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Using Water Quality Index to Assess Drinking Water For AL-Muthana Project

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ABSTRACT

The water quality index is the most common mathematical way of monitoring water characteristics due to the reasons for the water parameters to identify the type of water and the validity of its use, whether for drinking, agricultural, or industrial purposes. The water arithmetic indicator method was used to evaluate the drinking water of the Al-Muthana project, where the design capacity was (40000) m3/day, and it consists of traditional units used to treat raw water. Based on the water parameters (Turb, TDS, TH, SO4, NO2, NO3, Cl, Mg, and Ca), the evaluation results were that the quality of drinking water is within the second category of the requirements of the WHO (86.658%) and the first category of the standard has not been met due to defects in design and operation and the inlet and outlet values of dissolved minerals were very close due to the absence of soluble salt removal units in AL-Muthana project
.

Keywords: Assessment, Water Quality Index, Drinking Water

استخدام مؤشر جودة المياه لتقييم مياه شرب مشروع المثنى

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الخلاصة

يعتبر مؤشر جودة المياه من أكثر الطرق الحسابية شيوعاً لقياس جودة المياه لأسباب تتعلق بمعايير المياه لتحديد نوع المياه وصلاحية استخدامها سواء لأغراض الشرب أو الزراعة أو الأغراض الصناعية. تم استخدام طريقة المؤشر الحسابي لتقييم مياه الشرب لمشروع المثنى المصمم بطاقة (40000) م 3 / يوم والذي يتكون من وحدات تقليدية تستخدم لمعالجة المياه الخام. بناءً على معايير المياه (Turb، TDS، TH، SO_4، NO_2، NO_3، Cl، Mg and Ca) كانت نتائج التقييم أن جودة مياه الشرب تقع

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ضمن الفئة الثانية من متطلبات منظمة الصحة العالمية بنسبة (86.658٪) ولم يتم استيفاء الفئة الأولى من المعيار بسبب عيوب في التصميم والتشغيل, وكانت قيم المعادن الداخله والخارجة متقاربة نتيجة لغياب وحدات ازالة المعادن الذائبة في مشروع ماء المثنى .
الكلمات الرئيسية: التقييم, مؤشر جودة المياه , ماء الشرب.

1.INTRODUCTION

One of the most basic needs of humans and other living organisms is providing safe and adequate water, where clean water helps to keep the environment free of pollution. Water quality issues are complex and have received widespread attention in recent years **(Akter et al., 2016)**. In many parts of the world, the water is not considered safe enough to drink. Basic qualitative (qualitative) readings quickly determine if water is unsafe for consumption. However, there are also many "invisible" substances that must be professionally tested to identify contaminants and see how a specific type of polluted water can be purified. Testing can be done in the field using portable test kits or mobile laboratories. Samples can also be collected and sent to specialized laboratories **(Drinan 2012)**.

Water pollution is also one of the challenges that endanger human life because of its consequences and direct impact on the existence of life. The recent period witnessed a high rate of pollution and water deterioration due to the increase in population and industrial and agricultural activity, both of which had a negative impact on water resources (**Ewaid and Abed 2017)**. Contaminated water is a major medium for disease transmission, with approximately 1.8 million people dying each year, mostly children, due to waterborne diseases **(Galal Uddin, Moniruzzaman, and Khan 2017)**. According to **(A. Adnan, A. Mohammed, and T. Al-Madhhachi 2021),** the social and economic environment is related to surface water efficiency, which affects the quality and characteristics as a result of the behaviors of individuals within that community.

It is possible to improve the validity of water for various uses by comparing water properties with the World Health Organization's requirements which also determine whether it is safe for human consumption, known as water quality **(Ibrahim 2019).** Fresh water is commonly used as a manual to a system of rules based on its intended utilization water, which also is widely categorized as industrial usage, propaganda purposes (portability), as well as regeneration (in the surroundings, ordinarily for health care life), in which requirements are being used. Furthermore, to protect various types of water **(Banda and Kumarasamy 2020)**. Water used for drinking, for example, must meet higher standards than water used for agricultural or industrial purposes (as a result, water used for residential uses should be safe and non-toxic materials and microbes to avoid waterborne diseases). **(Kim et al. 2020).** The purpose of this study was to evaluate the treated water for AL- Muthana Project using the water quality index.

