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Evaluation of physical chemical and Biological characteristics of drinking water for some schools in Tikrit city

Elaf Mohammed Harz
Department of Biology, College of Education for Pure Science, University of Tikrit, Iraq
Corresponding Author E-mail: elaf.m.hazr@tu.edu.iq
Phone Number / 07735447540 / https://orcid.org/0009-0002-6442-4913

ABSTRACT:

The study, conducted between November 2021 and March 2022, aimed to evaluate the physical, chemical, and microbial properties of drinking water samples collected from three schools in Tikrit city: Amr bin Jundub Al-Ghafari School, Al-Nasr School, and Al-Jahafiliya Al-Takamiliya School. Significant variations were observed in the test results throughout the five-month study period. Water temperatures ranged from 8.1°C to 12.2°C, while Electrical Conductivity (EC) values fluctuated between 489 and 562 µS/cm. The pH values ranged from slightly basic to neutral, with values between 6.8 and 7.75. Total dissolved solids were recorded between 220 and 300 mg/L, and turbidity levels ranged from 0.6 to 10.3 NTU. The measured values for alkalinity, total hardness, calcium, and chlorides ranged from 122.0 to 146.0 mg/L, 195.0 to 271.0 mg/L, 50.0 to 74.0 mg/L, and 32.0 to 45.0 mg/L, respectively. Nitrate concentrations varied between 1.1 and 1.8 mg/L. Microbial tests revealed the presence of coliform bacteria, with concentrations ranging from 7.4 to 460.0 cfu/ml, the highest values occurring in December and the lowest in February.

Keyword : Drinking water, physical and chemical factor, bacteriological study.

إيلاف محمد حارز
جامعة تكريت, كلية التربية للعلوم الصرفة, قسم علوم الحياة

مستخلص:

أُجريت الدراسة في الفترة بين نوفمبر 2021 ومارس 2022، بهدف تقييم الخصائص الفيزيائية والكيميائية والميكروبية لعينات المياه الصالحة للشرب التي تم جمعها من ثلاث مدارس في مدينة تكريت: مدرسة عمرو بن جندب الغفاري، ومدرسة النصر، ومدرسة الجحفية التكاملية. لوحظت تفاوتات كبيرة في نتائج الاختبارات طوال فترة الدراسة التي استمرت خمسة أشهر. تراوحت درجات حرارة المياه بين 8.1°C و12.2°C، بينما تباينت قيم التوصيلية الكهربائية (EC) بين 489 و562 µS/cm. تراوحت قيم pH بين القيم القاعدية قليلاً والمحايدة، حيث كانت بين 6.8 و7.75. تم تسجيل إجمالي المواد الصلبة الذائبة بين 220 و300 mg/L، في حين تراوحت مستويات العكارة بين 0.6 و10.3 NTU. تراوحت قيم القلوية، العسر الكلي، الكالسيوم، والكلوريدات بين 122.0 و146.0 mg/L، 195.0 و271.0 mg/L، 50.0 و74.0 mg/L، و32.0 و45.0 mg/L على التوالي. تراوحت تركيزات النترات بين 1.1 و1.8 mg/L. كشفت الاختبارات الميكروبية عن وجود بكتيريا القولون، حيث تراوحت تراكيزها بين 7.4 و460.0 cfu/ml، وكان أعلى تركيز لها في شهر ديسمبر وأدنى تركيز في شهر فبراير.

الكلمات المفتاحية: مياه الشرب، العوامل الفيزيائية والكيميائية ، الدراسة البكتيرية.

1- Introduction

Water is one of the environmental components most vulnerable to pollution because it possesses unique properties that make it more susceptible to receiving different types of pollutants, which makes it unsuitable for the required uses [1]. Major public health problems such as cholera, malaria, dengue fever, polio, amoebic dysentery and other diseases are caused by unsafe drinking water and poor sanitation, These diseases kill more people every year than violence and war [2]. According to estimates issued by the World Health Organization, which indicated that the use of polluted and unhealthy water causes the death of 842,000 people annually as a result of diarrhea, and indicated that 2 billion people in the world's population use water sources contaminated with feces [2].

