ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 8 , August 2021

Assessment of the quality of groundwater in the Lower Sherikhan area, Nineveh Governorate for irrigation purposes using the pollution index model (Pij)

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ABSTRACT:A field survey was conducted for agricultural fields and farms in the Lower Sherikhan area north of Mosul city, Nineveh Governorate / Iraq, which uses well water for irrigation; Ten wells were identified for collecting water samples starting from September 2020 to February 2021(two samples per month for each well) to estimate (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)), permeability index (PI), Kelley ratio (KR), sodiumpercentage (% Na), Magnesium hazard (MH) and Potential Salinity (PS).The pollution index model (pij) was applied to assess the water quality for irrigation.
The results of the study indicated that the values of the water quality index fluctuated between (0.736 to 1.81) and that 90% of the studied water was from the category of lightly polluted, and the rest was from the category of good quality water for irrigation, this is because most of the studied parameters are within the international permissible limits for irrigation with problems of salinity and magnesium hazardin water in many samples and periods

KEYWORDS: pollution index (pij), groundwater quality, Lower Sherikhan region, Iraq.

I. 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, as well as countries whose water resources are from outside their territories, such as Iraq. Likewise, upstream countries are trying to exploit them politically and economically to achieve their goals, and studies indicated insufficient Water resources by the year 2025, especially the Middle East regions, including Iraq, although Iraq was rich in water resources until a few decades ago, climate change and the construction of many dams on the two rivers by neighboring countries caused water shortage and poor quality, so it is necessary to Focusing efforts on building service institutions to solve water resource pollution problems, building dams on rivers and water harvesting dams as well, rationalizing water consumption of all kinds, solving outstanding problems with upstream countries diplomatically, and not paying attention to negative and unhelpful projects (Bortolini et al., 2018; Al-Saffawi, and Al-Barzanji, 2020;Ewadi et al., 2019). Water enters the soil layers naturally due to the hydrological cycle of water, and its quality changes and varies during its movement through the geological layers, as groundwater is often characterized by the rise of calcium, magnesium and sodium salts, etc., according to the nature of the geological layers through which the water passes.In addition to the salts transferred to it from agricultural and animal activities, in addition to the increase in population centers around the areas of wells, all of this led to an increase in pollution problems and became a threat to health and the public interest, especially the consumers of the water from these wells (Al-Mashhadany, 2021a).

Therefore, scientific and practical solutions must be taken to address and mitigate this crisis. The solutions seem easy, and many of them are the use of integrated water management and the investment of surface water in a broader way, and when there is an urgent need, the role of groundwater comes despite its high concentration of salts that may cause problems for the soil and plants, and what complicates the Challenge is the high temperatures in Iraq in the summer (Kabalan, 2018) as well as the use of modern methods of irrigation with the determination of water quality using water quality models (WQI), It is an excellent way to give an idea of water quality for different purposes. As these models give one value that reflects the different interactions of the qualitative characteristics of the water instead of a large amount of data (Ramadhan et al., 2018; Al-Saffawi, 2019). Therefore, this study came to assess the water quality of the wells of the Lower Sherikhan area for irrigation purposes using the pollution index model (pij).

II. MATERIAL AND METHODS

I. General description of the study area: The current study dealt with the evaluation of some physicochemical properties of groundwater for the lower Al-Sherikhan area, located to the north-east of the city of Mosul, 7 km from the city center, which is distinguished by its agricultural nature that depends on well water as a main source of irrigation (surface wells because its depths do not It exceeds 20 meters) (Al-Saffawi and Al-Barzanji, 2020), and Table (1) and Figure (1) show some characteristics and locations of well sites that were determined using GPS for Google Earth.