2. Methodology and method of work

2.1.Description case study

The AL-Muthana project is located on the AL-Rumatha River in the AL-Rumatha district, which lies in the northern part of the AL-Muthana Governorate, and it consists of conventional units. AL-Muthana Project has played an important role in providing drinking water to AL-Samawa city. It was built with a design capacity of $(40000m^3/day)$ to meet the public's needs due to rapid population growth and water demand. **Fig. (1) and (2)** showed the AL-Muthana WTP's overall layout, including collection, treatment, and storage facilities. The following is a synopsis of all WTP units' component facilities

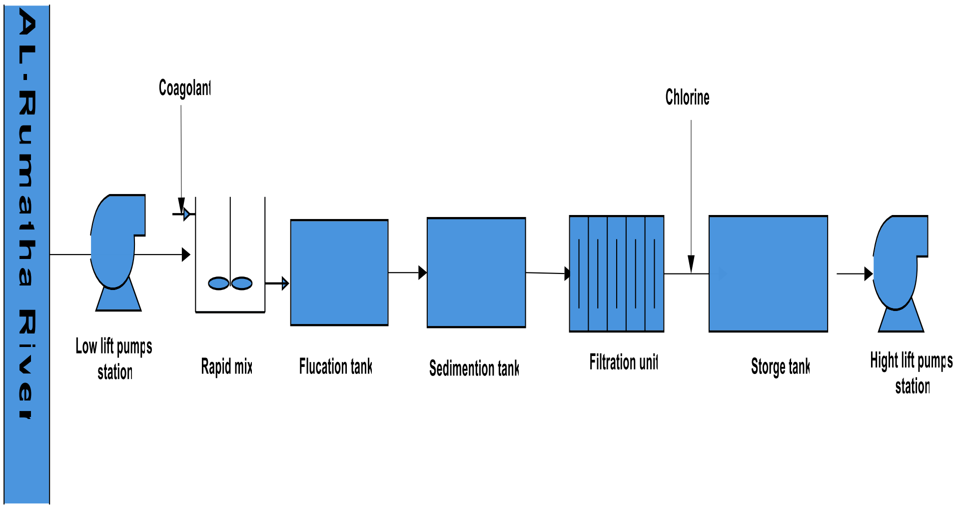

Figure 1. AL-Muthana water treatment plant train.

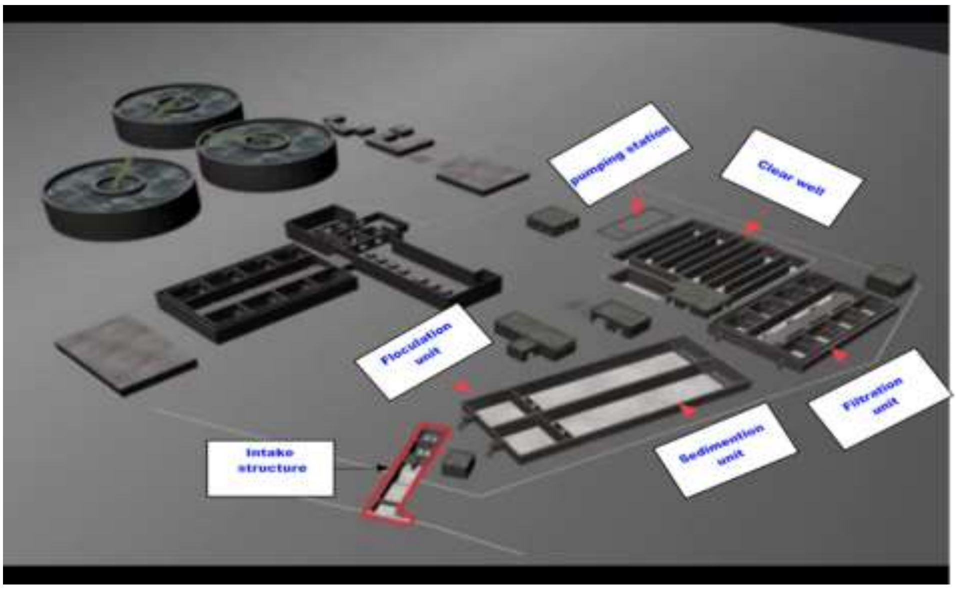

Figure 2. AL-Muthana WTP structure.

2.2.Filed sampling

A water body's chemical, biological, and physical parameters should always be measured to determine its performance. Chemical readings and biological survey data help to develop a "complete image of water quality." The list consists of (physical, chemical, and biological) factors collected from the field in February 2022 and widely used to analyze water quality.

- Physical indicators: (Turbidity, Temperature, Electric conductivity, Total suspended solid, and Total dissolved solid).
- Chemical indicators: (Total hardness, pH, Phosphates, Nitrates, Nitrite, Magnesium, Calcium, and Chloride).
- Biological indicators: (Fecal coliform).

2.3.Water quality index calculation

While many specifications are used to assess water, some variables appear to be similar in that they can compare water quality criteria with their own regulatory requirements, with the results being interpreted as positive or negative **(Al-rikabi and Abed 2021).**

Water quality applications based on parameters derived from the most common water quality variables: Temperature, BOD, fecal colon, pH, dissolved oxygen, Total phosphate, Nitrate, and Turbidity were used according to the below details **(Alobaidy, Abid, and Maulood 2010):**

$$WQI = \frac{\sum_i^n qi\, Wi}{\sum Wi} \qquad \textbf{(1)}$$

Where qi: quality rating scale which can be calculated by

$$qi = \frac{ci}{si} \times 100 \qquad \textbf{(2)}$$

Ci: Observed variable concentration (i)

Si: parameter(i) regular value according to WHO

The formula determined relative weight (w)

$$W = \frac{1}{si} \qquad \textbf{(3)}$$

The (i) variable's standard value was also inversely related to the varying weight. The relative weight (wi) can be calculated by using the following **(Alwaeli, Ali, and Mohammed 2021).**

$$wi = \frac{w}{\sum_1^n w} \qquad \textbf{(4)}$$

The sub-indices SIi and WQI are calculated using Equations (1) and (4), respectively. Where SIi is the I parameter's sub-index and qi is the rating based on the concentration of the I parameter, and SIi can be calculated using the equation

SIi =wi X qi **(5)**

WQI = $\sum SIi$ **(6)**

After that, the result was compared with WHO limitations listed in **Table 1.**

Table 1. Water quality evaluations according to WHO limitations.