Therefore, obtaining safe and pure drinking water has become one of the biggest challenges facing many countries around the world, as about 18 million people die in developing countries annually, the majority of whom are children, due to water pollution diseases. Since Iraq is one of the countries in the world, it suffers from the same problem, but to a greater extent due to the scarcity of rain and the decline in water levels due to problems related to the sources of rivers. Water pollution is mainly caused by industrial and agricultural activities, natural factors, and insufficient water supplies and wastewater treatment facilities. Industry is considered the main cause of water pollution. These industries include the tanning industry, the paper industry, the textile industry, the food industry, the iron and steel industry, and the Nuclear etc., many toxic chemicals, organic and inorganic substances, toxic solvents and volatile organic chemicals may be released in industrial production, and if these wastes are released into aquatic ecosystems without adequate treatment, they will cause water pollution [3]. Many studies have also proven that chlorine disinfection processes pose a threat to public health due to the secondary compounds produced during treatment, in addition to the fact that some bacterial species, such as fecal coliform bacteria, Escherichia coli, and Pseudomonas aeruginosa, are resistant to chlorine disinfection. The presence of bacteria in drinking water with the ability to exchange antibiotic resistance genes poses a significant public health concern. This highlights the importance of assessing the quality of drinking water and evaluating the efficiency of water treatment processes to prevent the spread of antibiotic-resistant microorganisms [4].

2- Aims of the study

Assessment of the Physical and Chemical Properties of Drinking Water in selected schools in Tikrit city, Salah al-Din Governorate.

Evaluation of Water Quality and Filtration Efficiency by assessing the effectiveness of drinking water filtration systems in these schools through bacterial testing.

3- Materials and Methods

3.1- Sample collection method

Samples were collected monthly from selected schools in Tikrit city, including Amr bin Jundub Al-Ghafari School, which is located in the Al-Qadisiyah area and supplied by the Al-Qadisiyah Water Filtration Project, Al-Nasr School located in the city of Tikrit, affiliated with the filtration project in the city of Tikrit, and Al-Jahfliyah School, located in the city of Tikrit also affiliated with the same project, Samples were collected using narrow-neck plastic bottles filled to their full capacity. As for bacteriological tests, they were collected using Samples were collected monthly from selected schools in Tikrit city, including Amr bin Jundub Al-Ghafari School, which is located in the Al-Qadisiyah area and supplied by the Al-Qadisiyah Water Filtration Project sterilized glass bottles (250 ml) and transported directly to the laboratory using a frozen cork container for bacteriological tests to be performed [5].

Physical and chemical tests of water

Physical and chemical tests for water were carried out using several analysis methods as a given in Table 1.

Physical and chemical tests

Physical tests

It was measured according to what was mentioned in [6].

Temperature

water temperature was measured at the site using a mercury thermometer (10-100) C°.

Electrical Conductivity (EC)

Electrical conductivity was measured using a Multi parameter analyzer type 830 CONTRAST (Belgium) after calibrating the device and the results were expressed in Ms/cm.

Turbidity

Turbidity was measured using a device (HANA-LP 2000 Turbidity meter made in Portugal) with Nephelormetric Turbidity Unit (N.T.U). samples were shaken before measurement to homogenize them and an average of two readings were taken for each sample.

TDS

Total dissolved solids were measured using a TDS-3 Meter according to the method [7]. presented and the results were expressed in mg/L.

Chemical tests

2.1.1. pH

pH was measured using an EC CONSORT C830 multiparameter analyzer (Beigium) and the device was calibrated using pH buffer solutions (9,7,4).

