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A Study of Some Physicochemical and Bacteriological Parameters of Water Treatment Plants in Al-Muthanna Governorate with the Application of Statistical Factors (Independent Samples t-test)

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Abstract. This study was conducted to evaluate the efficiency of water treatment plants in Al-Muthanna Governorate by examining the physical and chemical properties of raw and treated water and comparing them with Iraqi standard specifications. The study was conducted on four plants (Al-Samawah, Al-Rumaytha, Al-Warka, and Al-Khidr) for eleven variables: temperature, pH, electrical conductivity, total dissolved solids, turbidity, total hardness, sodium, calcium, magnesium, sulfates, and chlorides. The study was conducted in two phases. The first phase, the wet period, extended from November 2023 to March 2024. The second phase, the dry period, extended from May 2024 to September 2024. The results showed that the physical and chemical parameters were outside the permissible limits according to Iraqi specifications, and that the water was unfit for consumption.

1. Introduction

Water is essential for life and its continuation, without neglecting other elements, most importantly air. However, its direct importance lies in its comprehensive role in sustaining the lives of various living organisms, regardless of their specific needs. Humans rely on water directly and benefit from it in numerous ways. We must not overlook the fact that they use clean water daily to maintain their health (Al-Zahrani, 2002, p. 315), which is provided through water purification plants. Therefore, it is essential that drinking water be free from pollutants that could cause harm to the drinker, such as illness or pain (Al-Saadi et al., 1989, p. 510). Statistics and studies in the United States indicate that 59% of diseases are caused by drinking water pollution (Al-Safawi et al., 2013, p. 86). Reports from the United Nations Programme of Education (UNEP) in 1999 indicate that more than 80% of diseases and more than 33% of deaths in developing countries are caused by the pollution of drinking water sources (Raml, 2010, p. 20). Since there is no 100% pure water in nature (Cabelli, 1979), humans have long tried to control the problems of polluted water and have used several methods to purify it. One of these methods is boiling water, which is the first method humans used to obtain healthy water. In addition to its ease, it can be done by anyone and is suitable in emergency situations. However, the disadvantages of this method are that it produces undesirable water and is used for small quantities of water (Laubusch, 1971).

1.1 Area Description

Four drinking water treatment plants were selected in Al-Muthanna Governorate, drawing their water from the Euphrates River or its tributaries. Table (1) lists the names of the treatment plants and their associated complexes included in the study.

Table (1): Names of Treatment Plants in Al-Muthanna Governorate

No.	Location	Complex or Station	Source
1	Samawah	Barbuti Complexes	Samawah Canal / Euphrates River
2	Rumaytha	First Teachers' Neighborhood Complex	Rumaytha Canal / Euphrates River
3	Khidr	Al-Soub Al-Saghir Water Complex	Euphrates River
4	Warka	Al-Warka Water Project	Euphrates River

Source: Ministry of Construction, Housing, and Municipalities, General Directorate of Water, Department of Environment and Quality Control, Al-Muthanna Governorate, Unpublished Data, 2023.

1.2 Sampling Method

Samples were collected from water treatment plants between November 10, 2023, and September 15, 2024, using plastic containers that were washed twice before filling. Samples were taken from two locations at each plant: one for raw water and the other for treated water. The required tests were conducted at the Ministry of Environment/Al-Muthanna Governorate Environment Directorate/Al-Muthanna University/College of Agriculture.

1.3 Approved Specifications

The samples taken from the study area were compared with the updated Iraqi local standard specifications of 2009 (Table 2).

Table 2: Iraqi Environmental Specifications for Water Suitability for Human Use

No.	Element	Allowable limit	Unit of measurement
1	Temperature	-	C
2	PH	6.5-8.5	----------
3	Electrical Conductivity	2000	MS/CM
4	Total Dissolved Solids	1000	Mg/l
5	Turbidity	5	NTU
6	Hardness	500	Mg/l
7	Sodium	200	Mg/l
8	Potassium	10-12	Mg/l
9	Magnesium	100	Mg/l
10	Calcium	150	Mg/l
11	Sulfate	400	Mg/l
12	Chloride	350	Mg/l
13	Residual Chlorine	1.45 - 3	
14	Coliforms	0	Cell / 100
15	Fecal Bacteria	0	Cell / 100
16	Coliform Count	50	Cell / 100

Source: Ministry of Environment, Monitoring and Planning Department, Iraqi Drinking Water Specifications No. (417) of 2009, Second Update.