WQI level	Ratings of water quality
91–100	Excellent
71–90	Good
51–70	Medium
26–50	Bad
0–25	Very Bad

3. Result and discussions

3.1.Water Quality Index

WQI was used to evaluate the AL- Muthanna project's drinking water quality depending on water parameters field tests. Then, the results were compared to World Health Organization requirements to determine the level of water quality.

Tables 2 and 3 list the results of the WQI calculation, with a result of (86,568) %, revealing that the water quality was good. It falls into the second category according to WHO, indicating that it can be used for drinking purposes; also, tables listed that some water parameters, such as turbidity, electric conductivity and total dissolved solids, were higher than the WHO limitations. Still, the overall value of the water quality index was acceptable. at

Two reasons for not falling into the first class of WHO limitations: the first was due to defects in project design in which did not contain unit removed the dissolved mineral from influent raw water, and the Second was operational defects such as inexperience of workers, A jar test was not performed to determine the suitable coagulant dosage, and less detention time in the sedimentation unit were identified due to increased demand in which these causes consist with (**Abd Nasier and Abdulrazzaq 2021)**.

Table 2. Quality rating scale calculations.

Parameters	Permissible value (si)	Observed values (ci)	qi	WQI
TDS	500	900	180	86.568
Turb	5	6	120	
E.C	1000	1100	110	
Ca^{+2}	200	180	90	
Mg^{+2}	150	80	53	
TH	500	450	90	
pH	8.5	7.8	92	
Cl^{-}	250	200	80	
SO4	250	150	60	
NO3	50	30	60	
NO2	3	2	67	

Table 3. Relative weight calculations.

Parameters	W	Wi	Wi X qi
TDS	0.003	0.04	7.2
Turb	0.2	0.265	31.8
E.C	0.001	0.013	1.43
Ca+2	0.005	0.07	6.3
Mg+2	0.07	0.09	4.77
TH	0.002	0.026	2.34
pH	0.118	0.156	14.352
Cl-	0.004	0.053	4.24
SO4	0.004	0.053	3.18
NO3	0.02	0.026	1.56

Parameters	W	Wi	Wi X qi
NO2	0.333	0.44	29.48
Total	0.756	1.232	106.652

3.2.Treated Water Quality

Weekly samples of raw and treated water were collected to perform chemical and physical tests and compare the results to Iraqi and World Health Organization standards

Table 4. Descriptive statistics for raw water parameters**.**

Descriptive statistic	N	Minimum	Maximum	Mean	Std. Deviation
Cl^-	26	136.00	198.00	158.9231	19.90361
SO4	26	230.00	290.00	252.5769	19.31046
TH	26	513.00	560.00	533.5000	14.46720
TDS	26	870.00	1300.00	1023.1923	115.94551
Ca^{+2}	26	108.00	137.00	120.6154	8.92223
Mg^{+2}	26	57.00	71.00	63.6538	3.86722
pH	26	7.70	8.20	7.8846	.11204
Temp	26	10.00	33.00	21.5769	6.63429
Alk	26	125.00	145.00	131.7692	4.97440
EC	26	1265.00	1870.00	1476.8846	159.66398

Table 5. Descriptive statistics for treated water parameter.

Descriptive statistic	N	Minimum	Maximum	Mean	Std. Deviation
Cl	26	132.00	197.00	156.6538	20.08570
SO_4	26	229.00	288.00	250.7308	19.21782
TH	26	439.00	555.00	525.2308	22.90905
TDS	26	860.00	1290.00	1013.1923	115.94551
Ca	26	105.00	135.00	117.9615	9.39140
Mg	26	53.00	68.00	60.4615	4.31954
pH	26	7.60	8.00	7.7192	.09806
Temp	26	10.00	33.00	21.5000	6.64078