2.1.2. Total Hardness (T.H)

The method of screening was adopted with a standard sodium salt solution (Ethylene Diarine Tetra Na2 EDTA Acetic Acid) by adding (2) ml of a buffered ammonia solution to (50) ml of the sample, and it was flushed with a standard solution of sodium salt at a concentration of 0.02N until the color changed from burgundy red to The solid blue after adding (0.2) gm of (T-Eric Chrome Black) index before plastering, and study the physical and chemical properties of groundwater the hardness was calculated[8]. from the following equation:

〖T.H mg/L as CaCO〗_3=(V x N x eq.wt x 1000)/(ml of Sample)

where:

V: volume of eluted standard solution (EDTA).

N: Standard solution standard (EDTA).

eq.wt: equivalent weight of calcium carbonate CaCO3.

ml of sample: The volume of the sample (ml).

2.1.3. Calcium Hardness (Ca.H)

The measurement was made by adding (2)ml of sodium hydroxide solution with a concentration of (1) N to (50) ml of sample water, using (0.2) gm of meroxide dye as a guide to be colored with the previously mentioned sodium salt solution at the same concentration until the violet color appears. Solid instead of pink.

Using the following equation, calcium hardness was calculated in mg/L:

⟦Ca.H mg/L.as caco⟧_3=(V x N x eq.wt x 1000)/(ml of Sample)

where:

V: volume of the eluted standard solution (Na2EDTA).

N: Standard solution standard (Na2EDTA).

eq.wt: equivalent weight of calcium carbonate CaCo3

ml of sample: The volume of the sample (ml).

2.1.4. Total Alkalinity (T.A)

Total Alkalinity was measured by taking (50) ml of sample water, adding (3) drops of methyl orange indicator to it, then flushing it with sulfuric acid at a concentration of (0.02) standard and at the rate of two readings. Alkalinity is calculated when the pH reaches (4.2) according to the equation.

Using the following equation, Total Alkalinity was calculated in mg/L:

T.A ppm as CaCO3 =(A xN x1000x Mole-wt as CaCO3)/(volume of Sample (ml))

A = volume of pulverized acid.

N = standard acid, which is 0.02.

2.1.5. Chloride Ions

Chloride ions were measured according to what is described in (APHA, 1998), by taking (50) ml of sample water and then adding a few drops of potassium chromate K2CrO4. It was flushed with a solution of silver nitrate AgNo3 with a concentration of (0.0141) until the color turned flesh-red.

APHA. (1998). Standard method for the examination of water and wastewater, 20th ed Washington DC, USA.

Using the following equation, Chloride Ions was calculated in mg/L:

Clmg/L =(A xN x1000x Mole-wt as Cl)/(volume of Sample (ml))

A = volume of silver nitrate.

N = silver nitrate standard.

2.1.6. NO3-1 lons

The nitrate ion concentration in water samples was measured using a spectrophotometer according to the method described in [9] with a wavelength of 543.

Bacteriological examinations

Bacteriological examinations were performed using the most probable number method for the purpose of calculating the total number of coliform bacteria. The multiple tube method was used to calculate the most probable number of coliform bacteria, as stated in the American Public Health Association [10].

Statistical analysis

In this study, statistical analysis, including ANOVA and t-tests, was applied to assess the variations in water quality parameters across different periods and schools. These analyses were performed to determine if the observed differences in water properties were statistically significant.

4- Results and Discussion

4.1- Physical Characteristics

4.1.1- Water Temperature

Water temperature varies depending on geographical location and seasonal weather conditions, impacting human activities. During the study period, the temperature of the liquefaction water ranged between 9°C and 11°C, with the lowest temperature observed in February and the highest in January across all schools in Tikrit. This variation is primarily attributed to the timing of sample collection, which occurred from November (fall semester) to March (spring semester). Seasonal climate factors influence water temperature changes. Additionally, processes in water filtration plants such as sedimentation and filtration may have minor effects on the temperature of raw water, although this is often overlooked in many studies related to water filtration systems. The results of the current study were similar to what was recorded by [11] when they studied Tigris River within the Tikrit city, where they ranged between (9-28)C°. During the study, the water of the Tigris River was classified as warm water according to the classification [12]. The reason for the results of the current study goes back to the time of sample collection, as sample collection began at the beginning of November at the beginning of the fall semester and ended in March at the spring. Statistical analysis, according to the analysis of variance test, showed that there were significant differences at $p \leq 0.05$ between the temperature and the months of study, and this was confirmed by Duncan's results, which were divided into two groups: the first (Nov>Dec>Mar>Feb) and the second (Jan).