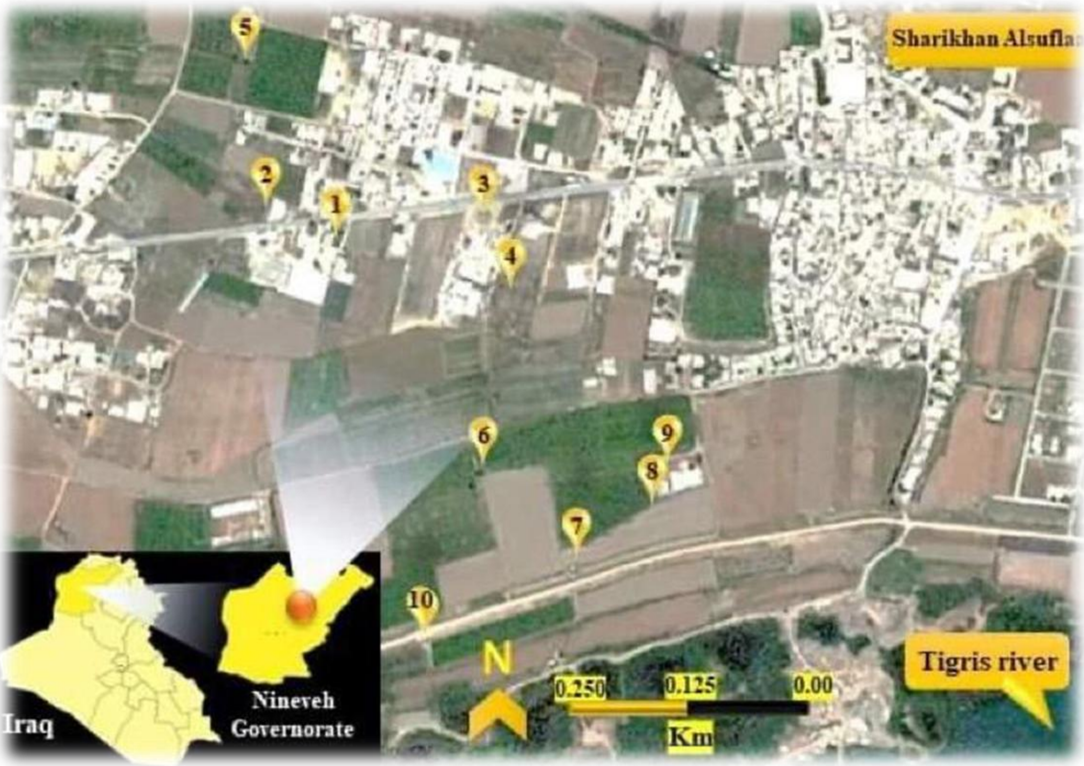
Table (1): Characteristics of the studied wells in the lower Sherikhan area.

Wells	latitudes	longitude	Depth	Altitude	Uses
1	36°24'09"N	43°03'58"E	7.0 m	223 m	for all uses
2	36°24'11"N	43°03'53"E	7.5 m	224 m	
3	36°24'10"N	43°04'05"E	7.5 m	223 m	
4	36°24'05"N	43°04'08"E	7.0 m	225 m	
5	36°24'15"N	43°03'54"E	7.0 m	224 m	
6	36°23'59"N	43°04'04"E	7.5 m	225 m	
7	36°23'56"N	43°04'10"E	8.0 m	226 m	
8	36°24'00"N	43°04'13"E	8.5 m	225 m	
9	36°24'02"N	43°04'14"E	8.0 m	225 m	
10	36°23'55"N	43°04'05"E	6.5 m	221 m	

II. Geology of the region: The geology of the study area consists of several layers, which are the Plaspi layer (Middle-upper Eiocene), The Al-Fatha formation (Middle Miocene), which contains salt and gypsum, as well as the Anjana formation (Upper Miocene), which is formed from a succession of clay, sandy rocks and marl, and these stratigraphic formations affect the quality of the water that passes through it (Al-Youzbaky and Eclimes, 2018; Al-Youzbaky et al, 2018).

III. Methodology: Samples were collected from ten selected wells in the Lower Sherikhan area, starting from (September 2020 to February 2021) at a rate of two repetitions per month for each well using clean polyethylene bottles. The samples are kept away from light until reaching the laboratory, and the international standard

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 8 , August 2021



Figure(1): shows a satellite view of the wells of the Lower Sherikhan area in Nineveh Governorate.

methods of analysis according to (APHA, 1998; 2017), where the pH was determined by(PH meter) after regulation with (PH: 4, 7, 9), electrical conductivity by (EC) meter with an adjustment of the reading to 25° C, bicarbonate ions by titration with sulfuric acid H_2SO_4 (0.02N) and the concentration of chloride ions by Moore's method by titration with a standard silver nitrate solution (0.0141N), calcium and magnesium ions by titration with Na_2EDTA solution and sodium and potassium ions with a flame Photometer (APHA 1998,2017). The standards irrigation parameters were also calculated using the following equations (Chegbeleh et al., 2020;Nag and Das, 2017,;Xu et al., 2019; Al-Saffawi, et al, 2020ab):

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

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

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

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

Magnesium Adsorption Ratio(MH) $= \frac{Mg\times100}{Ca+Mg}$

Kelly Ratio (KR)= $\frac{Na}{Ca+Mg}$=

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

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

Calculation of the water quality index (WQI): The pollution index model (Pij) was used for irrigation purposes using 11 parameters (pH, EC_{25}, SAR, Cl, HCO_3, RSC, PI KR, %Na, MAR and PS, and their comparison with the internationally approved standard limits for irrigation, which was referred to (Patel and Vadodaria, 2015), and to apply the (pij) pollution index model to assess water quality, the following steps were taken: (2016, Effendi; Riyadi et al, 2018):