Alk	26	118.00	140.00	126.4615	5.22479
EC	26	1265.00	1860.00	1467.2692	159.14435

I. Residual Chlorine

It is critical to use the correct amount of chlorine solution. If the chlorine concentration is insufficient, the process of destroying all harmful microorganisms may fail, and if it exceeds the required limit, health may suffer. Only the right amount of chlorine can kill most harmful microorganisms while also providing a safe level of residual chlorine. "Free residual chlorine" refers to chlorine that does not combine with other components and thus remains in the water. The presence of free residual chlorine ensures that chlorinated water is not re-contaminated during transportation and storage. The concentration of "free residual chlorine" in drinking water should be between 0.2 and 0.5 mg/L, according to WHO guidelines **(Susanto et al. 2020).** During the evaluation phase, the lowest residual chlorine value was around 0.95 mg/L, and the highest value was 3.5 mg/L, both of which were higher than the World Health Organization's guideline level. The most concerning aspect is the substances formed as a result of the interaction of chlorine with organic compounds in water, which produces harmful products known as (Trihalomethanes), which cause cell damage and increase the body's susceptibility to cancer, as well as an undesirable taste of the water produced. One of the most important reasons for not meeting the residual chlorine specification requirements is a lack of accurate calibration by employees to add these disinfectants due to a lack of experience and training on how to do so. **Fig. 3** showed the variation of residual chlorine during the evaluation period .

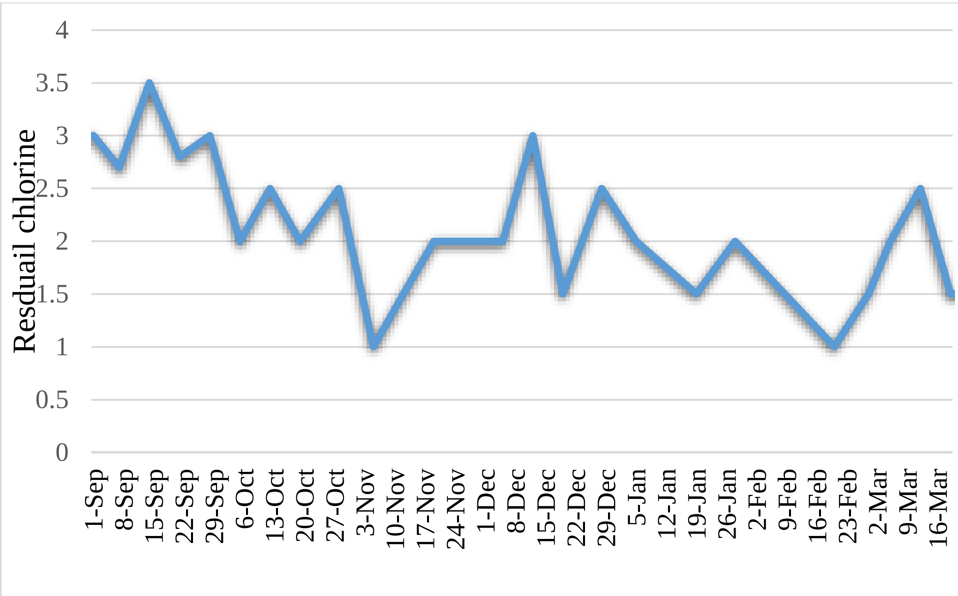

Figure 3. Residual chlorine in treated water.

II. Alkalinity

For treated and untreated water, the highest alkalinity value was (145-125) mg/L, and the lowest value was (125-120) mg/L, and both were less than the WHO 2011 limitations, as shown in **Fig. 4.** The impact of coagulants, which consume a portion of the alkaline materials, was responsible for the reduction in the alkalinity of the treated water **(Ncibi et al., 2017).**

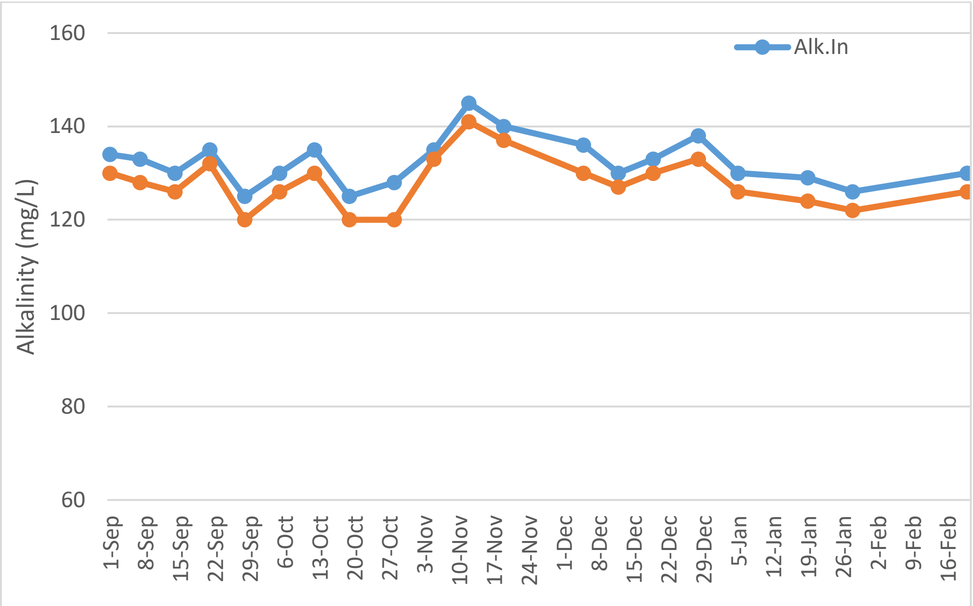

Figure 4. The alkalinity of raw water and treated water.