4.1.2- Turbidity

Turbidity values in liquefied water showed notable variation, ranging from 0.6 to 10.3 NTU (Table 1). The lowest turbidity was observed in February at Al-Nasr School, while the highest occurred in December at Amr bin Jundub Al-Ghafari School. A general increase in turbidity values was recorded in December, except at Al-Nasr School in November. This variation can be attributed to several factors, including the efficiency of the filtration stations and the presence of suspended materials in the water such as clay, silt, and microorganisms. These particles scatter and absorb light, causing water opacity. The results of this study are lower compared to previous studies, where turbidity ranged from 1.42 to 57.42 NTU and 13.6 to 202 NTU, respectively [13,14].

Statistical analysis (ANOVA or t-test) revealed significant differences in turbidity values among the three schools, with average turbidity values at Amr bin Jundub Al-Ghafari, Al-Jahafiliyah Al-Takamiliya, and Al-Nasr schools being 6.716, 1.422, and 2.926 NTU, respectively. The observed turbidity variations could be linked to rainfall, which can dissolve rocks containing positive ions, increasing pH, and runoff that carries suspended particles into water sources. This hypothesis is supported by the statistical analysis, showing a significant correlation between rainfall rates and changes in pH and turbidity. The results of statistical analysis according to the Pearson test showed that there is a direct correlation at a significance level of $p \leq 0.01$ between turbidity and the pH value, where (r=1.000**). This may be due to the fact that rainfall rates lead to the dissolution of rocks containing positive ions that work to raise pH value, as well as the occurrence of water turbidity, i.e. a direct relationship, and this was confirmed by the results of the statistical analysis. The results of statistical analysis according to Pearson's test also showed that there is an inverse correlation at a significance level of $p \leq 0.05$ between turbidity and total dissolved salts, where (r=-538*).(Table 2)

4.1.3- Electrical Conductivity (EC)

Electrical conductivity (EC) values during the study period ranged between 434 and 562 µS/cm. The lowest value was recorded at Al-Nasr School in November, and the highest at Amr bin Jundub Al-Ghafari School in February(Table 1). The variation in EC values can be attributed to seasonal temperature fluctuations. Higher temperatures increase ion mobility, leading to higher EC values, while lower temperatures reduce ion movement, resulting in lower EC readings. Other factors such as the concentration and type of ions dissolved in the water also influence EC. The values recorded in this study are consistent with standards for drinking water, as they fall below the WHO recommended limit of 1600 µS/cm. The results of the current study were lower than the value recorded by [15], as it recorded (1.42-57.42) NTU, and it was also lower than what was recorded by [16] in his study, where it was (13.6-202) NTU. The results of the statistical analysis according to the analysis of variance (ANOVA) test showed that there were significant differences at ($p \leq 0.05$) in time, that is, in relation to the months of study. This was confirmed by the results of Duncan's analysis test, as it was divided according to this test into two groups, the first includes (Dec.>Nov) and the second includes (Feb.>Jan.>Mar.) (Table 2).

4.1.4- Total Dissolved Solids (TDS)

TDS values during the study ranged from 220.0 to 300.0 mg/L, with the lowest value recorded at Amr bin Jundub Al-Ghafari School in November and the highest in January at Al-Jahafiliyah Al-Takamiliya School(Table 1). The TDS values in this study were lower than those reported by previous studies, such as [17] and [18], which recorded TDS values of 506.0–687.0 mg/L and 433.0–510.0 mg/L, respectively. These differences may be due to the presence of inorganic salts, organic compounds, and other substances. TDS levels are influenced by rainfall, with higher rainfall diluting surface water and reducing TDS concentrations. However, this effect is more applicable to natural water bodies. In treated drinking water, TDS levels are typically regulated by water treatment processes, and an increase in TDS can occur due to pollutants entering water sources through human activities [19].