1. Choosing the most important criteria affecting the quality of irrigation water.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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2. Calculation of Ci / Lij for all the criteria selected in the calculation of the mathematical model, where Ci represents the measured value of the parameter laboratory, and Lij represents the standard limits allowed for irrigation. If the value of Ci / Lij is greater than 1.0, it is modified to find a new value (Ci / Lij New) by the following equation:
New [Ci / Lij] =1+p log(Ci / Lij)Note that the value of p = 5
3 .Calculate the value of (Average) R (Ci / Lij), the Maximamvalue M (Ci / Lij), and taking into account the use of the laws of PH and dissolved oxygen when calculating the value of [Ci / Lij].
4. Calculate the value of the water quality index (pij) from the following equation:

$$pij = \sqrt{\frac{\left[\frac{ci}{lij}M + \frac{ci}{lij}R\right]^2}{2}}$$

After finding the value of WQI using the above equation. The water quality is classified according to the following table (2):

Table (2): Classification of water quality into four categories (Syamsiret al, 2019).

Pij value	$0 \leq$ to ≤ 1.0	$1.0 <$ to ≤ 5.0	$5.0 <$ to ≤ 10	> 10
Category	Good Condition	Lightly polluted	Moderately polluted	Heavily polluted
Class	I	II	III	IV

III. RESULTS AND DISCUSSION

The results shown in Table (3) were that the results of pollution index values ranged between (0.736 to 1.81) and after comparing with Table (2) to classify the quality of well water for irrigation purposes, all wells water were of the category of lightly polluted water (class II)., except for the water of well No. 1, which was of good condition for irrigation(class I).This relative deterioration of the water wells (2 to 10) due to the rise in most of the [Ci / lij] M values and the values of [Ci / lij] R to reach (2.45 and 0.753) compared with those of well water 1 which was (0.92 and 0.484) on the sequence, which was reflected in the Pij values, this can be clarified by the parameters used in calculating the water quality index values shown in Table (4).
Regarding electrical conductivity EC25 and P.S., the salinity risk is relatively high in well water (2 to 8) because salinity values fluctuate between (2485-1667) uS. cm-1, is a highly saline water type of poor quality (WHO, 2004). Also, salinity potential values expressing the effect of sulfate and chlorideions in irrigation water

Table (3): pollution index values Pij, Ci/lijR and Ci/lijM for Lower Sherikhan wells for irrigation purposes.

wells	[Ci/lij]M	[Ci/lij] R	pij	status
1	0.92	0.484	0.736	Good condition
2	1.72	0.634	1.290	Lightly polluted
3	1.54	0.639	1.180	Lightly polluted
4	2.28	0.753	1.690	Lightly polluted
5	1.81	0.647	1.360	Lightly polluted
6	2.45	0.702	1.810	Lightly polluted
7	1.82	0.555	1.350	Lightly polluted
8	1.84	0.613	1.370	Lightly polluted
9	2.10	0.708	1.570	Lightly polluted
10	1.99	0.601	1.470	Lightly polluted

Table (4): Results of water wells analysis in the lower Sherekhan area in Mosul city for irrigation purposes

Wells / Paramt.		1	2	3	4	5	6	7	8	9	10
PH	Max.	7.45	7.50	7.66	7.42	7.30	7.75	7.60	7.73	7.85	7.79
	Min.	7.01	7.10	7.01	7.00	7.05	7.30	7.23	7.01	7.25	7.40
	mean	7.17	7.26	7.22	7.21	7.17	7.47	7.37	7.17	7.46	7.62
Ec_{25}	Max.	1308	2184	2087	2326	1974	2575	1899	2114	2485	2005
	Min.	1177	1893	1667	2137	1875	2196	1697	1817	2328	1932