III. Total hardness

The average total hardness for raw and treated water was very close due to the nature of the AL-Muthanna project, which did not include units that could remove dissolved minerals. The project at all times had a total hardness above specification limits, as shown in **Fig. 5.** Water hardness is primarily caused by water-soluble calcium and magnesium cat ions, the most commonly positively charged ions in naturally hardened water. High hardness harms human health (osteoporosis, kidney disease, obesity) and negatively impacts pipes, household appliances, the textile industry, and boilers **(Akram and M 2018).**

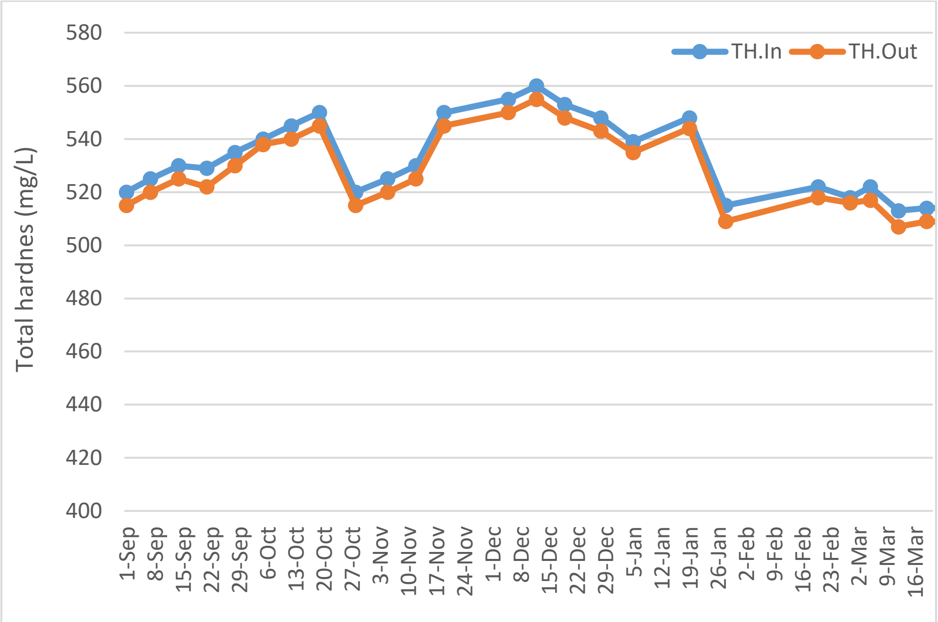

Figure 5. TH of raw water and treated water.

IV. Calcium and Magnesium

Calcium salts contribute to the body's need for calcium to build bones and teeth, and are also responsible for the hardness of water, which affects the performance of washing machines and cleaning powders. It also causes the formation of calcifications in water systems, boiling vessels and industrial boilers (Cormick et al. 2020). The upper and lower limits of calcium in raw and product water were (137-108) mg/L and (135-105) mg/L, respectively, which were greater than the Iraqi specifications' limitations, and it should be noted that the higher value occurs at lower temperatures as shown in Fig. 6. During the study period, the average magnesium observations for untreated and treated water were (63.5) mg/l and (60.3) mg/l, respectively, which excited the Iraqi limitations as shown in **Fig. 7.** Because the AL-Muthanna Project lacks a technology to remove calcium and magnesium ions, such as an ion-exchange method, the concentrations of calcium and magnesium in raw and product water were very close.