Statistical analysis according to the Pearson test showed that there is an inverse (negative) correlation between the total dissolved salts (TDS) and the months of study at a significant level ($p \leq 0.01$). At the overall significance level ($p \leq 0.01$), where (r=-.788**). The results of the statistical analysis according to the Pearson correlation coefficient also showed that there is a direct correlation at a significant level ($p \leq 0.01$) between the electrical conductivity and the total dissolved salts (negative and positive ions in the water) as (r=.764**) as the value increases Electrical conductivity. There is also an inverse significant correlation at a significant level ($p \leq 0.05$) between total dissolved salts and pH, as (r=-.545*). The reason for this is that there are negative ions that lead to lowering the pH value. While the results of the statistical analysis according to the analysis of variance (ANOVA) test showed that there were significant temporal differences at ($p \leq 0.05$) between Total Dissolved Solids and the months of study. This was confirmed by the results of Duncan's test, as they were divided according to this test into four groups: the first (Dec.>Nov), the second (Mar), the third (Feb), and the fourth (Jan) (Table 2).

4.2- Chemical Characteristics

4.2.1- pH

The pH values of liquefied water ranged from 6.8 to 7.8, with the lowest pH recorded at 6.8 in January at Al-Jahafiliyah Al-Takamiliya School and the highest at 7.8 in November at Amr bin Jundub Al-Ghafari School. The average pH values during the study period were 7.62, 7.31, and 7.46 for Amr bin Jundub Al-Ghafari, Al-Jahafiliyah Al-Takamiliya, and Al-Nasr schools, respectively(Table 1). These pH values are consistent with previous studies conducted on the Tigris River in the Saladin Governorate, and also align with the results of [20] in their evaluation of drinking water quality in Baghdad. The pH values of the water samples from all three schools fall within the acceptable range for drinking water, as they are all below 8.5, indicating suitability for human consumption. At a significance level of $P<0.01$, the Pearson correlation coefficient showed a positive association between pH and turbidity (1.000). At a significance level of $P < 0.05$, the Pearson correlation coefficient showed a negative association between pH and dissolved salts (545) (Table 2).

4.2.2- Total Hardness concentrations

Total Hardness concentrations in the liquefaction water during the study period ranged between (195.0-271.0) mg/L. The lowest value was observed in the month of November at Al-Jahafiliyah Al-Takamuliya School, and the highest value was in the month of January at the Amr bin Jundab Al-Ghafari School, as shown in the table (1). The results of the current study converged with the study conducted by [21] of drinking water in the city of Babylon, as it was between (257.0-450.0) mg/L. The increase in hardness values along the water course could be due to the presence of a number of gravel and sand quarries spread across the Tigris River before it passes through the city of Tikrit and the occurrence of deep holes, which leads to groundwater coming out and mixing with drinking water. In addition, the geological structure of the study area affects these values, or the reason may be due to lower water levels and increased evaporation, which leads to increased concentrations of ions that cause hardness, or due to industrial, human, and agricultural waste added to the river [22]. The results showed that the concentration of total hardness in liquefaction water from November to February at Amro bin Jundub Al-Ghafari School, where its values ranged between (205.0-279.0) mg/L. While in Al-Jahafiliya Al-Takamiliya School, the hardness values ranged between (195.0-263.0) mg/L. However, in Al-Nasr School, the hardness values ranged between (213.0-267.0) mg/L, from observing, we find that all water samples are suitable for drinking because values were less than 500 mg/l.

The results of statistical analysis according to the Pearson test showed that there is a direct significant correlation at a significant level ($p \leq 0.01$) between the total hardness and the electrical conductivity and total dissolved salts, where it was (r=.650**) and (r=.856**) on straight. There is also an inverse significant correlation at a significant level ($p \leq 0.01$) between total hardship and the months of study (r=-712**). The results of the analysis of variance showed that there were significant temporal differences at the level of ($p \leq 0.05$) between the total hardship and the months of study, and this was confirmed by the results of the Duncan test, which this test divided into three groups, the first of which included (Mar > Dec > Nov) and the second (Feb). And the third (Jun) in Table (2).