2. Results and Discussion

First: Physical and Chemical Tests of Raw and Treated Water from Water Treatment Plants in the Study Area

1: Temperature

Living organisms are affected by temperature changes, which in turn affect the physical and chemical properties of their environment (Al-Hadithi, 1986). Evison (1988) also indicated that temperature is one of the main environmental factors affecting the survival of microorganisms in water. Furthermore, the rate of corrosion in the water transmission pipe network is related to high temperature (Besner et al., 2002). Therefore, water temperature is used to determine the corrosion of water transmission pipes in the distribution network. It has been shown that the nitrification process, which leads to corrosion, often occurs at high temperatures exceeding 15°C (Kimeyer et al., 2002).

Table (3) shows that the temperature measurements during the wet and dry periods of raw water varied. The lowest temperature was recorded at the Rumaytha station, at approximately 10°C, while the highest was recorded at the Warka station, reaching approximately 17°C. For treated water, the lowest temperature recorded was approximately 26°C at

the Warka station, while the highest was recorded at the Samawah station, reaching approximately 32°C. This variation in temperature values between the wet and dry periods is a normal occurrence related to climate.

Table (3): Temperature Values for Stations in the Study Area

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
16	16	17	17	10	10	13	13	Wet period
28	28	26	26	27	27	32	32	Dry period

Source: Research conducted by the researcher based on analyses performed at the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from November 10, 2023, to September 15, 2024.

Second: pH

PH reflects the activity and effectiveness of hydrogen ions. Its rise and fall result from the presence of pollutants in the water (Abawi & Hassan, 1990). The pH values did not differ significantly across all study stations and water types (raw and treated), and they remained within the permissible limits according to Iraqi specifications, as shown in Table (4). The highest pH value during the wet period was recorded for raw water (7.9) at the Al-Khidr station, and the lowest value (7.6) at the Al-Warka station. For treated water, the highest value was recorded at the Al-Khidr station (7.6), while the lowest value was (7.3) at the Al-Warka station. Regarding the dry period, the Al-Khader station recorded the highest pH value for raw water at (8.1) and the lowest at (7.8). For treated water, the values ranged between (7.4-7.6) for all stations.

Table No. (4) pH Values for Stations in the Study Area

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
7.6	7.9	7.3	7.6	7.5	7.7	7.4	7.8	Wet period
7.6	8.1	7.4	7.8	7.6	7.9	7.6	7.9	Dry period

Source: Research by the researcher based on analyses conducted in the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from (10/11/2023) to (15/9/2024).

Electrical Conductivity

By observing Table No. (5), which shows the electrical conductivity values for raw and treated water for all stations in the study area and for the wet and dry periods, it is evident that the values vary between the stations. During the wet period, the Al-Khader station recorded the highest values for both raw and treated water, ranging from (2564-2554 µmH/cm), which exceeds the permissible limits according to Iraqi specifications. The remaining stations were below the permissible limits according to Iraqi standards for the same period. During the dry period, all studied stations recorded high values, ranging from (2979-2927 µmH/cm) for raw water and from (2965-2914 µmH/cm) for treated water. The water concentration (µS/cm) in the treated water exceeded the limits permitted by Iraqi specifications, which are set at 2000 µS/cm. This is due to insufficient water supply to these stations because of low river levels and the lack of rainfall during the winter season in quantities sufficient to raise the water level.

Table No. (5) Electrical Conductivity Values for Stations in the Study Area

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
2554	2564	1757	1776	1618	1632	1915	1924	Wet period
2943	2955	2453	2547	2965	2979	2914	2927	Dry period

Source: Research conducted by the researcher based on analyses performed at the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from November 10, 2023, to September 15, 2024.

Total Dissolved Solids (TDS): Table 6 shows the TDS values during the study period. The test results indicated that all values at all stations were outside the permissible limits according to Iraqi standards, which specify a maximum concentration of 1000 mg/L.