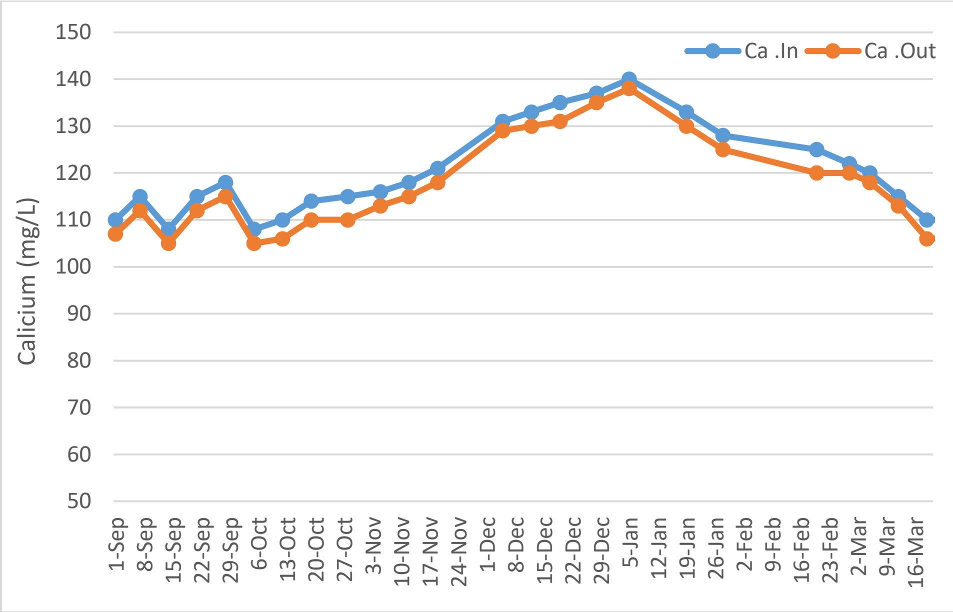

Figure 6. Ca^{+2} of raw water and treated water **.**

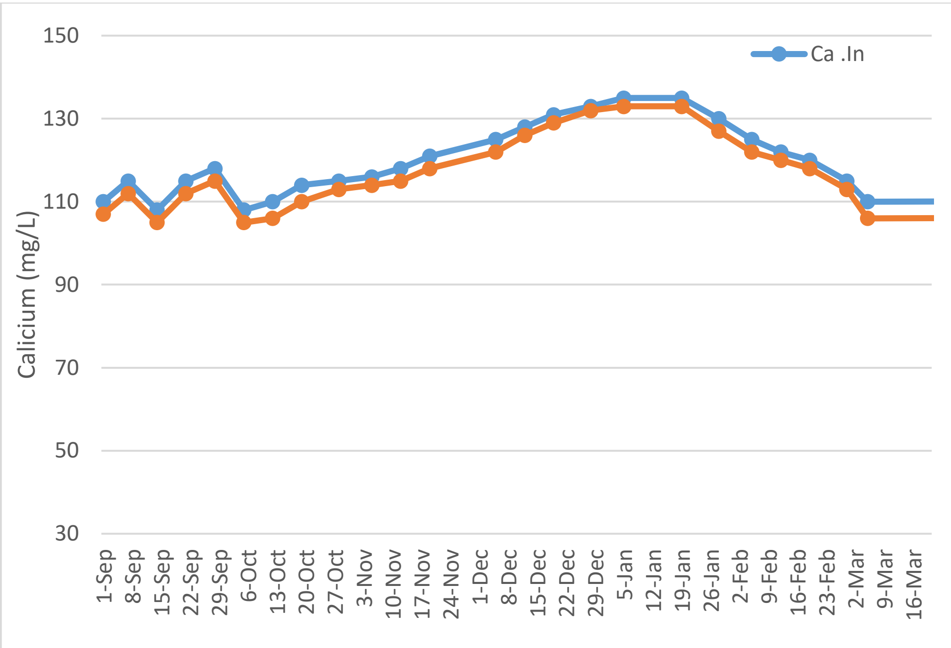

Figure 7. Mg^{+2} of raw water and treated water.

V. Total dissolved solids and Electric Conductivity

The total dissolved solids is an expression of the amount of solid salts dissolved in water, so that water contains many inorganic solid components, as salinity is not limited to only one type of salt, but rather is a percentage of the total concentration of dissolved salts together, such as potassium, magnesium, calcium, and sodium **(Wang, 2021).**

Fig. 8 shows that the Total Dissolved Solids of raw and product water did not exceed the Iraqi standard limitations during the study period, except for the period from the beginning of November to the end of December, which was larger than1000 mg./L, because the AL-Muthana Water Directorate was pumped water from the AL-Sobel River (which contains a very high percentage of TDS, see Chapter Three, Page No. 2, Paragraph No. 3) to Al-Rumaitha River (the source of raw water for the Al-Muthana project) to compensate for the shortage of water level. In addition, the figure shows that the inlet and outlet TDS values were very close due to the absence of soluble salt removal units. The electrical conductivity expresses the percentages of TDS in water, with a high value indicating a high concentration of salts in the water. The increase in salt is either a natural act, such as the nature of water and groundwater, or what dissolves and falls in rainwater from elements, or it is the result of industrial activities, such as the discharge of sewage or industrial water into natural water bodies **(Pal et al., 2015). Fig. 9** shows that the average of E.C for untreated and treated water was (1470-1455), which exceeded the Iraqi and WHO permissible limit in which both influent and out fluent values were very close.