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

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	Mean	1256	2027	1885	2237	1916	2416	1807	2000	2400	1969
HCO_3	Max.	537	549	500	500	610	403	378	354	525	366
	Min.	403	451	378	415	349	244	220	220	390	293
	Mean	476	499	459	459	484	351	295	298	445	332
CL	Max.	80	140	170	250	260	255	270	165	290	200
	Min.	50	75	95	225	135	215	145	145	205	150
	Mean	65	111	141	234	186	231	171	156	242	172
Na	Max.	96	119	138	102	148	105	94	130	117	151
	Min.	85	108	107	91	123	97	85	113	105	139
	Mean	90	113	125	96	138	101	90	121	112	144
RSC	Max.	-3.4	-12.4	-9.4	-11.2	-9.8	-17.6	-15	-14.6	-14.6	-13.6
	Min.	-9	-22.4	-18	-24.6	-20.4	-32	-20.6	-21.4	-25.4	-23.8
	Mean	-6.7	-18.1	-14	-18.5	-15.2	-23.7	-17.9	-19.4	-20.2	-20
PS	Max.	6.1	11.8	10.9	14.2	12.1	14.8	11.5	11.1	14.4	12.5
	Min.	4.3	8	6	11.8	8.7	12.9	8.8	9.3	11.9	9.9
	Mean	5.11	9.73	8.96	12.6	10.13	13.66	10.18	10.28	13.01	11.08
SAR	Max.	1.85	1.58	2.1	2.2	1.72	1.57	1.31	1.43	1.95	1.36
	Min.	1.30	1.25	1.50	1.50	1.29	1.12	1.03	1.21	1.31	1.02
	Mean	1.49	1.36	1.67	1.78	1.44	1.39	1.17	1.30	1.64	1.18
%Na	Max.	28.4	19.5	25.6	26.3	22.6	17.7	17	18.4	23.6	17.6
	Min.	17.9	13.6	16.2	15.4	14.3	11.3	10.5	14.1	13.7	11.6
	Mean	21.45	15.75	20.37	19.82	17.31	14.48	14.03	15.9	18.14	14.1
PI	Max.	47.6	30.8	38.2	37.3	34.8	25.3	26.1	27.7	31.9	27.8
	Min.	31.6	21.8	25.4	22.8	22.8	17	20	21.6	21.4	18.7
	Mean	36.97	25.07	30.77	28.48	27.56	21.28	23.02	23.88	26.31	22.22
MH	Max.	53.8	67.3	65.1	68	63.3	72.9	77.5	66	66.6	60
	Min.	28	48.4	45	40	37.5	36.6	31.3	35	36.7	33.8
	Mean	42.74	54.88	55.96	53.17	47.75	49.83	45.61	51.02	51.1	48.08
KI	Max.	0.41	0.25	0.35	0.36	0.31	0.22	0.21	0.23	0.29	0.22
	Min.	0.22	0.16	0.19	0.18	0.17	0.13	0.14	0.16	0.16	0.13
	Mean	0.28	0.19	0.26	0.25	0.21	0.18	0.17	0.19	0.22	0.16

(Hwang et al., 2017), Its rates ranged between (8.96-13.66) meq. l^{-1}. Most of the studied water is of the poor water category when irrigating sandy and clay soils (poor permeability) depending on Doneen's classification, this deterioration is due to the nature of the geological formations through which the water passes (Al-Assaf et al., 2020).

As for the Permeability & Infiltration Hazard represented by the parameters related to sodium ions such as the permeability index (PI), sodium adsorption ratio(SAR),Sodium percentage (% Na), and the residual sodium carbonate (RSC), there is no problem for the values of these parameters in the irrigation water due to the high concentrations of calcium and magnesium ions, therefore, they were within the appropriate limits for irrigation. (Nag and Das, 2017;Gungor and Arslan, 2016)

As for sodium ionsexpressed as (SAR) and chloride that causes specific ion toxicity to plants when they are present in high concentrations in irrigation water and that toxicity problems are associated with salinity and permeability problems (Al-Mashhadany, 2021b), the concentration of chloride ions did not exceed (290) mg. l^{-1}, so the water is considered Slight to Moderate Restriction, while there is no problem for toxicity from sodium ions (Moghimi, 2016). Finally, the results are shown in Table (4) indicate a high concentration of bicarbonate ions to reach 60% of the water samples of the highly restrictive water category. Also, 50% of the studied water is not suitable for irrigation according to the MH values, where the values ranged between (42.74 to 77.5), while there is no problem with the values of pH and KR(Moghimi, 2016).

IV. CONCLUSIONS & RECOMMENDATIONS

The studied well water was characterized by the relative high of some of the studied parameters such as electrical conductivity, P. salinity, bicarbonate ions and magnesium hazard, which leads to the relative deterioration of the irrigation water quality; As 90% of the values of Pij were from the Lightly polluted water category for irrigation.

Therefore, we recommend using the studied water to irrigate salinity-tolerant plants and trees growing in sandy and mixed soils, taking into account the washing processes to prevent the accumulation of salts in the soil.

ACKNOWLEDGMENT

The researchers extend their thanks and appreciation to the presidency of the University of Mosul / Iraq represented by Prof. Dr. Qusay Kamal Al-Din Al-Ahmadi for the facilities provided to researchers and for providing all requirements Scientific research, as well as the Deanship of the College of Education for Pure Sciences and the Departments of Biology and Chemistry to facilitate work in their laboratories and provide all research requirements.

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