For raw water and wet-dry water, TDS values ranged between 1040 and 1526 mg/L. While the total dissolved solids (TDS) levels ranged between 1314 and 1712 mg/L during the dry period, the levels in treated water ranged between 1032 and 1512 mg/L during the wet period, and between 1302 and 1698 mg/L during the dry period. Generally, the high TDS levels, in addition to the limited river water supply and the reduced water supply to the treatment plants, are attributed to the climatic conditions, specifically the extremely high temperatures during the dry period. Furthermore, the high salinity is due to the higher salinity of the soils through which the Euphrates River flows compared to the Tigris River (Al-Tufaili, 1999).

Table No. (6) Total Dissolved Solids Values for the Study Area Stations

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
1512	1526	1114	1128	1032	1040	1321	1376	Wet period
1698	1712	1302	1352	1302	1314	1388	1412	Dry period

Source: Research by the researcher based on analyses conducted in the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from (10/11/2023) to (15/9/2024).

Turbidity

Table No. (7) indicates the turbidity concentration values for all study stations during the wet and dry periods. We find that the raw water had very high turbidity concentrations for all stations, especially during the dry period, exceeding the permissible limits set by Iraqi specifications, which are (5). The Samawah and Al-Khader stations recorded the highest concentrations at (57-58). As for the treated water, the results showed that it did not conform to Iraqi specifications, as the turbidity concentration values were outside the permissible limits, less than (5) for most stations, with the exception of the Rumaytha station, which recorded a value of (2-3) during the wet and dry periods. The high turbidity levels observed in raw water at the studied stations and others indicate that the Euphrates River and its tributaries within Al-Muthanna Governorate contain significant amounts of sewage and industrial waste, in addition to numerous drainage canals and other contributing factors. The high turbidity levels in treated water at the stations are attributed to either the insufficient use of alum to effectively treat the turbidity or its complete absence during the filtration process. Furthermore, the lack of regular station maintenance and the fact that water consumption by residents exceeds the station's production capacity, preventing the water from settling in the sedimentation basins, exacerbate the problem.

Table (7) Turbidity Values for Stations in the Study Area

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
19	36	6	16	2	23	19	21	Wet period
28	57	14	31	3	55	36	58	Dry period

Source: Based on the researcher's work and analyses conducted at the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from November 10, 2023, to September 15, 2024.

Total Hardness: As indicated by the outcomes of the hardness test presented in Table 8, the results for both untreated and treated water exceeded the limit of 500 mg/L set by Iraqi standards, except for the Al-Rumaytha station, where the results were in the allowable range of 465-473 mg/L.

For raw water, the Al-Khader station recorded the highest concentration for both wet and dry periods, ranging from 648 to 739 mg/L. Similarly, for treated water, the same station recorded the highest concentrations for both wet and dry periods, ranging from 642 to 732 mg/L. The high hardness is attributed to the high salt content in the sedimentation basins and the lack of maintenance or regular tank cleaning.

Table (8) Total Hardness Values for Stations in the Study Area

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
642	648	507	513	465	473	589	596	Wet period
732	739	568	590	568	575	593	603	Dry period

Source: Research conducted by the researcher based on analyses performed at the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from November 10, 2023, to September 15, 2024.

Sodium (Sodium): Table (9) shows the sodium concentrations at the studied stations. Comparing these concentrations with Iraqi standards, they were within the permissible limits of 200 mg/L. For raw water during the wet period, the Al-Rumaytha station recorded the lowest value at 140 mg/L, while the treated water at the same station recorded 135 mg/L. However, the Al-Khader station exceeded the permissible limits for both the wet and dry periods. The sodium concentration in the raw water reached 229-280 mg/L, while the treated water concentration for both periods ranged from 220-275 mg/L.

Table No. (9) Sodium values for stations in the study area

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
220	229	150	150	135	140	178	180	Wet period
275	280	185	200	180	190	188	197	Dry period

Source: Research conducted by the researcher based on analyses performed at the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from November 10, 2023, to September 15, 2024.

Calcium: The amount of calcium may decrease, increase, or remain unaffected during filtration. This is attributed to the cleanliness of the sedimentation basins, filters, and water tanks, as well as the project's production capacity and local water consumption (Hamza, 1999). Although the results of the raw and treated water analyses were close to the permissible limit, they did not exceed it. This is evident from Table (10), which shows the calcium concentrations for all stations during both the wet and dry periods. These concentrations were within the limits permitted by Iraqi specifications, which set the limit at 150 mg/L, except for the Al-Khader station, which recorded values outside the permissible limits during the dry period for both raw and treated water, at 153-154 mg/L.

