vadodaria, 2015), this increase in values is due to the discharge of wastewater into the valley as well as the reactions that occur with water, as in the following equations, including (Al-Saffawi et al, 2021; Qaseem et al, 2022):

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

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$$\text{Organic} + O_2 \xrightarrow{Microorganisms} \text{Organic Acid} + H_2CO_3$$

$$CaCO_3\downarrow + H_2CO_3 \longrightarrow Ca(HCO_3)_2$$

$$CaMg(CO_3)_2 + 2H_2CO_3 \longrightarrow Ca(HCO_3)_2 + Mg(HCO_3)_2$$

So, it is necessary to take into account the cultivation of salt-tolerant plant species and the appropriate management of the soil to maintain the soil from the accumulation of salts as well, the potential salinity (P.S) that expresses the effect of sulfates and chloride in the water irrigation on soil and irrigated plants that ranged between (2.800 to 5.500) meq. l^{-1}, as it is suitable for irrigating sandy and alluvial soils, but of poor quality for irrigating clay soils according to Doneen classification (Al-Saffawi and Al-Sinjari, 2018).

This relative increase in concentrations of P.S is due to the increase in the concentration of sulfate and then chlorides ions, whose rates reached (4.250 ±0.454, 2.867 ±0.429) sequentially, as a result of the waste-water and sulfur springs discharge into the valley, as well as the biochemical reactions that occur to the organic materials present in the water. as in the following equations mentioned (Al-Saffawi and Talat, 2019; Qaseem et al, 2022):

$$CaSO_4 + 3[CH_2O] \longrightarrow 2CaCO_3 + 2S + CO_2 + 3H_2O$$

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

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

$$2SO_2 + 2H_2O \longrightarrow 2H_2SO_3$$

$$2H_2SO_3 + O_2 \longrightarrow 2H_2SO_4$$

Despite the high concentration of sulfate and chloride ions, it causes soil salinization and a decrease in the productivity of cultivated plants as a result of burning the leaves of the plants (Al-Saffawi and Al-Maathidi, 2017). These results are relatively consistent with the results reached by (Al-Saffawi and Al-Maathidi, 2017)) when they studied the waters of Eqab valley in Mosul city, northern Iraq, which did not exceed the EC25 and P.S. (0.970) dS. m^{-1} and (3.63) meq. l^{-1} respectively, as well as the case with the findings (Al-Saffawi and Al-Sinjari, 2018) of the waters of Alkharazi valley in Mosul city, which did not exceed (1.19) dS. m^{-1} and (5.60) meq. l^{-1} consecutively.

As for the permeability and infiltration risks, the high concentration of sodium ions and bicarbonate increases the problems of soil permeability, as sodium works to destroy soil construction, which negatively affects the deterioration of soil permeability. This deterioration also increases with the increase in the salinity of irrigation water (Sarfraz et al, 2018). Table (5) shows that the values of SAR, %Na and RSC ranged between (0.40 to 1.600), (12.00 to 25.50) and (-0.20 to -5.50) sequentially. This indicates that there are no problems for SAR, %Na and RSC when this water is used for irrigation (Al-Saffawi et al, 2021b).

As for the Miscellaneous Effects, table (5) indicates that the pH values fluctuate slightly near the neutral state, ranging between (7.18 to 8.16), so that the studied water is within the appropriate limits for irrigation, as for the bicarbonate ion, although it plays a vital role in the acidity neutralization capacity (ANC). Without this capacity, the negative effects would have been worse on the aquatic ecosystem (Qaseem et al, 2022). This high concentration is due to the reactions that take place in the water as shown in the previous equation. In general, the concentrations of bicarbonate ions ($HCO3^-$)in the studied water ranged between (3.200 to 8.700) meq. l^{-1}, and thus the water is classified as an increased problem (IP) category, and in some periods, it reaches severe problem (SP) category at site (S_5) according to Ayers & Branson classification (Moghimi, 2016).

The values of the permeability index (P.I) were within the appropriate irrigation limits, as was the case with the values of (K.R), whose relative decrease was attributed to the increased levels of calcium and magnesium ions compared to the concentration of sodium ions. Therefore, there were damages to magnesium (M.H), as all the studied water samples were within un suitable levels for irrigation (Moghimi, 2016).

CONCLUSIONS AND RECOMMENDATIONS:

1. The waters of Duhok valley were characterized by the relative highness of some parameters such as electrical conductivity, salinity, bicarbonate ions and the of magnesium hazard (M.H).
2. That % 66.7 of the values of the water quality index (Pij) were of the slightly polluted type and the rest of the type of good quality water for irrigation purposes

Therefore, we recommend periodic monitoring of water resources in the region and the cultivation of salt-tolerant plant species, as well as the use of scientific and modern methods in irrigation operations.