4.2.3 - Calcium Hardness

Calcium ion concentration ranged between (50.0 -74.0) mg/L. The lowest result was observed in the month of February, while the highest was recorded in the month of November at Al-Jahafiliyah Al-Takamiliya School(Table 1). The results showed that the hardness of calcium in liquefaction water from November to February at the Amro bin Jundub Al-Ghafari School ranged between (59.0 -67.0) mg/L. While in Al-Jahafiliya Takamiliya School, it ranged between (50.0-74.0) mg/L. In Al-Nasr School, the values ranged between (56.0-70.0) mg/L. The difference in results is due to several reasons, including increased evaporation in summer and increased condensation in winter, taking into account the nature of the soil and its components. The source of the calcium ion is due to the geological nature of the areas where the water flows, as well as the nature of the lands adjacent to the river. Calcium constitutes (30.23%) of sedimentary rocks and magnesium (47%) of carbonate rocks, and this explains why calcium ion concentrations are higher than magnesium concentrations in aquatic systems [23]. In addition, magnesium tends to precipitate in larger quantities than calcium ions, and this may be due to the fact that carbon dioxide interacts more than it interacts with magnesium ions, and thus larger amounts of calcium are transformed into dissolved bicarbonates and affect the hardness values [24]. From observing in the result, we find that all water samples meet the recommended drinking water standards, as their total hardness values were below 50 mg/L, which is within the acceptable range.

Results from Pearson's test indicate a strong inverse connection ($p \leq 0.05$) between calcium, electrical conductivity (r=610*), and TDS (r=.551*). Significant connection (r=.623*) was found between calcium hardness and study months ($p \leq 0.05$). Calcium and magnesium are the main dissolved minerals in hard water, hence calcium hardness and total hardness are inversely related (r=-.690**). If the water is harsh, washing your hands with soap may leave a film of soap residue. The calcium in hard water reacts with soap, leaving your hands sticky. Due to its high calcium and magnesium content, hard water can cause pipe peeling, RO membrane peeling, blockage, and equipment inefficiency. The analysis of variance test yielded significant temporal differences ($p \leq .05$) between calcium and study months, which were verified by the Duncan test. The first (Mar.>Jun.>Feb.) and the second. (Dec) Third (Nov) (Table 2).

4.2.4 - Total Alkalinity (T.A)

Results of the current study (Table 1) showed that the alkaline values during the study period were between (122.0-156.0) mg/L in liquefaction water. The lowest value of 122.0 mg/L was recorded in the month of March in Al-Nasr School, and the highest value of 156.0 mg/L was recorded in the month of November in the same school, and the results were less than the results mentioned by [25]. The results showed that the alkalinity values in liquefaction water from November to March at the Amr bin Jundub Al-Ghafari School ranged between (130.0-140.0) mg/L. While in Al-Jahafiliya Takamiliya School, it ranged between (128.0-146.0) mg/L. While at Al-Nasr School, it was recorded between (122.0-156.0) mg/L. The results of the statistical analysis according to the Pearson test indicated that there is a direct significant correlation at a significant level ($p \leq 0.05$), where (r=580*) between basicity and temperature, meaning that as the temperature increases, the value of basicity increases, and the reason for this may be due to the occurrence of more dissolution processes. The higher the temperature value in chemical reactions inside the water (Table 2).