Table No. (10) Calcium values for stations in the study area

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
133	134	109	110	101	102	120	125	Wet period
153	154	119	123	119	120	123	129	Dry period

Source: Research conducted by the researcher based on analyses performed at the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from November 10, 2023, to September 15, 2024.

Magnesium

Table 11 shows that the magnesium concentration values were within the permissible limits according to Iraqi specifications, which are set at 100 mg/L.

For raw and treated water during the wet period, the Al-Rumaytha station recorded the lowest values (54 mg/L) and (53 mg/L) respectively, and the highest concentration at the Al-Khader station (76 mg/L) and (75 mg/L). During the dry period, the same stations recorded the lowest concentrations for raw and treated water (67 mg/L) and (68 mg/L) at the Al-Rumaytha station, and the highest concentrations (86 mg/L) and (84 mg/L).

Table No. (11) Magnesium values for stations in the study area

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
75	76	57	58	53	54	62	69	Wet period
84	86	66	69	68	67	70	71	Dry period

Source: Research conducted by the researcher based on analyses performed at the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Directorate, from November 10, 2023, to September 15, 2024.

Sulfate

Table 12 indicates that sulfate concentrations varied between stations during the dry and wet periods. Regarding raw water during the wet period, the Al-Rumaytha and Al-Warka stations recorded the lowest values, ranging between 347 and 399 mg/L respectively, thus falling within the permissible limits of 400 mg/L according to Iraqi standards. Similarly, the treated water from the same stations recorded values of 344 and 394 mg/L respectively, also within the permissible limits. However, the Al-Samawah and Al-Khidr stations recorded high concentrations exceeding the permissible limits according to Iraqi standards.

During the dry period, sulfate concentrations at all stations were outside the permissible limits for both raw and treated water. The Al-Rumaytha station recorded the highest concentrations for both raw and treated water, at values of 608 mg/L and 602 mg/L, respectively.

Table No. (12) Sulfate Values for Stations in the Study Area

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
504	510	394	399	344	347	470	474	Wet period
602	608	448	466	450	455	476	482	Dry period

Source: Research conducted by the researcher based on analyses performed at the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from November 10, 2023, to September 15, 2024.

Chloride

Table 13 shows that the chloride concentration values at the treatment plants were within the permissible limits according to Iraqi specifications, which is 350 mg/L. The chloride concentration values for raw water ranged between 208 and 329 mg/L during the wet period, while the concentration values for treated water ranged between 206 and 326 mg/L during the same period. While the lowest values for raw water were recorded at the Rumaytha station (270 mg/L) and the lowest values for treated water at the Warka station (266 mg/L), the exception was the Khidr station, which exceeded the permissible limits for both raw and treated water during the dry period, recording values ranging from 418 to 423 mg/L.

Table No. (13) Chloride Values for Stations in the Study Area

Al-Khader Station,		Al-Warka Station,		Al-Rumaytha Station		Al-Samawah Station		Station
processor	raw	processor	raw	processor	raw	processor	raw	
326	329	206	208	252	257	269	275	Wet period
418	423	266	287	259	270	300	307	Dry period

Source: Research conducted by the researcher based on analyses performed at the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from November 10, 2023, to September 15, 2024.

(3-2) Bacteriological and Residual Chlorine Tests of Water Exhausted from Water Treatment Plants in the Study Area

Residual Chlorine

Chlorine is used to disinfect water intended for human consumption because it is an oxidizing agent that destroys microorganisms that were not removed by sedimentation and filtration processes (APHA, 1985). Therefore, the amount of chlorine added to the plants must be sufficient to ensure disinfection while maintaining a residue of (0.2–0.5) mg/L of free chlorine in the distribution networks (WHO, 1993).