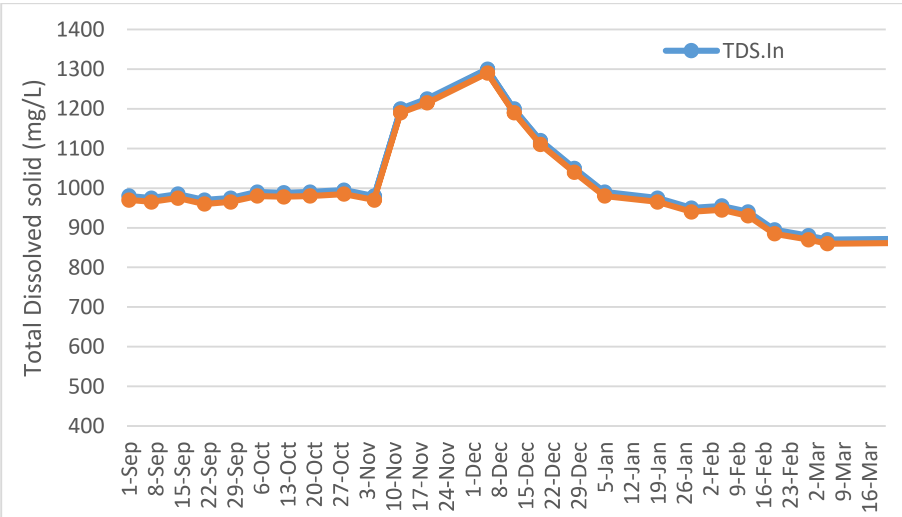

Figure 8. Total dissolved solids in raw and treated water.

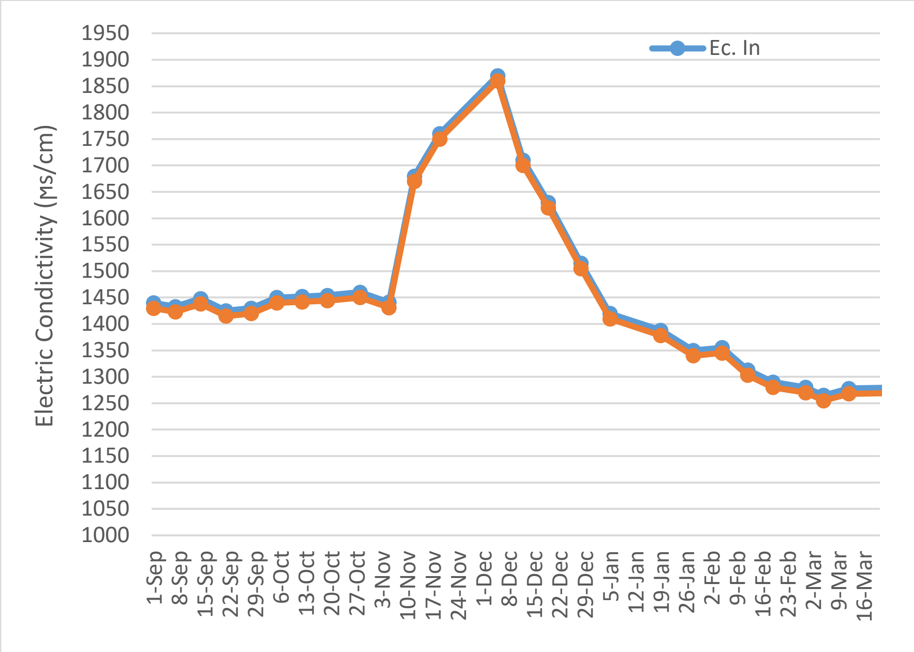

Figure 9. The electric conductivity of raw and treated water.

VI. Temperature and pH

Rising temperatures influence the chemical, biological, and physical reactions that occur during the stages of water treatment and act as a catalyst for these reactions. Furthermore, the low temperature reduces the solubility of gases in water, such as oxygen **(Agudelo-Vera et al., 2020).** During the study period, the maximum, minimum, and average temperatures were (33, 10, and 22)℃, as the temperature for September and October exceeded the limits of the Iraqi standard, while the rest of the months(January, February, and March) were within the requirements of the Iraqi standard**.** The average acidity level for raw and treated water was (7.9-7.7), which was within the Iraqi and WHO standards requirements. The reduction in pH for treated water was caused by the addition of coagulants, which consume a portion of it during the coagulation stage.

VII. Chloride and sulfite

The chloride ion is one of the most widely available negative ions in natural water, and when it combines with the sodium ion to form sodium chloride, the water gets on a salty taste (table salt). Chloride salts are characterized by their high water solubility. The presence of chloride ions in high concentrations in water has a toxic effect on crops, and a high percentage of chloride is present in domestic and industrial wastewater **(Bakshi, Doucette, and Kyser, 2021).** Furthermore, increasing the concentrations of chlorides reduces the effectiveness of disinfectants in reducing bacteria, as practical experiments revealed that the number of bacteria decreased when the concentrations of chlorides (10, 90, 290) mg/L were (5.6 log 10, 2.9 log 10, and 2.2. Log10), respectively **(Lehtonen et al., 2019).**The average chloride concentration in untreated and treated water was (158.9-

156.65) mg/L, above the permissible limit set by Iraqi and WHO standards, as shown in **Fig. 10.** When high concentrations of sulfates are present in drinking water, they can cause diarrhea in humans, especially if they are magnesium and sodium sulfate, also, calcium sulfate causes permanent hardness in water. The natural source of sulfate is rocks, while the industrial source is liquid waste **(Bashir, Ali, and Bashir 2012). Fig. 11** showed that the average amount of influent and effluent sulfates was (252.6 - 250.7) mg/L, which was slightly higher than the allowable limit of IRQ and WHO standards due to a significant increase in salt concentrations between the beginning of November to the end of December.