4.2.5- Chloride (Cl-)

chloride ion concentration in the liquefaction water, as shown in Table

(1), ranged between (32.0-45.0) mg/L during the study period, noting that the lowest value (32.0) mg/L was observed in the month of March at Al-Nasr School, and the highest value was (45.0) mg /L. It was observed in the months of December and February at the Amr bin Jundub Al-Ghafari School. These results were lower than the results of the study [26], which was (53.7) mg/L, and higher than the value recorded by [27], which was about (20.0) mg/L. Chloride ion concentrations in liquefaction water ranged between (35.0-45.0) mg/L at the Amro bin Jundub Al-Ghafari School. While in Al-Jahafiliya Takamiliya School, it ranged between (33.0-40.0) mg/L, and in Al-Nasr School, it ranged between (32.0-38.0) mg/L. The reason for these differences in chloride ion concentration may be due to the presence of chlorine salts or the presence of leakage of chlorine materials from industrial sources, neighboring factories, or water treatment plants, or perhaps the presence of natural deposits of chlorine salts in the soil or rocks in the areas surrounding water sources, which leads to high levels of chlorine ion concentration [28,29]. ANOVA analysis revealed significant differences ($p < 0.05$) between variables like chloride ion and study stations (schools). Duncan test findings verified this, dividing into two groups: Al-Nasr < Al-Jahafiliyyah Al-Takamiliya and Amro bin Jundub Al-Ghafari (Table 2).

4.2.6 - Nitrate (NO_3)

Nitrate ion is a plant nutrient in the aquatic environment as well as a potential contaminant in drinking water. Nitrates can be present in natural water sources and increase surface and groundwater pollution as a result of agricultural and industrial activities and wastewater discharge, When the concentration of this ion in drinking water increases, it leads to significant effects on human health, such as the occurrence of Methemoglobiolina [30]. The results of the current study showed that the nitrate ion values in liquefaction water were between (1.1-1.8) mg/L. The lowest value was recorded in February at Al-Nasr School, while the highest value was observed in November at Al-Nasr School and in March at Amro Bin Jundub Al-Ghafari School(Table 2). The results showed that the values of nitrate in liquefaction water from November to February at the Amr bin Jundub Al-Ghafari School ranged between (1.2-1.8) mg/L. While in Al-Jahafiliya Takamiliya School, it ranged between (1.4-1.7) mg/L. But in Al-Nasr School, it ranged between (1.1-1.8) mg/L,. Variation in the concentration of nitrate ion is due to the use of agricultural fertilizers, which leads to an increase in the concentration of this ion, as well as to the nature of the geology of the area that contains this ion, and domestic wastewater, especially those containing detergents [28]. From observing (Table 2), we find that all water samples are suitable for drinking because values were less than 50 mg/l. The analysis of variance revealed significant temporal differences ($p < 0.05$) between nitrates and study months, which were validated by Duncan's test. Two groups were formed (Dec>Jun and Mar>Nov) .

4.3- Bacteriological Study

Fecal Coliform Bacteria (E.coli) -4.3.1

A subset of total coliform bacteria is found naturally in large numbers in the intestines of humans and animals. The presence of this bacteria in water is evidence of its contamination with feces. Therefore, these bacteria are considered evidence of fecal contamination of water [31]. Any presence of fecal coliform bacteria in treated water indicates either insufficient treatment or contamination after the treatment process Results of the current study showed that the bacterial count in the liquefaction water was between (74.0-460.0). The lowest value was recorded in the month of March at Al-Nasr School, while the highest value was observed in the month of December at Al-Nasr School and Al-Jahafiliya Al-Takamuliya School(Table 1). results indicated that the bacterial count values in the liquefaction water of Amro bin Jundub Al-Ghafari School ranged between (93.0-240.0), and in Al-Jahafiliyah Al-Takamuliya School they ranged between (93.0-460.0), while in Al-Nasr School they ranged between (74.0-460.0).