The study results showed a similarity in residual chlorine values, as shown in Table (14), ranging between (1.5-3) mg/L during the wet period. This indicates that the values did not exceed the permissible limits according to Iraqi standards. However, during the dry period, the Samawah and Warka water treatment plants exceeded the permissible limit, recording values of (4) mg/L. This increase is attributed to the inverse relationship between residual chlorine and temperature, as chlorine decomposition increases with rising temperatures (Al-Qaisi, 2005). Therefore, it is essential to increase chlorine dosages in water treatment plant projects during the hot months of the year to ensure that sufficient chlorine levels reach the drinking water to eliminate any microorganisms present.

Table (14) Free Chlorine Values for Water Treatment Plants in the Study Area

Al-Khader Station, processor	Al-Warka Station, processor	Al-Rumaytha Station processor	Al-Samawah Station processor	Station
1.5	3	2	3	Wet period
3	4	3	4	Dry period

Source: Research conducted by the researcher based on analyses performed at the Soil and Water Laboratory, College of Agriculture, Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from November 10, 2023, to September 15, 2024.

Second: Bacteriological Tests

Among microorganisms, bacterial species constitute one of the main group present in water. Apart from indigenous bacterium associated with the aquatic environment and possibly capable of proliferating in it without being influenced by external agents, they could indicate the presence of another group of the bacteria which could flow into the water and be responsible for diseases creation. These invasive species may come from some aquatic sources including floods, melted snow, etc. The results of laboratory analysis conducted on the water from all sampling points is presented in Table 15. It is unequivocal that all treatment plants, regardless of weather conditions are free from coliforms and fecal bactefia. There is a decline of the amount of the bacteriological colonies at different sampling points over the period. The Samawah plant has demonstrated the highest content of bacteria colonies with an index of (66 cells/100) in the wet period. This number significantly exceeds the maximum permissible concentration of 50 cells/100. The incapacity of the plant to process water is owing to the fact that it is located in the city closer to the more active anthropogenic impact. It must also be noted that abundance of trees, fallen leaves and provide sufficient shade contributes to the higher amount of organic matter which together with low temperatures and less sunlight in winter create adverse conditions for microorganisms and thus prevents from effective treatment (Yehia and Sabea, 2011). The technological regime at the sites may not ensure the production of drinking water. In order to deal with the biological aspect of the treatment process, the procedures for the addition of chlorine must be implemented (Obaid, 2011).

In the remaining stations, the concentration of bacterial colonies ranged between (0-15 cells/mm^3) and did not exceed Iraqi environmental limits. This is attributed to the low level of human activity and the low percentage of organic matter in the surrounding areas. Additionally, the removal rate of these colonies was good, keeping the levels within acceptable limits.

Table No. (15) shows the numbers of coliform bacteria, fecal bacteria, and bacterial colonies at the stations in the study area.

Plate Count 37c/1ml	MPN of total E-coli 44c/100ml	MPN of total coliform 37c/100ml	Station	
66	0	0	Wet period	Al-Samawah Station
45	0	0	Dry period	
15	0	0	Wet period	Al-Rumaytha Station
10	0	0	Dry period	
13	0	0	Wet period	Al-Warka Station
0	0	0	Dry period	
14	0	0	Wet period	Al-Khader Station
0	0	0	Dry period	

Source: From the researcher's work based on analyses conducted in the Soil and Water Laboratory, College of Agriculture / Al-Muthanna University, and the Environmental Analysis Laboratory, Al-Muthanna Environment Department, from (10/11/2023) to (15/9/2024).

Third: Paired Samples t-test for comparing raw and treated water values.

The Independent Samples t-test was utilized to find whether there were any significant differences between the means of the two groups concerning some variable of interest that includes certain physical and chemical properties of water under observation (Ghadhban & Rasheed, 2021; Saeed & Mohammed, 2023). This statistical method is a technique that is used when there is a need for comparing the mean of a continuous variable, and this helps the researcher in determining whether the difference found between the means of groups is a true difference or occurred owing to random variation in the data (Ghufran, 2021). A significance level of 0.05 ($\alpha = 0.05$) was set for advocating the significance of the differences. The T-value is the test statistic that shows the degree of difference in the means of the two groups compared to the variation in the data, but in the same way, the "Sig." value is the probability value (p-value) to support statistically significant conclusions derived from the T-tests. When the Sig. value is smaller than 0.05, the difference between the groups is regarded as a statistically significant one; in case the Sig. value turns out to be greater than 0.05, the difference can be labelled as statistically insignificant.