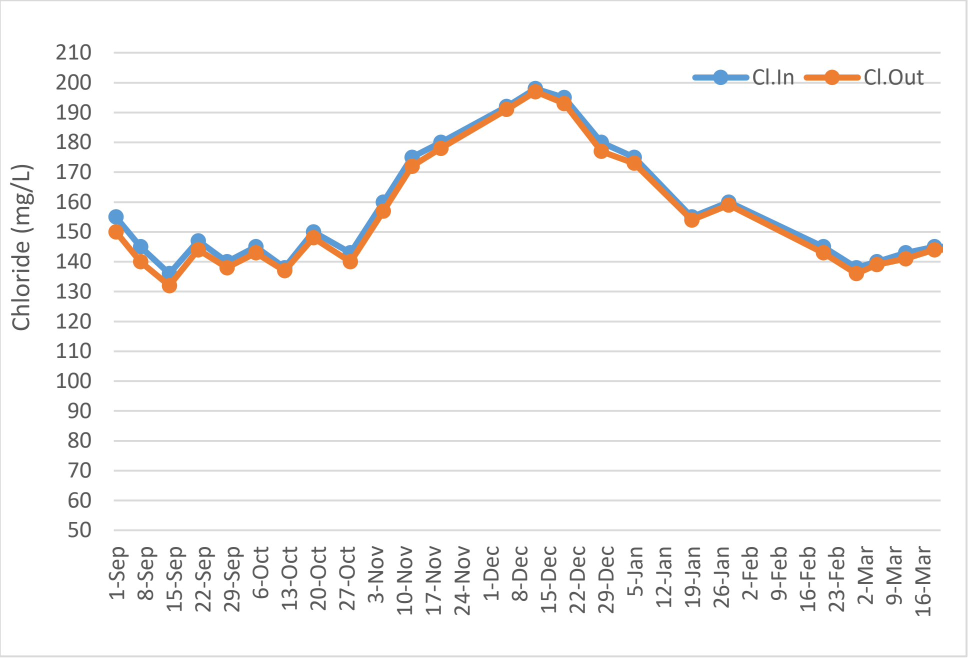

Figure 10. Chloride in raw and treated water.

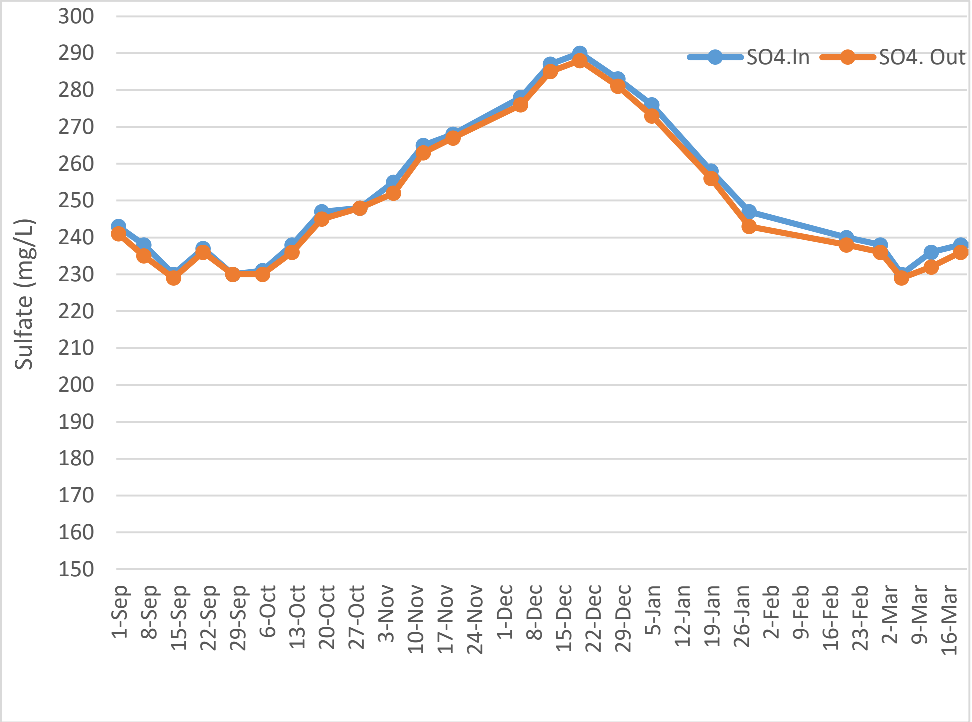

Figure 11. Sulfate in raw and treated water.

4. CONCLUSIONS

WQI was used to assess the suitability of water for use and consumption for human purposes. Despite the presence of some physical and chemical analyzes of the water samples implicitly exceeding World Health Organization requirements, the WQI of the Al-Muthanna Project was in class two, indicating that it is good and suitable for human consumption, although some water parameters were higher than the WHO limitations, but the overall value of the WQI was acceptable, and the inlet and outlet values of dissolved minerals were very close due to the absence of soluble salt removal units in AL-Muthana project

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