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REFERENCES:

Al-Bhar, B.M.A. and Al-Saffawi, A.Y.T. (2021). Health effects of nitrate concentrations in the groundwater of Al-Manara village, north-east of Mosul city, Iraq. Science Archives. 2(3): 267-271.

www.sciencearchives.org

Al-Hamdani, O.Z.A. and Al-Saffawi, A.Y.T. (2021). Assessment of the quality of groundwater in the Lower Sherikhan area, Nineveh Governorate for irrigation purposes using the pollution index model (Pij). Int. J. of Advanced Res. in Sci., Engin. and Techn. 8(8): 17941- 17946. www.ijarset.com

Al-Hamdany, N. A. S., Al-Shaker, Y. M. S. and Al-Saffawi, A. Y. T. (2020). Application of nitrate pollution index (NPI) to evaluate the health safety of well water for some quarters of the left side of Mosul city, Iraq. Biochem. Cell. Arch. 20(2): 6063-6068. https://connectjournals.com/03896.2020.20.6063

Al-Saffawi, A Y T, Bhat, M A. and Azhar A. Albaker, A A.(2020ab). Assessment of Groundwater for Irrigation Using (IWQI)Model, Located in Al-Nimrud Region at Southeastern of Mosul City, Iraq. Pak. J. Anal. Environ. Chem. 21(2): 349 – 357. http://doi.org/10.21743/pjaec/2020.12.37

Al-Saffawi, A. Y. T. and Talat, R.A. (2019). Using water quality model (IWQI) to assess the reality of water wells Hamdania products in Ninawa Governorate for irrigation, Iraq. Int. J. of Environment & Water. 8(4): 74-85.

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

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

Al-Saffawi, A.Y.T., Bhat, M. A. and Azhar A. Albaker, A.A. (2021b). Assessment of Groundwater for Irrigation Using (IWQI) Model, Located in Al-Nimrud Region at Southeastern of Mosul City, Iraq. Pak. J. Anal. Environ. Chem. 21(2): 349 – 357 http://doi.org/10.21743/pjaec/2020.12.37

Al-Saffawi, A.Y.T., Bhat, M.A. and Albaker, A.A. (2020B). Assessment of Groundwater for Irrigation Using (IWQI) Model, Located in Al-Nimrud Region at Southeastern of Mosul City, Iraq. Pak. J. Anal. Environ. Chem. 21(2): 349 – 357. http://doi.org/10.21743/pjaec/2020.12.37

Al-Saffawi, A.Y.T., Ibn Abubakar, B.S.V.and Abbass, L.Y.(2020a). Assessment of groundwater quality for potential irrigation purpose using the IWQI index in AL-Kasik sub-district. Iraq. Nigerian Journal of Technology (NIJOTECH). 39 (2): 632–638. http://dx.doi.org/10.4314/njt.v39i1.35

Al-Sardar, N. M., Al-Saffawi, A. Y. T.& Al-Shanona, R. A. A. (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.

APHA, AWWA and WCPE (1998). "Stand Method for Examination of water and wastewater American public Health Association, 20th ed., Washington DC, USA.

APHA, AWWA and WCPE (2017). "Stand Method for Examination of water and wastewater American public Health Association, 23RD ed., Washington DC, USA. https://doi.org/10.2105/SMWW.2882.216

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Al-Sinjari, W.E.A. and Al-Saffawi, A.Y.T. (2018). Assessment of water quality for irrigation by using water quality index (IWQ index) in Al- Kharrazi Valley at Mosul city. Al-utroha for Environmental Sci. 5: 57-71. www.alutroha.com

Chegbeleh, L. P., Akurugu, B. A., and Yidana, S. M. (2020). Assessment of Groundwater Quality in the Talensi District, Northern Ghana. The Scientific World J., 2020(8450860)., :1-24. doi.org/10.1155/2020/8450860

Hoya, A.L., Nany, Y., Utomo, S. and Maharlika, A.R. (2020). Water quality assessment and control efforts use the pollution index method in the Sikendil river. E3S Web of Conferences 202, 06039 ICENIS (2020). https: //doi.org/10.1051/e3sconf/202020206039

Moghimi, H. (2016). The Assessment of groundwater resources for irrigation by water quality index (Case study Ghazvin plain, northwest Iran). Caspian Sea Journal. 10(4): 538-548.

Patel, Y. and Vadodaria, G. P. (2015) Hydro-chemical analysis of groundwater quality for irrigation of mehsana district, gujarat state, India. Int. J. of sci. and research (IJSR). 4 (2)., :2319-7064. www.ijsr.net

Qaseem, M.H., Al-Saffawi, A.Y.T. and A.Khalid, M.A. (2022). Assessment of the environmental reality of Duhok valley water and the expected effects on the water of the Mosul Dam Lake using weighted mathematical models (under publication).

Sarfraz, M., Sultana, N. and Jamil, M. (2018). Groundwater Quality and Health Risk Assessment in Rural Areas of District Jaffarabad, Baluchistan (Pakistan). Pak. J. Anal. Environ. Chem. 19(1): 79 – 85. http://doi.org/10.21743/pjaec/2018.06.08

Simsek, C. and Gunduz,O. (2007). IWQ index: AGIS integrated technique to assess irrigation water quality. Env.Monit. Asse.128: 277- 300. DOI.10.1007/S10661-006-9312-8.

Talabi, A. O., Abdu-Raheem, Y. A., Afolagboye, L. O., Oguntuase, M. A., and Akinola, O. O. (2020). Hydrogeochemistry of shallow groundwater in Ado-Ekiti Area, Southwestern Nigeria. Groundwater for Sustainable Development,11 (October 2020).1-20. https://doi.org/10.1016/j.gsd.2020.100386

Tanjung, R.H.R. Hamuna, B. and Alianto. (2019). Assessment of Water Quality and Pollution Index in Coastal Waters of Mimika, Indonesia. Journal of Ecological Engineering (JEE). 20(2): 87–94. https://doi.org/10.12911/22998993/95266

Xu, P., Feng, W., Qian, H. and Zhang, Q. (2019). Hydrogeochemical Characterization and Irrigation Quality Assessment of Shallow Groundwater in the Central-Western Guanzhong Basin, China. Int. J. Environ. Res. Public Health. 16(1492): 1-18. www.mdpi.com/journal/ijerph