Table (16): t-test comparing raw and treated water at the study plants.

Parameter	T	Sig.	Result
pH	7.348	0.005	Significant difference
Electrical Conductivity	5.719	0.011	Significant difference
Total Dissolved Solids (TDS)	2.098	0.127	Not significant
Turbidity	4.173	0.058	Not significant
Total Hardness	14.100	0.001	Highly significant difference
Sodium	1.958	0.134	Not significant
Calcium	2.000	0.139	Not significant
Magnesium	1.667	0.194	Not significant
Sulfate	6.971	0.006	Significant difference
Chloride	4.382	0.022	Significant difference

• If Sig. < 0.05 ⇒ There is a significant difference (statistically significant).
• If Sig. > 0.05 ⇒ There is no significant difference.

As shown in Table (16), the treatment processes resulted in different responses in terms of physical and chemical characteristics. While some variables showed statistically significant differences, others did not meet the level of significance. This variation is due to the differences in the characteristics of the water components and their features of response to the treatment processes.

pH

Findings from the Paired Samples t-Test indicated a statistically significant difference between raw and treated water in terms of pH level (T = 7.348; Sig. = 0.005, sig < 0.05). This shows that the treatment has successfully resulted in a

statistically significant change in pH, which can be explained by how different water treatment processes change the chemical balance of the constituents in the water solution; additionally, removing ions and dissolved substances is capable of changing acid-base characteristics of the water. pH is an important property of water quality as it is connected to solubility of different substances in a solution and their chemical properties.

Electrical Conductivity (EC)

Electrical conductivity tests displayed a notable contrast between untreated water and treated water (T = 5.719; Sig. = 0.011, less than 0.05). This displays that there is a significant statistical alteration in the ion composition and ionic material concentration of the water because of the treatment process. The ratio of electrical conductivity is significant since it shows the chemical content of water in terms of ionic products, and it's a recognised fact that electrical conductivity is directly proportional to the ion presence in water. Hence, the change of EC after the treatment will denote the presence of the lesser proportion of dissolved ionic materials, especially in the cases when membrane technology has been used (Al-Radaideh, 2010).

Total Dissolved Solids (TDS)

The T-value and Significance (Sig) for Total Dissolved Solids were 2.098 and 0.127 respectively. Since the latter exceeds the 0.05 limit, then it means that the difference between the raw and treated water is not statistically significant. However, the fact that there is no statistical significance does not mean that there was no actual reduction in the TDS; it rather means that the change was not enough to achieve statistical significance. The TDS relates to the total amount of substances, salts and dissolved solids in the water, thus the changes in the TDS happen depending upon how much salt comes into the treatment unit and how efficient the elimination devices are.

Turbidity

The T-value for turbidity was 4.173 with a Sig. value of 0.058. Though this value is slightly above the cut-off for significance level (0.05), turbidity was classified as statistically insignificant. However, because the Sig. value is approaching the significance threshold, this indicates that there may be some change occurring close to statistical significance. Turbidity measurements are actually of great importance in practical terms since they determine the efficiency of filtration and the removal of particles and suspended solids. Turbidity can be viewed as an important physical characteristic in assessing the quality of water because it provides information about the concentration of fine particles and suspended solids that provide the water with its appearance and affect efficiency at various stages of treatment process.

Total Hardness

With the T-value of 14.100 and Sig. value (significance value) of 0.001, total hardness, among all studied factors, had the highest coefficient of difference. The statistic shows a significant difference between raw and treated water. Total hardness is largely determined by the presence of calcium and magnesium ions in water, thus, changes in the level of hardness after water treatment will show how successful the processes of removal of those ions were. Additionally, reducing hardness is important from practical perspectives in order to lower the risk of scaling in pipes, equipment and facilities.

Sodium (Na)

When it comes to sodium, the T-value recorded was 1.958 with the Sig. value being equal to 0.134. Because the Sig. value is greater than 0.05, it can be concluded that there is not a meaningful difference between raw water and treated water in terms of sodium concentration as the changes observed were neither consistent nor substantial enough; thus, there could be other factors influencing the variations in sodium concentrations among stations and ion removal efficiencies during the water treatment process.