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Table (1) Physical and chemical characteristics for several months in several schools in Tikrit Governorate.

parameters	Schools	Nov.	Dec.	Jan.	Feb.	Mar.
Temp.	Amro bin Jundub Al-Ghafari	10.0	9.5	12.2	8.1	9.1
	Al-Jahafilia Al-Takamiliya	10.5	10.0	12.2	9.0	10.0
	Al-Nasr	12.0	11.7	11.8	10.5	9.2
Turb.	Amro bin Jundub Al-Ghafari	9.08	10.3	6.4	4.0	3.8
	Al-Jahafilia Al-Takamiliya	1.5	2.0	1.31	1.10	1.20
	Al-Nasr	6.2	6.13	0.7	0.6	1.0
E.C	Amro bin Jundub Al-Ghafari	456.0	469.0	542.0	562.0	492.0
	Al-Jahafilia Al-Takamiliya	490.0	481.0	540.0	545.0	548.0
	Al-Nasr	434.0	497.0	536.0	556.0	530.0
T.D.S	Amro bin Jundub Al-Ghafari	220.0	241.0	298.0	270.0	251.0
	Al-Jahafilia Al-Takamiliya	230.0	259.0	300.0	278.0	272.0
	Al-Nasr	256.0	264.0	292.0	289.0	279.0
pH	Amro bin Jundub Al-Ghafari	.78	7.75	7.2	6.83	7.63
	Al-Jahafilia Al-Takamiliya	7.9	7.50	6.8	7.10	7.25
	Al-Nasr	7.5	7.67	7.4	7.36	7.40
T.H	Amro bin Jundub Al-Ghafari	205.0	220.0	271.0	242.0	222.0
	Al-Jahafilia Al-Takamiliya	195.0	211.0	263.0	255.0	235.0
	Al-Nasr	225.0	238.0	267.0	243.0	213.0
Ca.H	Amro bin Jundub Al-Ghafari	59.0	64.0	60.0	62.0	67.0
	Al-Jahafilia Al-Takamiliya	74.0	67.0	56.0	50.0	59.0
	Al-Nasr	70.0	66.0	58.0	56.0	66.0
T.A	Amro bin Jundub Al-Ghafari	135.0	140.0	140.0	130.0	135.0
	Al-Jahafilia Al-Takamiliya	128.0	140.0	146.0	133.0	137.0
	Al-Nasr	156.0	140.0	136.0	124.0	122.0
Cl^-	Amro bin Jundub Al-Ghafari	40.0	45.0	38.0	35.0	45.0
	Al-Jahafilia Al-Takamiliya	38.0	33.0	39.0	33.0	40.0
	Al-Nasr	38.0	33.0	37.0	32.0	36.0
NO_3	Amro bin Jundub Al-Ghafari	1.3	1.6	1.3	1.2	1.8
	Al-Jahafilia Al-Takamiliya	1.7	1.4	1.5	1.4	1.5
	Al-Nasr	1.8	1.5	1.3	1.1	1.7
E.coli	Amro bin Jundub Al-Ghafari	240.0	93.0	150.0	120.0	210.0
	Al-Jahafilia Al-Takamiliya	240.0	460.0	210.0	93.0	150.0
	Al-Nasr	150.0	460.0	93.0	15.0	7.4

Table (2) Statistical relationship for temporal and spatial characteristics.

	schools	Months	E.C	pH	TDS	Tur.	Temp.	T.A	T.H	Ca.H	Cl	NO_3
Month	.000											
E.C	.067	−853**										
pH	−.325	297.	−.396									
TDS	.350	−.783**	.764**	−.545*								
Tur.	−.332	.301	−.391	1.000**	−.538*							
Temp	.404	.051	−.137	−.080	.347	−.080						
T.A	−.020	.316	−.503	−.037	−.011	−.031	.580*					
T.H	.094	−.712**	.050**	.350	.856**	−.340	.414	.199				
Ca.H	.054	.623*	−.610*	−.133	−.551*	−.141	.024	.116	−.690**			
Cl	−.566*	.092	−.381	.178	−.395	.179	−.074	.260	−.220	.227		
NO_3	.078	.349	−.553*	−.214	−.380	−.220	.011	.298	−.480	.653**	.517*	
E.coli	.080	.581*	−.359	.113	−.276	.109	.225	.230	−.296	.365	−.280	.026

*correlation is significant at the 0.05 level (2-tailed).
**correlation is significant at the 0.01 level (2-tailed).