Calcium (Ca)

For calcium, the T-value recorded was 2.000, and the Sig. value was 0.139. Since it is more than 0.05, there was no significance in difference between the observed water data. While calcium is a major element with relation to hardness, the absence of significant difference between calcium levels focused on its distribution may indicate sample weight and magnitude of value differences of the attained readings. Thus, statistical significance evaluation is not connected only with the amount of reduction but also with the variability of obtained results.

Magnesium (Mg)

For magnesium, the T-value was 1.667 and the Sig. value was 0.194. As this exceeds 0.05, there is no statistically significant difference between the raw and treated water. While magnesium is associated with total water hardness, the lack of a significant difference in its concentration may be due to limited variation between measurements or differences in concentration levels across stations.

Sulfate (SO_4^{2-})

Sulfate levels showed a clear, significant difference, with a T-value of 6.971 and a Sig. value... = 0.006, which is less than 0.05. This result indicates a statistically significant change in sulfate concentration between the raw and treated water. Sulfates are important dissolved ions in water; therefore, their reduction following treatment suggests the removal of a portion of dissolved ions resulting from the separation and treatment processes.

Chloride (Cl^-)

Test results revealed a significant difference in chloride concentration, with a T-value of 4.382 and a significance (Sig.) value of 0.022—both below the 0.05 threshold. This result indicates a clear statistical change in chloride concentration after treatment. Chloride is a major dissolved ion in water and is linked to water salinity and chemical composition; thus, its reduction after treatment may reflect the removal of some salts and dissolved ions.

3. Results

Based on data analysis, it has been determined that the quality parameters of water collected from both sites of the facility are identical. Analysis of the quality parameters of both untreated and treated water shows high concentrations exceeding both Iraqi standards and making the water unsuitable for application purposes. Results of the study show that the technological devices of the facility do not function normally, and only serve to transport water. Large amount of physical and chemical constituents in raw water suggest that the Euphrates River is highly polluted. Results of the independent samples t-test demonstrate high statistical significance of the difference between the two groups for five parameters: pH, electrical conductivity, total hardness, sulfates, and chloride, with the biggest difference found for total hardness (Sig=0.001).

In turn, no statistically significant differences for Total Dissolved Solids, turbidity, sodium, calcium, and magnesium were noted, since Sig values for these variables were above 0.05.

4. Recommendations

1- Innovations at filtration facilities will update and upgrade treatment technologies to reduce the level of salt and total hardness:
Refurbish and upgrade filtration facilities with advanced treatment techniques. For example, one can consider the incorporation of technology for ion exchange or reverse osmosis. By doing so it is possible to eliminate the problem of rising levels of total hardness, TDS, sulfate and chloride ions, which conventional technologies fail to resolve.
2- Introduction of automation in the process of dose application for coagulants and disinfectants:
Integrate advanced methods of dosing chemicals into the process of adding treatment agents such as alum for turbidity reduction and chlorine for disinfection with flexibility to the seasonal fluctuations in the dose applied. This is done to

avoid discharging treated water with prolonged turbidity higher than national standards at Al Samawah, Al-Khidr and Al Warka plants.
3- Designing a maintenance plan for sedimentation and filtration basins:
Putting in place a comprehensive program for doing preventive maintenance, which will ensure regular cleaning and backwashing of sedimentation and filtration basins with the aim of preventing salt build up and sludge formation. Results of the experiment show that improper maintenance of the plants results in loss of efficiency of filtration process.
4- Monitoring pollution sources at the intakes, and eliminating pollution of the Euphrates and its tributaries:
Introducing strict environmental monitoring programs at the Euphrates River and its tributaries to ensure that no effluents from sewage, agricultural and industrial plants are discharged close to the plants' intakes. This is necessary in order to minimize the discharge of biological load and turbidity caused by the pollution of the water bodies.
5- Capacity building of the personnel of the Muthanna Water Directorate:
Organizing capacity-building initiatives aimed at development of the expertise of monitoring personnel. This is done in cooperation with educational institutions.
6- Implementation of statistical monitoring and quality control programs:
Implementation of the statistical methods of monitoring (t-tests and multivariate analyses) for the provision of quality reports that would help assess the effectiveness of each stage of the process used in the Muthanna environmental monitoring system.

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